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UNITED LAUNCH ALLIANCE – ESTABLISHING HEAVY LIFT CAPABILITY ON THE WEST COAST

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ABSTRACT

On 19 September 2009, the Delta Mariner pulled into a small harbor located on the California Coast, in the south area of Vandenberg Air Force Base (VAFB). There it off-loaded the three boosters and second stage that would later be assembled in the Horizontal Integration Facility (HIF) into the first Evolved Expendable Launch Vehicle (EELV) with Heavy Lift capability to be launched from the West Coast.

In the HIF, the port and starboard liquid rocket boosters were mated to the core. The second stage was then mated to the vehicle, and, after a series of tests and checkouts, the vehicle was rolled out to the pad, Space Launch Complex 6 (SLC-6). On 29 January 2010, the vehicle was vertically erected onto the launch pad to begin an exhaustive series of integrated system tests and checkouts, including cryo-loading the fuel and oxidizer tanks in the first and second stages, culminating in a full wet dress rehearsal of a launch countdown followed later by a final Integrated System Test (IST).

The United Launch Alliance Heavy Launch Vehicle (HLV) has the highest mass-to-orbit performance capability of any available U.S. Expendable Launch Vehicle. This paper summarizes the launch system modifications and integrated testing necessary for a successful launch and to establish U.S. West Coast Heavy Lift capability.

I. INTRODUCTION – ULA

Formed in December 2006, United Launch Alliance (ULA) is a 50-50 joint venture owned by Lockheed Martin and The Boeing Company. ULA brings together two of the launch industry's most experienced and successful teams – Atlas and Delta – to provide reliable, cost-efficient space launch services for the U.S. government and commercial customers.

Atlas and Delta expendable launch vehicles have supported America's presence in space for more than 50 years, carrying a variety of payloads including weather, telecommunications, and national security satellites that protect and improve life on Earth, as well as deep space and interplanetary exploration missions that further our knowledge of the universe.

With three families of launch vehicles – Atlas V, Delta II, and Delta IV – ULA continues the tradition of supporting strategic U.S. space initiatives with advanced, robust launch solutions to provide assured access to space and 100 percent mission success. Launch operations are located at Cape Canaveral Air Force Station (CCAFS), FL, and at Vandenberg Air Force Base (VAFB), CA Reference website: http://ulalaunch.com/site/. The following section describes the history of the VAFB launch complex.

I.I Introduction – Space Launch Complex Six

Space Launch Complex 6 (SLC-6) at VAFB, California, USA, is the West Coast launch site for ULA's Delta rocket.

The launch facility was originally built for the Manned Orbiting Laboratory (MOL), part of the United States Air Force's (USAF) manned spaceflight program. The laboratory was attached to a spacecraft, which was derived from Gemini, and would be launched atop the Titan rocket. The program was discontinued in 1969 before anything launched off the pad.

It was not until 1975 that SLC-6 sprang back to life, this time as the approved site for a West Coast Space Shuttle to launch polar orbit payloads for the USAF. Massive construction efforts ensued, including using the existing Mobile Service Tower and moving it 150 feet, and creating a Shuttle Assembly Building, which was added in 1981. Many fit checks and operational pathfinders took place using the Enterprise Space Shuttle (Fig. 1).

As NASA and the USAF prepared for the inaugural launch, the Shuttle fleet was grounded suddenly and unexpectedly due to the Challenger disaster on 28 January 1986. The West Coast Shuttle Program never recovered and was eventually mothballed in September 1989.

The USAF looked at using the pad for Titan IV/Centaur, but SLC-6 eventually became operational for Athena, a family of small launch vehicles that included commercial payloads. The first launch in August 1995 was unsuccessful due to a booster failure. The next two Athenas launched successfully from SLC-6, one in Aug 1997 (Fig. 2) and another in Sept 1999.

Fig. 1: *Enterprise* at SLC-6 in Launch Configuration in October 1985. Source: Image Released to public. Ref: http://www.dodmedia.osd.mil/DVIC_View/Still_Details.cfm?SDAN=DFST9904905&JPGPath=/Assets/1999/Air_Force/DF-ST-99-04905.JPG.

Fig. 2: Lockheed-Martin's Athena 1 at SLC-6, August 1997. *This work is in the public domain in the United States because it is a work of the United States Federal Government under the terms of Title 17, Chapter 1, Section 105 of the US Code.*

It was in that same year, in 1999, that the USAF approved modifying SLC-6 to support the Delta Launch Vehicle under the Evolved Expendable Launch Vehicle (EELV) program. Much of the hardware meant for shuttle use was retained and adapted for use for the Delta IV rocket. This included the main service tower (MST), and the shuttle assembly building, renamed the main assembly building (MAS). The first Delta rocket to lift off SLC-6 occurred on 27 June 2006. It was a resounding success, and marked the first EELV West Coast Launch and the first National Reconnaissance Office payload to launch on EELV (Fig. 3).

