EVOLVED EXPENDABLE LAUNCH OPERATIONS AT CAPE CANAVERAL

2002 – 2009

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History Office

PREFACE

This study addresses ATLAS V and DELTA IV Evolved Expendable Launch Vehicle (EELV) operations at Cape Canaveral, Florida. It features all the EELV missions launched from the Cape through the end of Calendar Year (CY) 2009. In addition, the first chapter provides an overview of the EELV effort in the 1990s, summaries of EELV contracts and requests for facilities at Cape Canaveral, deactivation and/or reconstruction of launch complexes 37 and 41 to support EELV operations, typical EELV flight profiles, and military supervision of EELV space operations.

The lion's share of this work highlights EELV launch campaigns and the outcome of each flight through the end of 2009. To avoid confusion, ATLAS V missions are presented in Chapter II, and DELTA IV missions appear in Chapter III. Furthermore, missions are placed in three categories within each chapter: 1) commercial, 2) civilian agency, and 3) military space operations. All EELV customers employ commercial launch contractors to put their respective payloads into orbit. Consequently, the type of agency sponsoring a payload (the Air Force, NASA, NOAA or a commercial satellite company) determines where its mission summary is placed.

Range officials mark all launch times in Greenwich Mean Time, as indicated by a "Z" at various points in the narrative. Unfortunately, the convention creates a one-day discrepancy between the local date reported by the media and the "Z" time's date whenever the launch occurs late at night, but before midnight. (This proved true for seven of the military ATLAS V and DELTA IV missions presented here.) In any event, competent authorities have reviewed all the material presented in this study, and it is releasable to the general public. Any factual errors noted by the reader may be addressed to the 45th Space Wing History Office, 1201 Edward H. White II Street, PAFB, FL 32925-3299.

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CHAPTER I

EELV PROGRAM OVERVIEW

Evolved Expendable Launch Vehicle (EELV) Contracts and Requests for Facilities

After many years of government-funded studies, the Air Force developed a "roadmap" in 1994 for the acquisition of Evolved Expendable Launch Vehicles (EELVs) to succeed the then-current generation of DELTA IIs, ATLAS IIs and TITAN IVs at Cape Canaveral.[1] The Space and Missile Systems Center (SMC) released a Request for Proposal in May 1995, and four companies (e.g., Alliant Techsystems, Boeing, Lockheed Martin and McDonnell Douglas) were each awarded 15-month-long Phase I contracts in August 1995 to elaborate their concepts for the EELV. On 20 December 1996, two of the aforementioned contractors — Lockheed Martin and McDonnell Douglas — were each awarded a $60 million Phase II contract to complete independent 17-month-long Pre-Engineering & Manufacturing Development studies for the EELV. Boeing bought McDonnell Douglas Aerospace in August 1997.[2] Consequently, it was Boeing that proposed a new family of "spacelifters" based on McDonnell Douglas' DELTA IV launch vehicle design. Lockheed Martin proposed its version of the EELV, which became known as the ATLAS V. The ultimate objective of the EELV program was to reduce space launch costs by at least 25 percent while improving the Defense Department's ability to meet "war fighter operability" requirements.[3]

The U.S. Government planned to award two separate $800,000,000 contracts for the development, manufacture and deployment of *a single family* of medium and heavy EELVs in

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1 Unlike earlier efforts to develop a new generation of space launch vehicles from a "clean sheet of paper," the EELV concept capitalized on proved hardware found in DELTA II, ATLAS II/CENTAUR, and TITAN IV vehicles. The goal was the creation of a cost-efficient and reliable family of right-sized spacelifters based on standardized fairings, liquid core boosters, upper stages, and solid rockets.

2 On 1 August 1997, McDonnell Douglas became a wholly-owned subsidiary of the Boeing Company. In his letter to the Honorable Robert Pitofsky, Chairman of the Federal Trade Commission, Deputy Secretary of Defense John P. White advised Mr. Pitofsky on 1 July 1997 that the Defense Department considered the proposed acquisition of McDonnell Douglas by the Boeing Company "acceptable." The decision followed the Department's comprehensive review of the proposed transaction and its potential effect on the various defense contracts held by both companies.

3 Briefing Slides, Brigadier General DeKok, AFSPC/XPX, "Booster Roadmap," 15 Dec 1994; Memo, Mr. Edmond F. Gormel, 45 SW Plans, to 45 SW Offices, "Evolved Expendable Launch Vehicle (EELV) Procurement," 16 Mar 1995; Briefing Slides, SMC/MV, "EELV Government Day," 18 Oct 1995; "Lockheed Martin and McDonnell Douglas move forward in EELV competition," *45th Space Wing Missileer*, 10 Jan 1997; Discussion, M. Cleary, 45 SW History Office, with Mr. Frank Mann, CSR, 6 Nov 1997; "Countdown to the Future," *The Guardian*, Aug 1996; News Release, U.S. Department of Defense, "DOD Finds Boeing's Acquisition of McDonnell Douglas Acceptable," No. 351-97, 1 Jul 1997; News Release, Boeing, "McDonnell Douglas Commences a Fixed Spread Tender Offer of Notes," (cited as Boeing subsidiary), 6 Oct 1997; Discussion, M. Cleary, 45 SW/HO, with Lt. Colonel Wayne Eleazer, 45 SW Plans, 9 Jan 1998.

June 1998. However, Pentagon officials eventually approved the new plan to encourage development of *two families* of EELVs for government and commercial space missions. On 16 October 1998, Acting Secretary of the Air Force F. Whitten Peters announced the award of two $500,000,000 contracts to Boeing and Lockheed Martin for Engineering and Manufacturing Development (EMD) of their respective EELV families. At the same time, Boeing was awarded another contract worth $1.38 billion for 19 government-sponsored launches between Fiscal Year (FY) 2002 and the end of FY 2006. For its part, Lockheed Martin was awarded a $650,000,000 contract for nine government-sponsored launches between FY 2002 and the end of FY 2005. Spurred on by the commercial market as well as government interest, Boeing and Lockheed Martin became quite keen to develop EELVs to meet a wide range of missions at lower cost.[4]

Lockheed Martin initially proposed a family of EELVs consisting of small, medium and heavy vehicles based on a Common Core Booster (CCB). The CCB would be a self-supporting (non-pressurized) aluminum first stage, slightly wider than the first stage on earlier ATLAS vehicles. It would be powered by an RD-180 liquid oxygen/kerosene engine, to be based on the Russian RD-170 first stage engine used on the ZENIT space launch vehicle.[5] The small variant was dropped quickly, and Lockheed Martin focused its development efforts on a middle-sized EELV with considerable growth potential. It was called the HLV-A, and it employed a CENTAUR upper stage powered by either one or two Pratt & Whitney RL10A-4-2 engines rated at 22,300 pounds of thrust each. Several variants were advertised, included basic "400" models equipped with up to three strap-on Aerojet Solid Rocket Boosters (SRBs)[6] and "500" models equipped with up to five SRBs. In its tallest configuration, the ATLAS V (400) stood about 194 feet tall. When a 77-foot-long payload fairing was used, the more powerful ATLAS V (500) stood 205 feet tall.[7]

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[4] 45 SW History, 1 Jan - 31 Dec 1997, Vol I, p 48; "Pentagon OKs Two EELVs," *Aviation Week & Space Technology*, 10 Nov 1997; "DoD Reverses Strategy on Evolved Expendable Launcher," *Launchspace*, Apr 1998; News Release, Defenselink, "Evolved Expendable Launch Vehicle Contract Award," 16 Oct 1998; "EELV Win Boosts Boeing Launch Plans," *Aviation Week & Space Technology*, 26 Oct 1998.

[5] Designers at Pratt-Whitney and NPO Energomash expected the RD-180 engine to provide 860,200 pounds of thrust at sea level and 933,400 pounds of thrust at altitude. The new engine could be throttled from 40 percent to 100 percent of rated thrust. As the project evolved, the RD-180 built by NPO Energomash met the designers' expectations. The CCB was 12.5 feet in diameter and 106.5 feet long.

[6] The ATLAS V's SRBs were approximately 61 inches in diameter and 67 feet long. According to Lockheed Martin's fact sheets circulated in 2002 and 2003, each of the SRBs provided 306,000 pounds of thrust at altitude. Lockheed Martin and Aerojet reported an average thrust of "over 250,000 pounds" during test firing of some upgraded ATLAS V SRBs at Edwards AFB, California, in late May 2005.

[7] "DoD Reverses Strategy on Evolved Expendable Launcher," *Launchspace*, Apr 1998; "Lockheed Martin EELV Designed for Flexibility," *Aviation Week & Space Technology*, 20 Jul 1998; Fact Sheet, Pratt & Whitney, "The RD-180 engine," 8 Mar 2004; Fact Sheet, Pratt & Whitney, "RD-180," copyright 2005; Fact Sheet, Pratt & Whitney,"RL10," copyright 2005; Fact Sheet, Lockheed Martin, "ATLAS V Fact Sheet," undated; Summary, Lockheed Martin, "Atlas," 4 Sep 2002; Summary, International Launch Services, "ATLAS V Family," 16 Sep 2003; Summary, International Launch Services, "ATLAS V 400 Series," 16 Sep 2003; Summary, International Launch

Boeing also suspended its plans for a small variant of its DELTA IV, and it concentrated its EELV effort on developing a new – and impressively large – liquid hydrogen/oxygen-fueled Common Booster Core (CBC) powered by a Rocketdyne RS-68 engine rated at 650,000 pounds of thrust at sea level. There would be five variants: 1) a basic DELTA IV Medium featuring a four-meter-diameter payload fairing, a CBC, and a cryogenic upper stage equipped with the Pratt & Whitney RL10B-2 engine[8] taken from Boeing's short-lived DELTA III program; 2) a DELTA IV Medium (4,2) equipped with the basic DELTA IV Medium's four-meter-diameter payload fairing and upper stage, and two new Alliant Techsystems Graphite Epoxy Motors (GEMs)[9]; 3) a DELTA IV Medium-Plus (5,2) featuring a five-meter-diameter payload fairing, two new GEMs, and an RL10B-2-powered upper stage equipped with larger fuel and oxidizer tanks; 4) a DELTA IV Plus (5,4) equipped with a five-meter fairing, four new GEMs, and an upper stage with larger fuel and oxidizer tanks, and 5) a DELTA IV Heavy, consisted of three CBCs strapped together side-by-side, a cryogenic upper stage equipped with larger tanks, and a five-meter-diameter fairing. All primary structures on the DELTA IV (except those coming in contact with cryogenics) would be built from composite materials to reduce weight and parts count. A $400,000,000 CBC production facility was under construction in Decatur, Alabama, in 1998, and it was expected to employ nearly 2,500 people. Halter Marine (Pascagoula, Mississippi) was under contract to Foss Maritime (Seattle, Washington) to build a vessel that could transport as many as three CBCs at a time from the CBC production facility in Decatur to Cape Canaveral. Once the CBCs and upper stages arrived at the Cape, they would be assembled *horizontally* at Boeing's Horizontal Integration Facility (HIF) before being taken to the launch pad and mated to their encapsulated payloads. Completely assembled, the flight-ready DELTA IV Medium and DELTA IV Medium-Plus (4,2) were about 205 feet tall. DELTA IV Medium-Plus (5,2) and (5,4) were about 225 feet tall. The DELTA IV Heavy was about 235 feet tall.[10]

Services, "ATLAS V 500 Series," undated; News Release, Lockheed Martin, "Lockheed Martin and Aerojet Complete Successful Atlas V Block B Solid Rocket Booster Test," 1 Jun 2005.

[8] The RL10B-2 was rated at more than 19,000 pounds of thrust at altitude.

[9] Alliant Techsystems derived the new GEMs from the 46-inch diameter GEMS it supplied for the DELTA III program. Each of the new GEMs was 60 inches in diameter and 65 feet long. A pair of them weighed approximately 149,000 pounds, and they raised the total thrust of the basic DELTA IV launch vehicle to about 1,000,000 pounds at lift-off.

[10] "DoD Reverses Strategy on Evolved Expendable Launcher," *Launchspace*, Apr 1998; "EELV Win Boosts Boeing Launch Plans," *Aviation Week & Space Technology*, 26 Oct 1998; "Boeing Plans EELV/Delta 4 Horizontal Launch Processing," *Aviation Week & Space Technology*, 20 Jul 1998; "Boeing Adds To Delta 4 Launch Line," *Aviation Week & Space Technology*, 21 Sep 1998; Fact Sheet , Boeing, "The Delta IV Family: the Best Value EELV," Jan 1998; Fact Sheet, Boeing, "Delta IV Launch Vehicles," 4 Sep 2002; Handout, Boeing, "Delta IV – the Satellite Launch Solution," Apr 1999; Boeing, "DELTA IV Payload Planners Guide," pp 1-1, 1-2, 1-5, Oct 2000.

To get things started at the Cape, Boeing requested the use of excess Air Force property at Cape Canaveral Air Force Station for its EELV operations.[11] Boeing requested the use of Hangars C and F for launch vehicle processing and a license to use Complex 37 for DELTA IV launch operations. Boeing also requested use of the blockhouse on Complex 37, and the company vied with Lockheed Martin to acquire use of the Motor Inert Storage (MIS) facility and the Centaur Processing Facility (CPF).[12]

As events unfolded, Boeing's request for the CPF and other facilities came at a very good time. The CPF, which had been built at a cost of more than $50,000,000, was designed and built to handle a projected increase in CENTAUR upper stage operations. The facility consisted of three buildings: 1) The CENTAUR Cryogenic Tanking Facility (CCTF), 2) the Operations Support Building (OSB) and 3) the CENTAUR Processing Building (CPB). The facility was completed in 1996, just about the time Air Force Space Command informed the Secretary of the Air Force (SAF/AQSL) that *there was no longer any requirement for processing, tanking or storing CENTAURs at the CPF*.[13] Funding for the CPF's aerospace ground equipment was returned – saving about $50,000,000 – and the 45th Space Wing (as Air Force Space Command's agent) began maintaining the CCTF in October 1996 and the CPB in October 1997. The 45th Space Wing was paying at least $1,300,000 per year for facilities it could not use. If the CPB and CCTF could be transferred to an EELV contractor, the facilities would be put to good use, and the Wing would save the cost of maintaining them.[14]

On 23 January 1998, The Space and Missile Systems Center (SMC) approved Boeing's request for the Centaur Processing Building and the Centaur Cryogenic Tanking Facility. In early

[11] Traditionally, commercial operators were allowed use of Air Force property on a non-interference basis. Excess Air Force property, if not scheduled to support of a new program or provide space for an existing program, could be used for commercial programs. Licenses were used for existing launch property, and leases were used to allow commercial use of unimproved land. The Air Force could not charge rent for launch property, but the contractor agreed to restore the launch site to its original condition once the property was turned back to the government. In some instances, the Air Force could accept site modifications as "improvements" if it chose.

[12] Briefing Slides, Lt. Colonel Wayne Eleazer, 45 SW Plans, "EELV Facility Issues," 9 Oct 1997; Discussion, M. Cleary, 45 SW History Office, with Lt. Colonel Wayne Eleazer, 45 SE Plans, 9 Jan 1998; Summary, 45 SW Plans, "Main Points, CCAS Facilities for EELV," undated; Letter, Matthew A. Flanders, Lockheed Martin, to SMC, "Contract F04701-97-C-003, Request For Use of Buildings at CCAS During EMD Phase," 30 Sep 1997.

[13] Due to budget cuts and a change in programming philosophy, the NRO's demand for large military reconnaissance satellites was curtailed significantly. Emphasis shifted to smaller, less expensive spacecraft that (in most instances) would not require TITAN IV class boosters and their associated systems. The CPF was a casualty of the change in policy.

[14] Memo, Brigadier General F. Randall Starbuck, 45 SW/CC, to Lt. General Lance W. Lord, AFSPC/CV, "Centaur Processing Facility (CPF), 3 Nov 1997; Memo, Lt. General Lance W. Lord, AFPSC/CV, to 45 SW/CC, "Centaur Processing Facility (CPF) (Your Memo, 3 Nov 97),"17 Nov 1997; Memo, 45 SW/CC to HQ AFSPC/DSV. "Centaur Processing Facility (CPF)," 19 Nov 1997; Draft Memo, HQ AFSPC/DR to 45 SW/CC, "Centaur Processing Facility (CPF) (Your Memo, 19 Nov 1997)," undated.