Fig. 3: Successful NRO/EELV/SLC-6 First Flight, 27 June, 2006

The Delta configuration was a medium class (single booster), with a 4-meter diameter fairing enshrouding the payload and two strap-on solid rocket boosters. SLC-6 still required many modifications to accommodate the Delta HLV configuration.

I.II Vehicle Description

The HLV configuration can deploy large payloads to geosynchronous transfer orbit (GTO), polar, Sun-synchronous, planetary/escape, and direct insert into geosynchronous Earth orbit (GEO).

The configuration of the first EELV heavy launch vehicle to lift-off the West Coast consists of a 5-m diameter, 19.2-m long payload fairing and the 5-m payload attach fitting assembly (Fig. 4). The second stage consists of a 5-m diameter LH2 tank and the RL10B-2 engine with an extendible nozzle. There are three boosters, known as Common Booster Cores (CBC) – the starboard and the port strap-on boosters and the center core. The RS-68 engine powers each CBC.

Fairing access door locations and blanket modifications were designed to accommodate mission-specific needs. Further modifications to the vehicle allowed for Lift-off Instrumentation, designed to capture environments from T-0 seconds to approximately T+5.5 seconds.

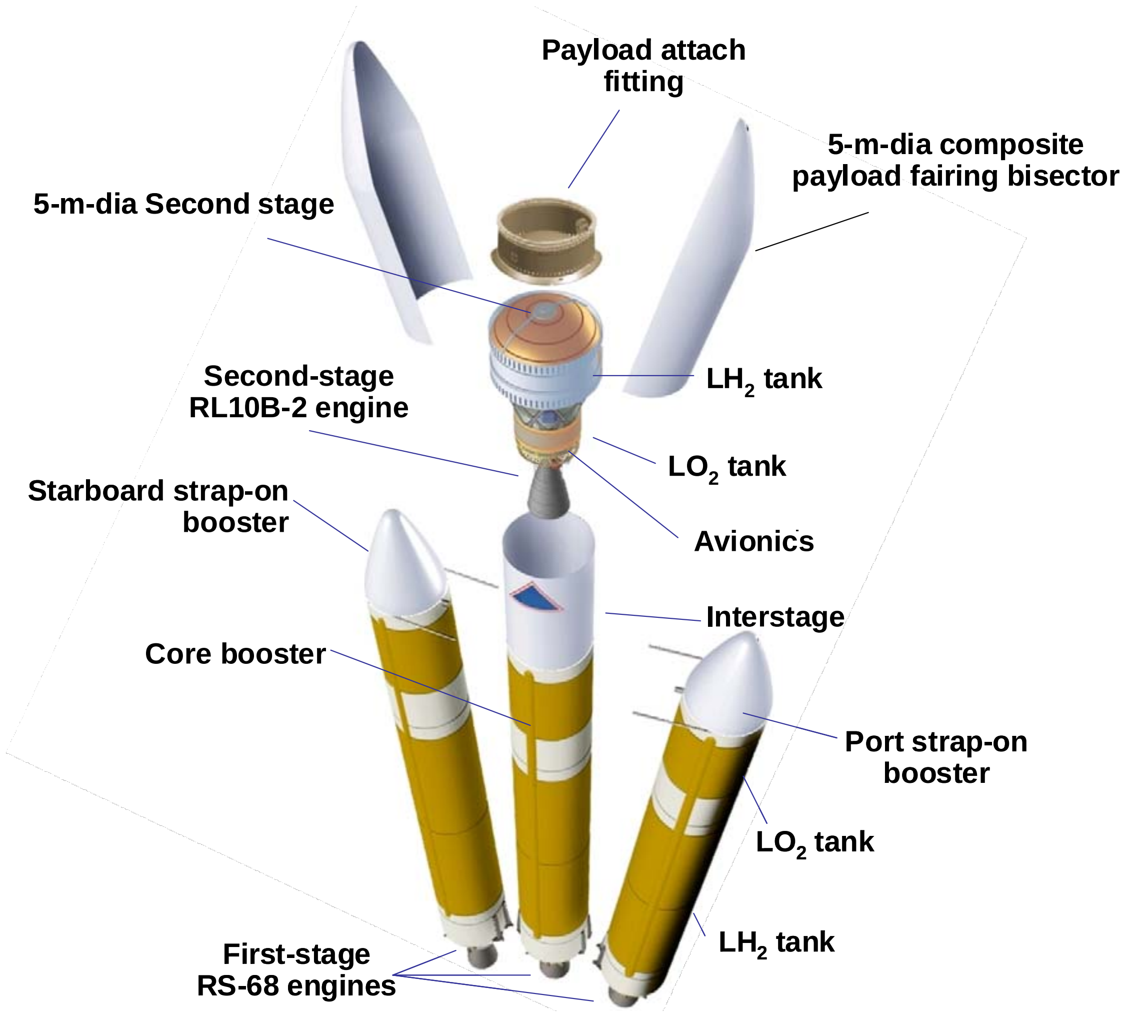

Fig. 4: First West Coast Heavy Vehicle Configuration

II. SLC-6 MODIFICATIONS

The launch system went through modifications and a series of integrated tests to prepare for a successful launch and establish US West Coast Heavy Lift capability.