February 1998, Boeing asked to use the Cape's Receipt, Inspection Storage (RIS) building and Segment Ready Storage (SRS) building for its EELV program. Four months later, the company provided more information on its intended use of the RIS building. The facility would be used for the processing and staging of DELTA IV Heavy separation motors as well as GEM-60 Solid Rocket Motors (SRMs). In early July 1998, Brigadier General F. Randall Starbuck asked SMC to remove the SRS and RIS buildings from Lockheed Martin's list of facilities so they could be licensed to Boeing for its EELV program. Boeing agreed to assume all Operation and Maintenance (O&M) costs and modification costs for both facilities. The Center and Air Force Space Command both agreed, and the reallocation was approved in mid-July 1998.[15]

For its ATLAS V operations, Lockheed Martin proposed to use Launch Complex 41 at Cape Canaveral. Toward that end, Lockheed Martin hired AJT & Associates (Cape Canaveral) to draw up new plans for the launch pad and contracted Hensel Phelps Construction Company (Greeley, Colorado) to modify the pad once the government granted Right of Entry (ROE). In Lockheed's vision of its future EELV operations, payloads would be processed and encapsulated off-site before they were mated to the new vehicles in a vertical processing building. As part of Lockheed Martin's "clean pad" launch philosophy, the vehicle and its payload would arrive at the launch pad already assembled. The ATLAS V could be fueled and launched within 24 hours.[16]

The timing of Lockheed Martin's proposal could not have been better. Several years earlier, the Air Force decided the TITAN IV launch rate at Cape Canaveral did not justify operating Complex 41 after FY 1999. Initially, the plan was to deactivate Complex 41 and 'mothball' it as a hedge against a catastrophic launch failure on Complex 40. By the end of 1995, other options – including complete demolition of the site – were considered. Nevertheless, Detachment 8 of the Space and Missile Systems Center and the 45th Space Wing agreed that nothing substantive could be accomplished until EELV plans were firmed up. Once Lockheed Martin was selected as one of two EELV finalists in December 1996, planning began again. By

[15] Memo, Joyce M. Mullenbach, SMC/MVK, to Lockheed Martin Astronautics, "CPF/MIS ALLOCATION FOR EELV," 23 Jan 1998; Memo, Joyce M. Mullenbach, SMC/MVK, to McDonnell Douglas (Boeing Subsidiary), "CPF/MIS ALLOCATION FOR EELV," 23 Jan 1998; Letter, Gregory Petrick, Boeing Facilities Management, "CCAS-Solid Rocket Motor and Separation Motor Staging," 3 Jun 1998; Memo, Brigadier General F. Randall Starbuck, 45 SW/CC, to SMC/CL, "Reassignment of the Receipt Inspection Shop and Segment Ready Storage Facilities," 6 Jul 1998; Memo for Record, Brigadier General F. Randall Starbuck, 45 SW/CC, "Commercial Space Launch Use of the Receipt Inspection Shop and Segment Ready Storage Facility by Boeing," 6 Jul 1998; Memo, Brigadier General F. Randall Starbuck, 45 SW/CC, to HQ AFSPC/DR, "Reassignment of the Receipt Inspection Shop and Segment Ready Storage Facilities to Boeing," 9 Jul 1998; Memo, Colonel Brian E. Carron, HQ AFSPC/DR to SMC/MV, "Reallocation of 45 SW Facilities Receipt Inspection Shop (RIS) and Segment Ready Storage (SRS) from Lockheed Martin (LM) to Boeing EELV," 16 Jul 1998; Memo, Scarlett S. Small, SMC/MVK, to McDonnell Douglas (Boeing Subsidiary), "Receipt Inspection Storage (RIS) and Segment Ready Storage (SRS) Allocation," 17 Jul 1998; Memo, Scarlett S. Small, SMC/MVK, to Lockheed Martin Astronautics, "Receipt Inspection Storage (RIS) and Segment Ready Storage (SRS) Allocation," 17 Jul 1998.

[16] "Lockheed Martin EELV Designed for Flexibility," *Aviation Week & Space Technology*, 20 Jul 1998.

August 1997, the Air Force's position was that Complex 41 would be deactivated immediately after that complex's final TITAN IV launch. Aerospace Ground Equipment (AGE) and Real Property Installed Equipment (RPIE) would be identified and removed by Detachment 8 and the 45th Civil Engineer Squadron respectively.[17] Detachment 8 also became responsible for integrating the removal of other equipment owned by the Wing, CSR, Bionetics, Johnson Controls, Sverdrup, EG&G and Boeing into the master schedule for equipment removal. The 45th Maintenance Squadron was directed to manage the removal of the pad's communications equipment, and the Eastern Range photographic services contractor was instructed to remove the site's camera equipment under the supervision of the 45th Communications Squadron. Once EELV construction got underway, approximately $5,000,000 would be needed to clean up PCB contamination in areas disturbed by the new construction. The clean-up operation would be financed by Air Force Space Command and supervised by the 45th Civil Engineer Squadron. Responsibilities were firmed up in a Memorandum of Agreement dated 6 August 1998.[18]

Since Complex 41 extended into the Merritt Island Launch Area (MILA) relatively close to Shuttle complexes 39A and 39B, the General Counsel to the Secretary of the Air Force (SAF/GCN) decided to draft a permit for NASA's approval. The permit would clarify Air Force/EELV contractor intentions and confirm NASA's support of the Air Force's decision to lease the complex to Lockheed Martin for its EELV program.[19] Comments on the drafted permit were solicited in August 1998, and Mr. William W. Brubaker (NASA's Director of Facilities Engineering) signed the permit on 23 October 1998. The permit would be in force from 1 November 1998 through 31 December 2021. Mr. Brubaker indicated in his cover letter to the signed agreement that "all NASA approval requirements for leasing and construction have been removed." The Air Force only had to: 1) provide NASA an opportunity to review EELV plans, 2) give "full consideration" to NASA's comments, and 3) coordinate construction details with the Kennedy Space Center's Master Planning and Siting Office (so NASA would have a record of changes in the site's description). With NASA's approval, the Air Force was free to turn Complex 41 over to Lockheed Martin for EELV operations.[20]

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[17] A notable exception to the plan was the disposal of the Mobile Service Tower (MST). In September 1997, Cape Engineering decided to fold the MST demolition into the EELV contract and have the EELV contractor sell the MST for scrap to help pay the cost of demolition.

[18] 45 SW History, 1 Jan – 31 Dec 1998, Vol I, pp 47, 48.

[19] The situation begs a question: was a permit required? According to the Webb-McNamara Agreement of 17 January 1963 and the Huston-Debus Memorandum of Agreement (signed 19 and 23 October 1964), all property within the security fence around Complex 41, supporting facilities, utilities, access roads, parking lots, paved areas, the rail transport system, and an area 200 feet wide on each side of the tracks extending from the Cape boundary to the fenced complex *were not included in the Merritt Island Launch Area*. In effect, the 1963 and 1964 agreements extended the Cape boundary into Merritt Island to surround Complex 41 as part of the Air Force's territory.

[20] Memo, Mr. David D. Stone, Acting Chief, 45 SW Plans, to 45th Support Group Commander et al, "Draft NASA Permit to the AF for Use of SLC 41 Property," 11 Aug 1998; Letter, Mr. William W, Brubaker, NASA Director of Facilities Engineering, to Ms. Cassandra Brown, HQ AFSPC/CEFR, "Kennedy Space Center Launch Complex 41,"

On 8 September 1998, Brigadier General Starbuck approved a comprehensive list of Cape facilities to be allocated to Boeing and Lockheed Martin for their respective EELV programs. For Boeing, the list included Complex 37, a site for the company's new Horizontal Integration Facility (HIF), the CENTAUR Processing Facility (CPF), facilities in the Hangar C area, the RIS Building and the SRS Building. Much of the list had been anticipated, and Boeing had already received a Right of Entry (ROE) to Complex 37 on 8 June 1998. Lockheed Martin's share of the list included Complex 41, Hangar J, the Motor Inert Storage building, rooms in the Launch Operations Control Center and various 29100-series facilities. Due to the requirement for a NASA permit (mentioned earlier), Lockheed Martin did not receive its ROE to Complex 41 until 24 October 1998, but the company moved its construction trailers onto the complex to begin clearing and grubbing for the new Vertical Integration Facility (VIF) shortly thereafter. Hensel Phelps served as the EELV subcontractor for Lockheed Martin, and the company also handled TITAN IV deactivation work under Titan-0012 Contract Mod KX-0143. Work was underway at both EELV launch sites by the close of 1998.[21]

The imminent prospect of EELV operations at the Cape prompted the government to spell out how it would supervise the new programs. In this, the Air Force departed from the traditional oversight policy it had enforced for many decades. Under the EELV Concept of Operations (CONOPS) signed in early September 1997, the EELV contractor was given total system responsibility and retained ownership of all EELV flight hardware. The contractor would also maintain all critical ground support equipment and facilities. Air Force Space Command would determine the most cost-effective way to maintain *non-critical* ground support equipment, and who — contractor, Air Force or third party — would maintain it. The EELV contractor would be responsible for manufacturing, processing and launching the vehicle. As a result, the U.S. Government's role would shift from oversight to *insight*. This shift was designed to reduce bureaucratic layering and get the Air Force out of the "product testing" business. Nevertheless, Air Force Materiel Command would retain sufficient insight to ensure EELVs were flight-worthy, and Air Force Space Command would ensure the safety of the EELV in ground and flight operations after the vehicle arrived at the Cape. The 45th Space Wing Commander remained the Launch Decision Authority (LDA) and made the final decision to launch. Though the EELV contractor was expected to have his own system safety program, the Wing Commander had to ensure that operational hazards were identified and safety risks were minimized. As was true of earlier launch programs, the EELV contractor had to obtain Air Force Space Command's approval for all EELV flight plans and launch operations.[22]

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22 Jul 1998; Letter, Mr. William W. Brubaker, NASA Director of Facilities Engineering, to Mr. Jimmy G. Dishner, SAF/MII, "NASA John F. Kennedy Space Center (KSC) Launch Complex 41," 23 Oct 1998; Permit, NASA, "National Aeronautics and Space Administration Permit to the Department of the Air Force to Use Property on Kennedy Space Center, Florida," signed 23 October 1998.

21 45 SW History, 1 Jan – 31 Dec 1998, Vol I, pp 49, 50.

22 45 SW History, 1 Jan – 31 Dec 1998, Vol I, p 50.

Deactivation of Complex 41 and Construction for ATLAS V

The ATLAS V program achieved a major milestone when the U.S. Government granted Lockheed Martin its Right of Entry (ROE) to Complex 41 on 24 October 1998. In support of the overall effort, the 3rd Space Launch Squadron and 45th Civil Engineer Squadron worked with ten separate contractors and representatives from AFSPC, AFMC and the NRO to complete Complex 41's deactivation. As part of the deactivation process, technicians flushed all fuel lines on the complex, and workers shipped out approximately 20 train carloads of soil for sanitizing and reuse. On 14 October 1999, the Olshan Demolishing Company used 180 pounds of explosives to topple the site's old TITAN IV Mobile Service Tower (MST) and Umbilical Tower (UT). Workers gleaned about $2.5 million worth of salvage from the complex before the event, and they removed approximately 8 million pounds of steel following the demolition. In all, 72 days were required to completely decommission the site's hypergolic propellant systems. Officials deactivated the complex 42 days ahead of schedule.[23]

With a workforce of nearly 500, Lockheed Martin and its assistant contractor, Hensel Phelps, completed facility modifications for the ATLAS V in the spring of 2001. On the Vehicle Integration Facility (VIF) site 1,800 feet south of Complex 41, workers poured more than 1,500 cubic yards of concrete on 27 March 1999 to create the VIF slab.[24] By the end of 1999, construction reached the 250-foot level of the 292-foot VIF structure. Construction was also underway on the Entry Control Building (ECB) and the HVAC (Air-conditioning and Humidity Control) Shelter, just south of the VIF. Workers "topped off" the VIF in early March 2000, and they started building the new Mobile Launch Platform (MLP) south of the VIF during the summer of 2000.[25] Work was underway in 2000 to renovate the Missile Inert Storage (MIS) Building to accommodate the ATLAS V Launch Control Center (LCC) and the Mission Director's Center (MDC). Upon completion, company officials renamed the MIS the ATLAS V

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23 45 SW History, 1 Jan - 31 Dec 1999, Vol I, pp 20, 21; "3rd Space Launch Squadron clears way for space progress," *45th Space Wing Missileer*, 15 Oct 1999; "Launch complex becomes scrap in seconds," *Florida Today*, 15 Oct 1999; "Launch towers at SLC 41 toppled," *45th Space Wing Missileer*, 22 Oct 1999.

24 The five-foot thick slab rested on 65-foot-deep pilings to ensure a solid foundation for the ATLAS V launch vehicle. In compensation for the 10.4 acres of "low quality" wetlands required in the VIF construction area, Lockheed Martin agreed to pay the U.S. Fish and Wildlife Service to restore/create more than 54 acres of high-quality wetlands along the Banana River south of the VIF site. Wetland restoration was underway in 1999, and it was completed in 2000.

25 As its name implied, the VIF was used to stack and integrate the ATLAS V on the Mobile Launch Platform. In accordance with Lockheed Martin's new streamlined procedures, VIF operations began about nine days before workers rolled the vehicle out to the pad. The ATLAS V was ready to go when it departed the VIF, and the vehicle could be launched a mere 12 hours later. Since most of the ATLAS V Aerospace Ground Equipment (AGE) resided in the VIF and the ATLAS V Spaceflight Operations Center, very little ground equipment was exposed to blast damage in the event of a launch mishap or accident on the pad. The new design promoted safety, efficiency and flexibility.

Spaceflight Operations Center (ASOC).[26] Workers delivered and installed a 42,000-gallon liquid hydrogen tank and two 45,000-gallon stainless steel RP-1 fuel tanks in the fall of 2000. A 465,000-gallon liquid oxygen spherical tank was in place before the end of the year. By the time the first ATLAS V arrived in early June 2001, Complex 41 was ready to begin pathfinder operations.[27]

Unlike Boeing, Lockheed Martin decided to use its first Evolved Expendable Launch Vehicle (designated AV-001) as both a pathfinder and a launch vehicle. The first ATLAS V booster and upper stage arrived at the Cape during the first week of June 2001. After several weeks of booster and facility tests in the ASOC, technicians moved the ATLAS V to the VIF in October 2001. They stacked the vehicle on the Mobile Launch Platform, and they added a payload simulator to the vehicle in early November 2001. Following additional facility tests in the VIF, workers de-stacked the ATLAS V and returned it to the ASOC for final horizontal checkout and avionics installation in December 2001. Technicians erected AV-001 again on 22 February 2002 and the *operational* AV-001 was rolled out to Complex 41 on 6 and 7 March 2002.[28]

DELTA IV Program Developments on Complex 37 and Related Sites

In addition to receiving its ROE to Complex 37 on 8 June 1998, Boeing received its ROE to the Centaur Processing Facility in October 1998. The company began transforming the Centaur Processing Building (Building 38835) into a technical support facility for the DELTA IV staff. On 30 April 1999, Boeing signed long-term leases for Complex 37, a DELTA IV complex and substation, a 25-acre site for the new Horizontal Integration Facility, and a four-acre support facilities area. Boeing also signed short-term (e.g., five-year) licensing agreements

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[26] The four-story-tall ASOC was located four miles from the launch pad. It replaced 13 old ATLAS facilities, and it gathered customer support, vehicle checkout, and launch control operations under one roof. The ASOC included a two-story amphitheater, a mission operations center, a two-story launch control center, and various management/engineering support rooms. With 30,000 square feet of floor space, the ASOC could process up to six ATLAS Vs at a time. Since most checkout operations would be completed at Lockheed Martin's Denver plant before the ATLAS V was shipped, checkout at the ASOC might require as little as one day of work for each vehicle.

[27] 45th Space Wing History, 1 Jan –31 Dec 1998, Vol I, p 50; 45th Space Wing History, 1 Jan – 31 Dec 2000, Vol I, p 23; 45th Space Wing History, 1 Jan – 31 Dec 2001, Vol I, p 28; "Lockmart Bets Launch Future on Atlas V," *Aviation Week & Space Technology*, 10 Dec 2001; E-Mail, Suzanne Schulman, 45 CES/CEL to 45SWHO, "Input for Cape History Books," 11 Jan 2000; Discussion, M. Cleary, 45 SW/HO, with Ms. Suzanne Schulman, 45 CES/CEL, 8 Feb 2000.