As you can see in the timeline (Fig. 5), the bulk of the modifications and site activation testing occurred between Nov 2006 and Aug 2009. In parallel, design, fabrication, and activation testing to meet the unique requirements for the payload to fly on the first heavy was occurring. This paper does not detail the payload- or mission-unique modifications.

An auxiliary Liquid Oxygen (LOX) storage capability was fabricated off-site, shipped to the launch site, and is currently undergoing installation, with completion expected in October 2010. The launch pad qualification testing successfully occurred starting in April 2009 and culminating with the vehicle going vertical on the launch pad on 29 January 2010. See Fig. 6.

Once the launch vehicle was on the pad, the launch infrastructure and vehicle underwent a series of integrated testing referred to as First Article Testing. This included cryogenic loading of the tanks representative of the actual day of launch timeline.

In order to certify the vehicle and launch pad as being ready for launch, the hardware and analyses underwent scrutiny in a series of readiness reviews. The Air Force customer and their consultants, in partnership with ULA, reviewed the pedigree of key critical components and assemblies on the rocket to ensure the hardware was qualified and acceptance tested to all the harsh environments expected during lift-off and flight. In addition, reviews tied to production and mission-processing milestones were held to obtain ULA and customer concurrence to proceed to the next milestone.

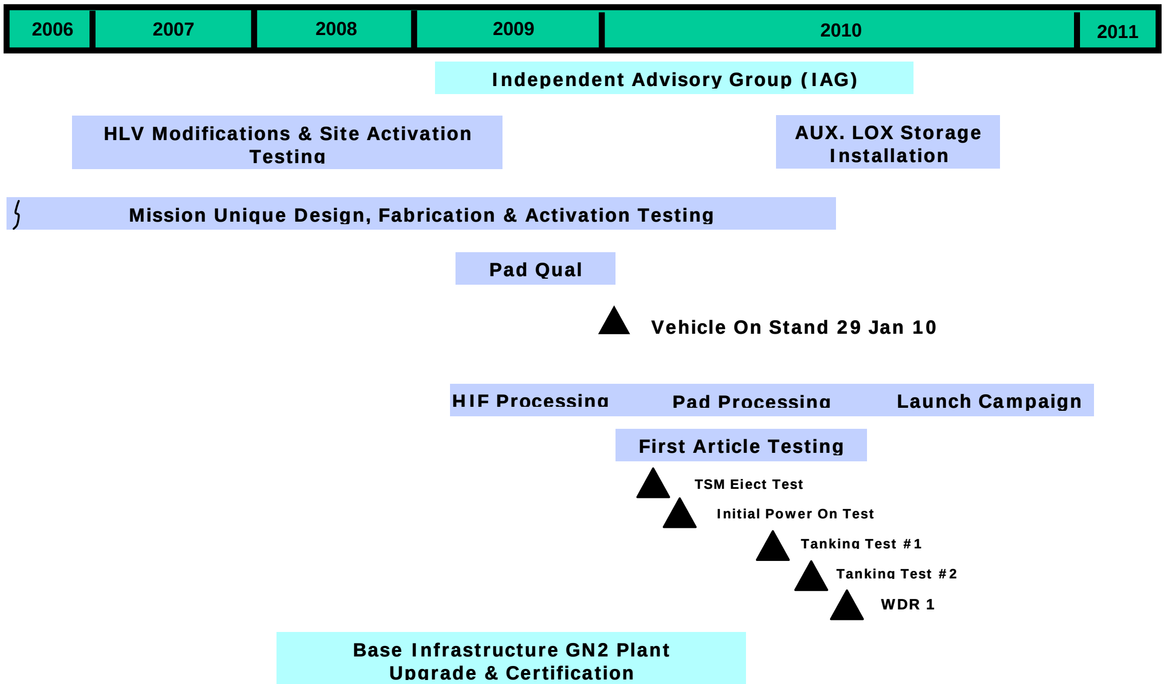

Fig. 5: SLC-6 Modification timeline for establishing West Coast Heavy Lift capability.