[28] "Lockmart Bets Launch Future on Atlas V," *Aviation Week & Space Technology*, 10 Dec 2001; "Lockheed Martin Ships Atlas 5 Segment to NASA," *Space News*, 14 May 2001; "Atlas 5 arrives for first flight," *Florida Today*, 7 Jun 2001; "Atlas V booster arrives," *45th Space Wing Missileer*, 8 Jun 2001; "Atlas V Stacked," *Aviation Week & Space Technology*, 29 Oct 2001; Discussion, M. Cleary, 45 SW/HO with Mr. Ken Warren, 45 SW Public Affairs, 19 Feb 2002; Summary, Lockheed Martin Space Systems, "Atlas V/EELV Chronology," undated.

for the RIS Building, the SRS Building, and a portion of Hangar E. Boeing's plan for DELTA IV operations at the Cape revolved around the facilities and functional areas listed below:[29]

PROPOSED DELTA IV FACILTIES

- Complex 37 (including a Support Equipment Building and a Launch Support Shelter)
- The Horizontal Integration Facility (HIF)
- The Precision Clean Lab (PCL – Building 43400)
- DELTA IV Complex (i.e., built astride the old Centaur Processing Facility. It included the DELTA IV Operations Center [DOC], the Flight Hardware Building [FHB] and the Technical Support Building [TSB])
- DELTA IV Substation (Pump House 5)
- Solids Area (the RIS and SRS Buildings)

Boeing awarded Raytheon the overall contract to rebuild Complex 37. However, in June 1999, Boeing signed an agreement with the Spaceport Florida Authority (SFA) to finance and build the DELTA IV Horizontal Integration Facility (HIF). The SFA agreed to sponsor the facility and lease it back to Boeing under a long-term agreement. The SFA signed a contract with Haskell Engineering (Jacksonville, Florida) to build the seven-story-high structure.[30] Work on the HIF began in August 1999, and it went well. Workers erected the facility's structural steel and most of its siding in 1999. Administrative areas were under construction at the end of the year.[31]

By the end of 1999, construction on Complex 37 was approximately 45 percent complete. Contractors poured more than 32,000 cubic yards of concrete to build the complex's Launch Support Shelter, Launch Deck, Flame Duct, and foundations for its gas farms. Workers

[29] Staff Summary Sheet, Det 1, 45 SPTG, "Out-of-Cycle Space Allocation, CCAS, Approval of Evolved Expendable Launch Vehicle use of 45 SW Facilities," 14 Aug 1998 (initialed by 45 SW/CC 8 Sep 1998); Summary, Mr. Michael G. Woolley, Boeing Launch Site Activation Lead, "1999 Delta IV History," undated.

[30] The 100,000-square-foot HIF was the center of Boeing's DELTA IV integration and testing operations at the Cape. Following processing at the HIF, technicians transported the DELTA IV horizontally to Pad 37. The remaining preflight operations were largely a matter of erecting the DELTA IV at the pad, attaching a payload, fueling the vehicle, and launching it. The HIF had two active vehicle-processing bays and an annex to stage the boosters and equipment. Each bay was seven stories high and measured 100 x 250 feet. Each DELTA IV booster was 180 feet long and 16 feet 7 inches in diameter.

[31] 45 SW History, 1 Jan – 31 Dec 1999, Vol I, p 20; Summary, Boeing, "Horizontal Integration Facility (HIF) For Boeing's Delta IV," Sep 2000; Summary, Boeing, "Space Launch Complex 37, Cape Canaveral Air Station, Fla." Sep 2000; "Delta IV Goes Horizontal," *Inside DELTA,* Oct 2000; "Delta IV facility unveiled," *45th Space Wing Missileer,* 15 Sep 2000.

excavated the pit for the Fixed Platform Erector (FPE),[32] and builders got to work on the Launch Support Shelter's rooms. The Support Equipment Building (SEB) refurbishment effort was well underway in 1999. While some contractors removed hazardous materials from the SEB, others resurfaced the facility's roof. Technicians were installing electrical and air-conditioning systems in the SEB by year's end. The 250,000-gallon Liquid Oxygen (LOX) tank on Complex 37 was built and hydro-tested in 1999, and the site's 850,000-gallon Liquid Hydrogen tank was 95 percent complete.[33]

On 2 March 2000, Raytheon "topped off" the new 330-foot-tall Mobile Service Tower (MST).[34] Contractor personnel started working on the fixed Umbilical Tower (UT) in March, and they completed the job in November 2000. Astrotech started building the DELTA IV Satellite Processing Facility in March 2000. Inside the DELTA IV Operations Building, workers completed construction of the Launch Control Center (LCC) and the Mission Director's Center (MDC). Technicians added consoles and launch control equipment to the LCC before the end of the year. Following completion of the HIF in June 2000, Boeing held a dedication ceremony for the HIF on 11 September 2000. In the meantime, the 65 x 45 x 23-foot Launch Table (weighing 600 tons) was delivered to the Kennedy Space Center Press Site Wharf via barge. Workers transported the Launch Table to Complex 37. Once there, they bolted it to the launch deck in November 2000. The first of two Elevating Platform Transporters (used to move booster cores and satellites) arrived in June 2000. The Precision Clean Lab and the DELTA IV Machine Shop were completed in September 2000.[35]

In October 2000, Durocher Dock & Dredge completed a $1,387,749 contract to prepare the Air Force Wharf for DELTA IV off-loading operations at Port Canaveral. The *DELTA IV Mariner*, which was built to transport DELTA IV boosters and other components from the DELTA IV factory in Decatur, Alabama, made its first visit to the wharf on 15 October 2000.[36] Canaveral Construction completed a $225,000 contract in October 2000 to modify the roadway

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[32] The FPE pit eventually housed two enormous hydraulic pistons. Engineers designed the pistons to erect a DELTA IV booster and place it on the Launch Table. After the pistons were installed, steel plating was used to cover the FPE pit and serve as a foundation for the booster as it was being erected.

[33] Summary, Mr. Michael G. Woolley, Boeing Launch Site Activation Lead, "1999 Delta IV History," undated.

[34] The new MST was 90 feet wide and 60 feet deep. With all of its equipment installed, the MST weighed approximately nine million pounds.

[35] Summary, Mr. Michael G. Woolley, Boeing, 19 Dec 2000; "Boeing, Lockheed Martin to showcase new launch sites," *Florida Today,* 2 Mar 2000; "Lockheed, Boeing top off EELV site," *45th Space Wing Missileer,* 10 Mar 2000.

[36] The visit allowed the crew to accomplish a "wharf fit check" and complete some training in off-loading operations. The *DELTA IV Mariner* was built by Halter Marine for Foss Maritime. Boeing agreed to pay Foss Maritime for the use of the ship. The *DELTA IV Mariner* was 312 feet long, and it had an 82-foot beam. The vessel registered at 2,820 long tons, and it could make 15 knots in calm water. Fully loaded, the ship could carry three DELTA IV booster cores, a pair of nosecones, two upper stage rocket engines, and a 48-foot-long payload fairing.

between Poseidon Avenue, Phillips Parkway, and the DELTA IV Complex for the EELV program. In addition, a nine-mile-long high-pressure helium pipeline from the Kennedy Space Center Helium Facility to Complex 37 was commissioned on 2 November 2000.[37]

Sadly, as Boeing, Raytheon and various subcontractors completed their tasks on Complex 37 in 2001, two fatal accidents occurred. On 8 July 2001, a subcontracted employee was killed when a pipe he was disconnecting broke loose under pressure and struck him in the head.[38] Three other workers were injured, but they were released after treatment at a local hospital. On 1 October 2001, Bill Brooks, a Boeing employee, was killed atop Complex 37's MST when he was pinned between a crane and a support structure. The accident occurred around 6:00 p.m. Mr. Brooks was pronounced dead on arrival at the Cape Canaveral Hospital in Cocoa Beach. The government's Occupational Health and Safety Administration (OSHA) investigated both accidents.[39]

Among the many DELTA IV-related efforts at the Cape in 2001, three milestones stand out: 1) DELTA IV pathfinder operations, 2) arrival of the first DELTA IV space launch vehicle, and 3) the Complex 37 Dedication Ceremony. Concerning the first milestone, a DELTA IV Static Test Common Booster Core (CBC) was used as the pathfinder vehicle.[40] The *Delta IV Mariner* delivered the pathfinder to Port Canaveral on 29 May 2001, and workers transported the booster to the HIF to ensure compatibility with Aerospace Ground Equipment (AGE) and working areas inside the HIF. Following pathfinder operations in the HIF, technicians moved the CBC to Complex 37 on 22 August 2001 to continue the pathfinder process. The booster was placed on the Fixed Pad Erector (FPE) and erected on the Launch Table on 23 August 2001. Pathfinder operations continued at the launch pad through 15 October 2001 to ensure the launch platform was configured properly and the vehicle had enough clearance.[41] In the meantime, the first DELTA IV upper stage arrived at Complex 37 on 10 September 2001.[42]

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[37] Summary, TESS, "Construction Scope of Work Report," 16 Oct 2000; Summary, Mr. Michael G. Woolley, Boeing, 19 Dec 2000; "New Vessel Launched To Haul Delta 4 Rockets," *Space News,* 10 Jan 2000; "EELV ship docks at Cape Canaveral," *45th Space Wing Missileer,* 27 Oct 2000; Summary, Foss Maritime, "Foss Maritime is Committed to Support the Success of the Delta IV Program," undated.