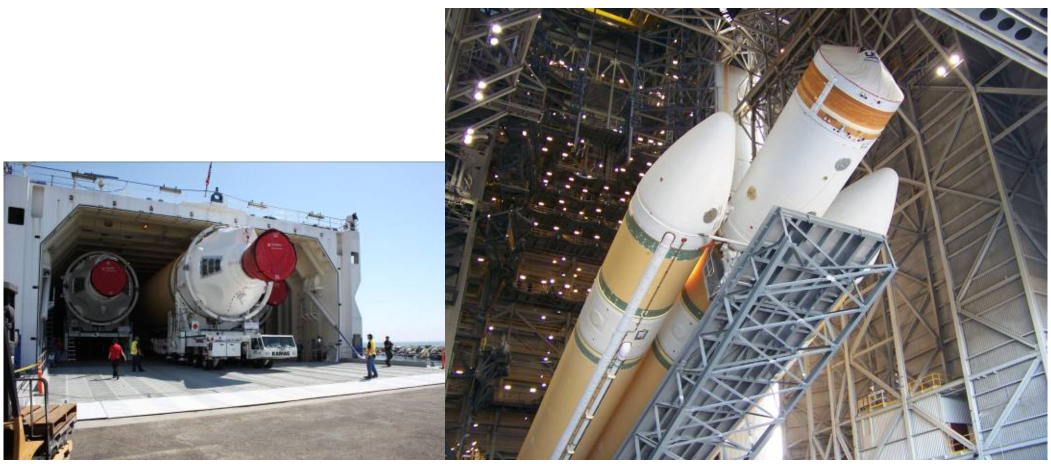

Fig. 6: Arrival of the heavy rocket in VAFB 19 Sep 09; vertical pad erection of ULA's Heavy Launch Vehicle at SLC-6, 29 Jan 10.

The USAF customer and ULA also formed an Independent Advisory Group consisting of a team of knowledgeable experts to identify and mitigate risks associated with SLC-6 HLV activation. The team also helped improve the effectiveness of the readiness review process through active engagement incorporating lessons learned from previous launch site activation efforts. The team provided recommendations and observations to senior management on a recurring basis and will continue their role through launch.

The following sections detail the modifications actually took place.

II.I Heavy Lift Facility Modifications and Site Activation Testing

Some of the larger efforts to adapt the launch pad for a heavy launch vehicle dealt with providing conditioned air to vehicle compartments, like the centerbody. The system that conditions air is known as the Environmental Control System (ECS). This system controls the temperature, humidity, and flow of the air to meet vehicle structural requirements during pad processing and cryogenic fueling. Fig. 7 summarizes pad modifications. After the ECS system was modified, it was tested and checked out prior to receipt of the launch vehicle.