[38] The deceased had been an employee of Precision Fabricating and Cleaning, which was under contract to the Washington Government Group.

[39] "Accident at Cape kills contractor," *45th Space Wing Missileer,* 31 Jul 2001; "Boeing Employee Killed in Accident," *Space News,* 8 Oct 2001; "Boeing employee dies in accident at Delta 4 pad," *Spaceflight Now,* 2 Oct 2001; "Crane Accident Kills Boeing Worker at Cape," *Florida Today,* 4 Oct 2001.

[40] Prior to its arrival at the Cape in May, the Static Fire CBC had been fired five times at NASA's Stennis Space Center in Mississippi to help qualify the DELTA IV's RS-68 engine for flight. Additional RS-68 engine tests (presumably involving other hardware) were conducted in late September 2001 to validate changes in the engine's turbo pump design. Boeing hoped to have three RS-68 engines ready by the end of 2001. Eight more might be ready in 2002.

[41] The pathfinder team operated the FPE and moved the MST around the vehicle to make sure the booster meshed properly with the MST's working platforms. Technicians installed equipment to confirm they could process a

Initially, technicians installed the DELTA IV upper stage in Bay 3 of the DELTA IV Operations Center. Following a nozzle extension demonstration, the DELTA IV upper stage was moved into Bay 1 of the HIF to begin power-on testing on 7 November 2001. Technicians completed upper stage telemetry bus voltage measurements on 8 November, and they verified proper operation of the upper stage's rocket engine modules on 9 November 2001. (The test marked the first use of the DELTA IV Guidance Computer at the launch site.) Elsewhere in the local area, the *Delta IV Mariner* delivered the First Flight CBC to Port Canaveral on 4 October 2001. Workers moved the First Flight CBC to the HIF where mechanical and electrical pathfinder operations were soon underway. Workers transferred the upper stage to a cradle pallet on 21 November, and the DELTA IV upper stage was "soft" mated to the First Flight CBC on 29 November 2001. Technicians completed a hard mate of the two stages on 13 December 2001.[43]

Boeing hosted the Complex 37 Dedication Ceremony at the HIF on 9 October 2001. More than 450 guests attended the ceremony. The Secretary of the Air Force, Dr. James G. Roche, was the keynote speaker. Other dignitaries included Mr. Harry C. Stonecipher (Vice Chairman, Boeing), Congressman Dave Weldon, Mrs. Darlene Druyun (Deputy Assistant Secretary of the Air Force for Acquisition and Management), and Florida Lieutenant Governor Frank T. Brogan. The ceremony marked the official completion of Complex 37's reconstruction for DELTA IV operations. In its new streamlined configuration, Complex 37 would be able to process and launch all five variants of the DELTA IV. The first DELTA IV launch was anticipated around June 2002. Once DELTA IV operations became routine, Boeing hoped its launch team would be able to process and launch a DELTA IV within 30 days of its arrival at the Cape. Boeing designed the new equipment and procedures to reduce on-pad time from about 22

DELTA IV on the pad and remove and replace components as required. They also placed an inert Graphite Epoxy Motor (GEM) in four different positions and mated it to the pathfinder to verify compatibility. Data was collected on the various pathfinder operations including the FPE's performance in various positions as the CBC was lowered. In addition to confirming booster/pad compatibility, Boeing determined how much time was needed to complete various operations (e.g., erection, mating, demating, and lowering a vehicle for weather or equipment problems).

[42] Summary, Mr. Michael G. Woolley, DELTA IV Launch Sites IPT, "Delta IV 2001 History," 11 Feb 2002; "Delta IV – Key Element In Boeing's Strategy," *Aviation Week & Space Technology*, 10 Dec 2001; "U.S. Air Force Says Delta 4 Still on Track," *Space News*, 4 Oct 2001; Fact Sheet, Boeing Space Systems, "RS-68 Propulsion System," 20 Nov 2000; "Fired Up On Progress," *Access*, 1 Oct 2001, Vol 1, No. 1; "Delta IV test booster rolls to SLC 37 for pathfinder tests," *45th Space Wing Missileer*, 31 Aug 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "Static Fire Unit Secured/Moved to Horizontal Integration Facility," 15 Oct 2001.

[43] Summary, Mr. Michael G. Woolley, DELTA IV Launch Sites IPT, "Delta IV 2001 History," 11 Feb 2002; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "First Flight Upper Stage moved to Horizontal Integration Facility," 5 Nov 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "First Flight Upper Stage Power On," 9 Nov 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "Upper Stage Transfer to Cradle Pallet," 23 Nov 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "Upper Stage Mate to Common Booster Core," 29 Nov 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "Second Stage Mated to CBC," 14 Dec 2001.

days (for the DELTA II) to about 10 days (for the DELTA IV). Together with other innovations, the reduction in processing time translated to costs savings for Boeing and its customers.[44]

ATLAS V and DELTA IV Flight Profiles

In a typical ATLAS V (400 variant) flight scenario, the launch vehicle's RD-180 ignited about three seconds before lift-off. Rising vertically for approximately 250 feet, the vehicle rolled into its flight azimuth and began its initial roll, pitch, and yaw program under the control of the CENTAUR upper stage's inertial guidance system. Once its fuel was depleted (e.g., typically between four minutes and four and one-half minutes into the flight), the RD-180 shut down, and the booster separated from the CENTAUR. The CENTAUR fired about ten seconds after separation from the booster. The payload fairing was jettisoned during the ATLAS V's boost phase or during the CENTAUR's first 'burn.' In either case, the first CENTAUR burn lasted from about five minutes to as much as 14 minutes depending on the configuration of vehicle, and it injected the upper stage and spacecraft into a "moderately eccentric" parking orbit. Following a coasting period lasting from eight minutes to more than one hour, the CENTAUR restarted and fired to place the payload in Geosynchronous Transfer Orbit (GTO). The spacecraft separated from the upper stage some minutes later, and it used its onboard propulsion system to achieve final orbit.[45]

Range instrumentation support for a typical ATLAS V flight from Cape Canaveral included radars at the Cape, Patrick AFB, Jonathan Dickinson Missile Tracking Annex and the island of Antigua. Command transmitter/exciters at the Cape, Jonathan Dickinson and Antigua provided command and control. HH-60G helicopters operated out of Patrick AFB to provide safety sea surveillance, and an SCE Learjet provided weather reconnaissance. Telemetry units on Merritt Island, Jonathan Dickinson and Antigua supported the flights, and so did the Centralized Telemetry Processing System (CTPS) at Cape Canaveral. Optical support included the Distant Object Attitude Measurement System (DOAMS), the Advanced Transportable Optical Tracking System (ATOTS) at the Cape, and cameras at other range sites to ensure at least four optical systems covered each launch. Patrick's WSR-74C weather radar, Melbourne's WSR-88D radar and a whole host of weather instrumentation systems at Cape Canaveral supported each flight.[46]

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[44] Summary, Mr. Michael G. Woolley, DELTA IV Launch Sites IPT, "Delta IV 2001 History," 11 Feb 2002; "Delta IV – Key Element In Boeing's Strategy," *Aviation Week & Space Technology*, 10 Dec 2001; Memo, David A. Herst, Director, Delta IV/EELV Launch Sites, "Space Launch Complex 37 Dedication Ceremony," 10 Oct 2001; "Boeing unveils Delta IV complex at Cape," *45th Space Wing Missileer*, 12 Oct 2001; News Release, Boeing Space Systems, "Boeing dedicates new Delta IV launch complex at Cape," 9 Oct 2001.

[45] 45 SW History, 1 Jan - 31 Dec 2006, Vol I, pp 64, 65; 45 SW History, 1 Jan - 31 Dec 2007, Vol I, p 75; 45 SW History, 1 Jan -31 Dec 2008, Vol I, pp 106, 107.

[46] 45 SW History, 1 Jan - 31 Dec 2006, Vol I, p 65; 45 SW History, 1 Jan - 31 Dec 2007, Vol I, p 76; 45 SW History, 1 Jan - 31 Dec 2008, Vol I, p 107.

In a typical DELTA IV Medium flight scenario, the launch vehicle's RS-68 engine ignited shortly before lift-off from Complex 37B. After rising vertically for approximately 250 feet, the vehicle rolled over and began its journey downrange. The RS-68 continued to thrust until Main Engine Cutoff (MECO) approximately four and one-half minutes after lift-off. Following first stage separation, the second stage ignited. The payload fairing was jettisoned between seven and 12 seconds into the second stage's first burn. Depending on the mission, the second stage continued to thrust for as little as seven minutes and 20 seconds or as much as nine minutes and 20 seconds. Following a coasting period of almost 12 minutes, the second stage fired once or twice more to inject the spacecraft into GTO. The spacecraft separated from the vehicle, and it used its onboard propulsion system to achieve final orbit.[47]

The major staging sequences for a DELTA IV Heavy flight corresponded to flight events for its less powerful sibling, but the precise timing of DELTA IV Heavy and DELTA IV Medium flight events (e.g., engine ignition, shutdown, stage separation, etc.) differed. On each of two DELTA IV Heavy missions launched from Cape Canaveral in 2007 and 2009, three RS-68 engines ignited shortly before lift-off and continued to provide thrust for approximately five and one-half minutes. The first stage separated from the launch vehicle, and the second stage ignited about 15 seconds later. The payload fairing was jettisoned early in the second stage's first burn. Depending on the mission, the second stage continued to thrust for approximately seven minutes. Coasting periods alternated with two additional firings of the second stage's RL10B-2 engine, which finally shut down between five and one-half hours and six hours and 15 minutes into the flight. The payload separated from the vehicle less than 10 minutes later, and the spacecraft used its onboard propulsion system to achieve final orbit.[48]

An impressive array of range instrumentation supported each DELTA IV mission. This support included radars at the Cape, Jonathan Dickinson Missile Tracking Annex, Merritt Island and the island of Antigua. Command transmitter/exciters at the Cape, Jonathan Dickinson and Antigua provided command and control. Two HH-60G helicopters operated out of Patrick AFB to provide sea safety surveillance, and an SCE Learjet provided weather reconnaissance. Telemetry units on the Cape, Merritt Island, Jonathan Dickinson and Antigua supported each flight. Optical support included two Distant Object Attitude Measurement Systems (DOAMS), two Advanced Transportable Optical Tracking Systems, and at least one other optical camera site. A whole host of weather instrumentation systems at Cape Canaveral supported each flight.[49]

Military Supervision of ATLAS V and DELTA IV Space Operations

As mentioned earlier, ATLAS V and DELTA IV contractors were responsible for manufacturing, processing and launching their launch vehicles. Moreover, they retained

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[47] 45 SW History, 1 Jan - 31 Dec 2003, Vol I, pp 119, 120; SW History, 1 Jan -31 Dec 2007, Vol I, p 105.

[48] 45 SW History, 1 Jan -31 Dec 2007, Vol I, p 107, 108.

[49] 45 SW History, 1 Jan - 31 Dec 2003, Vol I, p 120; SW History, 1 Jan - 31 Dec 2007, Vol I, p 106.

ownership of all flight hardware, and they were given total system responsibility under the EELV Concept of Operations signed in September 1997. Though this new concept of space operations appeared to diminish the Air Force's supervision of launch-related activities from the Cape, Air Force Materiel Command retained sufficient insight to ensure EELVs were flight-worthy. For its part, Air Force Space Command ensured the safety of all EELV operations after the vehicles arrived at the Cape. The principal local agencies providing those services were Detachment 8 of the Space and Missile Systems Center (for flight-worthiness) and the 45th Space Wing (for safety).

Detachment 8's role in ATLAS V and DELTA IV operations at the Cape changed dramatically following the much-heralded 45th Space Wing Organizational Transformation in December 2003. In accordance with Air Force Space Command Special Order GD-002 (dated 24 November 2003), the 45th Launch Group (45 LCG) was constituted and assigned to Air Force Space Command (with further assignment to the 45th Space Wing) and activated at Cape Canaveral Air Force Station. Furthermore, per Special Order GD-002, the following actions were taken as part of the transformation effective 1 December 2003:[50]

- The 45th Range Management Squadron was reassigned from the 45th Maintenance Group to the 45th Operations Group at Cape Canaveral Air Force Station.
- Detachment 8, Headquarters Space and Missile Systems Center was inactivated at Cape Canaveral Air Force Station.
- The 45th Range Squadron was inactivated at Cape Canaveral Air Force Station.
- The 1st Range Operations Squadron (1 ROPS) was constituted and assigned to Air Force Space Command with further assignment to the 45th Operations Group. The 1 ROPS was activated at Cape Canaveral Air Force Station.
- The 1st and 3rd space launch squadrons (1 SLS and 3 SLS) were reassigned from the 45th Operations Group to the 45th Launch Group at Cape Canaveral Air Force Station.
- The 5th Space Launch Squadron (previously inactivated on 29 June 1998) was assigned to Air Force Space Command and activated (i.e., re-activated) at Cape Canaveral Air Force Station effective 1 December 2003. The squadron (a.k.a. 5 SLS) was further assigned to the 45th Launch Group on the same date.

[50] Headquarters AFSPC Special Order GD-002, 24 Nov 2003; Slide, 45 SW, "Wing Transformation – Get It!" 1 Dec 2003; "Wing undergoes historic transformation," *45th Space Wing Missileer*, 5 Dec 2003; "Straight from the Commander's Desk," *45th Space Wing Missileer*, 5 Dec 2003.

Colonel Michael T. Baker, Detachment 8, SMC Commander, became the 45th Launch Group's first commander on 1 December 2003. That action – and more importantly, the transfer of insight for DELTA IV and ATLAS V operations to the 5th Space Launch Squadron from Detachment 8 – marked the consolidation of all military space launch operations under one organization. According to Brigadier General J. Gregory Pavlovich, the Wing's transformation aligned "acquisition and launch operations under the 45th Space Wing." Colonel Baker echoed that sentiment when he said, "the 45th Launch Group is a blending of teams bringing the Wing in line with what [Air Force Under Secretary Peter Teets] sees as a renewed focus on successful payload delivery on orbit." The transformation prompted a ceremonial activation of the 1 ROPS at Cape Canaveral at 2:00 p.m. on 1 December 2003. The 5th Space Launch Squadron Activation Ceremony was held in Boeing's Horizontal Integration Facility (HIF) at Cape Canaveral at 10:00 a.m. on 5 December 2003. Finally, at 9:00 a.m. on 26 January 2004, the 45th Space Wing Organizational Transformation Ceremony was held at the Air Force Space and Missile Museum at Cape Canaveral to formalize the transformation that occurred on 1 December 2003.[51]

The 5 SLS training program in 2004 owed much to the standards applied to the Cape Consolidated Task Force (CCTF) around the turn of the century. It was clear from the outset that CCTF supervision of ATLAS V and DELTA IV space operations would be handled differently from the ATLAS II, DELTA II and TITAN IV programs. Put simply, Air Force Space Command intended to buy commercial launch services from Lockheed Martin and Boeing for the EELVs, and the CCTF would not control launch processing or countdowns to launch. Instead, the CCTF role was limited to insight (e.g., monitoring, providing risk analysis, updating status and making recommendations). Nevertheless, personnel assigned to the CCTF had to have "a level of expertise…to provide value-added assessments of launch site activities." Incoming personnel were presumed to be subject matter experts, and their follow-on training would be adjusted to "specific requirements and levels of depth identified by leadership and program management." Officials expected the CCTF training program to address *all* contractor and government activities related to EELVs, not just the on-console activities of the Mission Leader and Integrated Product Team (IPT) Leader. As such, the training program would be flexible, and it would consist of one-time and recurring training requirements based on formal courses, briefings, individual self-study efforts and one-on-one instruction.[52]

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[51] Headquarters AFSPC Special Order GD-002, 24 Nov 2003; "Wing undergoes historic transformation," *45th Space Wing Missileer*, 5 Dec 2003; "Straight from the Commander's Desk," *45th Space Wing Missileer*, 5 Dec 2003; Program, 45 LCG, "5th Space Launch Squadron Activation Ceremony," 5 Dec 2003; Program, 45 SW Protocol Office, "45th Space Wing Organizational Transformation Ceremony," 26 Jan 2004.