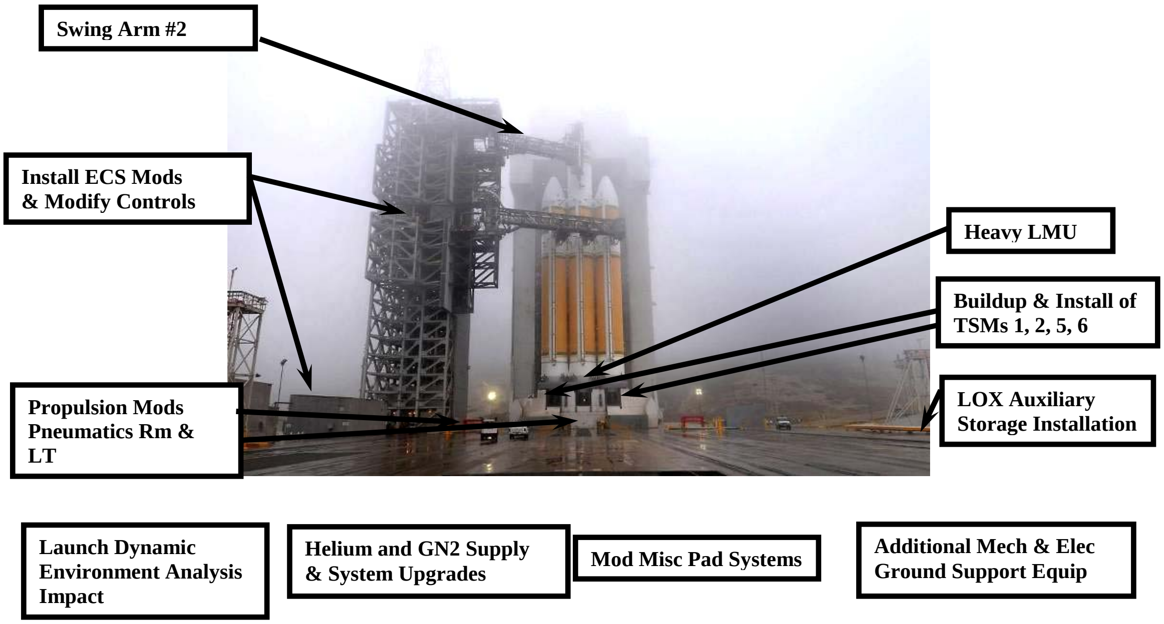

Fig. 7: SLC-6 Heavy Launch Vehicle (HLV) Modification Overview

A significant amount of effort was dedicated to adapting the pad to be able to cryogenically fuel the starboard and port boosters. This included building up and installing the tail service masts (TSM) (Fig. 8). Also, new cryogenically rated fill and drain lines for fuel and oxidizer were installed (Fig. 9).

Fig. 10 shows the auxiliary LOX tank is in its position on the pad. This additional LOX storage capacity allows for six launch attempts of an HLV over a 9-day period.

In addition to these hardware changes, valuable analyses took place to asses launch dynamic environment impacts to the launch pad and launch vehicle. Trade studies occurred on pad acoustic water suppression systems. Lift-off acoustic data were gathered from three previous heavy launches from the ULA Delta launch pad at CCAFS. These data, along with scale wind tunnel testing data, were valuable in assessing the acoustic environments on the West Coast. However, the launch pad at VAFB differs in geometry and geography than the CCAFS pad and it was found that the acoustic lift-off environment was higher on the West Coast at the lower frequencies. Certain pad components were required to undergo testing at the higher levels, such as the TSM Pneumatic Actuation Assembly in the launch table, and were "re-qualified" as part of the pad activation testing.

Critical to the success of launch are the Western Range assets, which are owned, managed, and maintained by the USAF. These assets, among other functions, provide the Delta rocket with the required gaseous nitrogen (GN2) commodity to support cryogenic tanking and the launch. To accommodate the HLV, the USAF successfully upgraded and certified the existing GN2 plant for additional capacity. This capability was proven out during the tanking tests, which is detailed in the following section.

II.II First Article Testing

Site activation testing refers to qualifying the pad systems for receipt of the launch vehicle. First Article Testing on the other hand refers to testing to prove out the successful integration of the launch vehicle and the pad systems. This testing included the TSM eject, Initial Vehicle Power On, Tanking Test 1 & 2, and Wet Dress Rehearsal (Fig. 5). The following paragraphs detail the tanking tests.

Prior to mating the encapsulated payload to the launch vehicle, the launch vehicle underwent a series of cryogenic propellant loading tests. ULA used the day of launch countdown timeline as a model for the timing and order of activities. The purpose of the tests was to demonstrate the physical and functional integrity and integration of the launch vehicle and SLC-6 under prelaunch and post-abort conditions.

Fig. 8: Tail Service Mast (TSM) main structure and housing installation.

Fig. 9: Vacuum Jacketed Fill/Drain Line Installation

The first tanking test successfully occurred on 30 June 2010 (Fig. 11). The objectives that were achieved included loading of the CBC LH2 and LO2 tanks and loading of the second stage LH2 tank to near flight levels. Pressurization of the booster and second stage helium bottles was achieved as well as activation of the booster hydraulic system. Lessons learned were taken from the SLC-6 GHe system and the Range GN2 plant operation. Overall, the team and systems performed very well in this first propellant test of the modified SLC-6 systems and procedures.

The second taking test occurred on 30 July 2010. Lessons learned from the first tanking test were incorporated. Significant accomplishments included: (1) loading all three boosters with LH2 and LOX to 100% levels, (2) loading the second stage LOX tank to 100% levels, (3) loading the second stage LH2 to the required levels to start vent and relief checks, and (4) establishing flight pressures on the CBC He bottles.

III. CONCLUSION

Completing site activation and pad qualification testing, First Article Testing, and the cryogenic propellant loading tests marked significant milestones toward the validation of all the extensive modifications the launch pad underwent to prepare for and establish U.S. HLV capability on the West Coast.

Fig. 10: The Cylindrical Auxiliary LOX Tank in Position

Fig. 11: First Tanking Test, 30 June 2010