[52] Slides, CCTF, "Cape Consolidated Task Force Training Plan 'Approach' (Compared to 14AFI36-2201)," CCTF Mission, ca 2001; Draft, 5 SLS, "5 SLS OI 36-2201, Education and Training Plan for the 5th Space Launch Squadron," Mar 2004; E-Mail, Mr. Keith Auger, 5 SLS, to Mark Cleary, 45 SW History Office, "5 SLS Training Concepts," 24 Aug 2004.

Boeing or Lockheed Martin provided 'baseline' training in safety, technical matters and ancillary activities for the initial CCTF cadre (both contractor and military). As EELV operations progressed, there were block reviews of major program changes. The contractor provided additional training in those areas. Recurring training was applied at the discretion of the IPT Leader and/or the individual team member's request. Finally, the EELV contractor provided upgrade training as needed to strengthen the educational foundation given to (and later, by) the initial cadre. The contractor's classroom training modules were tied to the contractor's surveillance plans, and both efforts provided a homogeneous approach to the overall supervisory effort.[53]

The Squadron's role in EELV operations and maintenance was limited to insight "achieved through watchful observation." While Air Force officials did not have "approval or disapproval rights," they had access to EELV contractor facilities, and they could attend contractor meetings, observe contractor operations, and enroll in contractor training programs on a space-available basis. The 5 SLS did not direct or control launch processing or countdowns, but it monitored those activities to provide status to higher headquarters, to accomplish risk analysis, and to make recommendations. Significantly, 5 SLS personnel were not formally certified to provide insight, but they were selected based on their experience and qualifications. As such, the 5 SLS training program was designed to "add depth to the foundation that each 5 SLS member possesses, as well as organizing and tracking unit training requirements."[54]

It must be emphasized, however, that 45th Space Wing Safety had extensive responsibilities for launch vehicles and payloads, flight trajectory analysis, and launch operations involving *all* types of space vehicles. Wing Safety supported the Wing Commander, who was directly responsible for ensuring public safety at the Cape, Patrick AFB and the Eastern Range. Consequently, military and civilian officials could stop any unsafe practice they observed before it became a problem. Likewise, military and civilian Mission Flight Control Officers (MFCOs) acted as the Wing Commander's direct representatives during launch operations, and they sent destruct commands to an errant launch vehicle in the event of a launch mishap. In August 2000, the MFCOs were transferred from Wing Safety to the 45th Operations Group per higher headquarters direction, but their role remained unchanged under the new arrangement.[55]

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[53] Slides, Captain Christopher Haury, CCTF Support Branch Lead, "EELV CCTF Training Plan," undated.

[54] Draft, 5 SLS, "5 SLS OI 36-2201, Education and Training Plan for the 5th Space Launch Squadron," Mar 2004.

[55] 45 SW History, 1 Jan - 31 Dec 2000, Vol I, pp 55, 56.

CHAPTER II

ATLAS V LAUNCH OPERATIONS

ATLAS V Commercial Space Operations

ATLAS V (EUTELSAT HOT BIRD 6), AV-001, 21 August 2002

The object of the AV-001 mission was to place the EUTELSAT HOT BIRD 6 commercial communications satellite in a super-synchronous transfer orbit from Pad 41. Significantly, the mission was also the inaugural flight of the ATLAS V (400) Evolved Expendable Launch Vehicle (EELV). Alcatel built the 8,600-pound HOT BIRD 6 spacecraft for the Eutelsat Corporation. The satellite was based on Alcatel's Spacebus 3000B3 design, and it was equipped with 28 Ku-Band and four Ka-Band transponders to provide digital television and radio broadcast services to Eutelsat's customers in Europe, North Africa and parts of the Middle East. The payload was the "most powerful satellite" launched for Eutelsat, and it had an operational life expectancy of more than 12 years. The HOT BIRD 6 was processed at Astrotech's space operations facility in Titusville, Florida. Lockheed Martin Astronautics built the ATLAS V launch vehicle, integrated it with the payload, and launched it.[1]

Lockheed Martin decided to use the AV-001 vehicle as both a "pathfinder" and a launch vehicle. The first ATLAS V booster arrived at the Cape during the first week in June 2001. Following several weeks at the ATLAS V Spaceflight Operations Center (ASOC), technicians moved the ATLAS V to the Vehicle Integration Building in October 2001. Contractor personnel stacked the vehicle on the Mobile Launch Platform, and they added a payload simulator to the ATLAS V in early November 2001. Engineers completed their tests and de-stacked the vehicle by 14 November, and they returned AV-001 to the ASOC for additional checks. As preparations for the first ATLAS V mission got underway, the successful flight of the first ATLAS IIIB/CENTAUR on 21 February 2002 was encouraging — it featured the successful debut of the "stretched" CENTAUR on which the ATLAS V's upper stage was based. Technicians erected AV-001 (again) on 22 February 2002, and the *operational* AV-001 was rolled out to Complex 41 on 6 and 7 March 2002. Officials conducted a Wet Dress Rehearsal (WDR) in mid-March, and the launch campaign WDR was completed 15-17 July 2002. The launch was scheduled for 12 August, but it slipped into indefinite status on 26 July to give the contractor additional time to perform some final tests. (Officials settled on a firm date of 21 August 2002 a few days later.) Engineers mated the HOT BIRD 6 to the vehicle on 9 August 2002, following spacecraft and payload fairing operations at Astrotech's new Lee processing facility in Titusville.[2] Officials

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[1] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, pp 95, 96; Summary, International Launch Services, "HOT BIRD 6 Mission Overview," Aug 2002; News Release, International Launch Services, "Inaugural Atlas V Scores Success for ILS. Lockheed Martin," 4 Sep 2002.

[2] Astrotech began processing payloads for the Cape in 1985, but the HOT BIRD 6 was the first payload to be processed in the Lee facility. Astrotech named the facility after the late Captain Chet Lee, the former president of

completed the Integrated System Test (IST) on 13 August 2002. Throughout the entire campaign, the 45th Space Wing's safety organization provided oversight for launch and payload processing, facility and ground support equipment designs, and over 200 first-time hazardous and safety-critical processing procedures.[3]

In keeping with Lockheed Martin's streamlined new launch system, the ATLAS V was delivered to the launch pad only one day before the launch. Typically, ATLAS IIA/CENTAURs needed more than a month at the launch pad before a countdown, but most of the final preparations for the ATLAS V could be made *before* the completed vehicle and its payload went to the pad. The local weather cooperated, and the countdown proceeded smoothly. There were no unscheduled holds, and the ATLAS V lifted off Complex 41 at 2205:00.193Z on 21 August 2002. The $120 million HOT BIRD 6 spacecraft entered the proper orbit approximately 31 minutes later. In what Lockheed Martin characterized as a “flawless flight,” all systems performed properly. As the first operational flight of the ATLAS V, the success of the HOT BIRD 6 mission validated the launch vehicle and all the new ground facilities Lockheed Martin built for its new ‘clean pad’ concept of operations. The AV-001 launch was a major milestone for the Cape as well.[4]

ATLAS V (HELLAS-SAT), AV-002, 13 May 2003

The object of the AV-002 mission was to place the HELLAS-SAT commercial communications satellite in a super-synchronous transfer orbit from Complex 41. Alcatel built the 7,603-pound HELLAS-SAT spacecraft for HELLAS-SAT Consortium, Ltd. (Nicosia, Cyprus). The satellite was an Astrium Eurostar 2000-Plus model, and it was equipped with 30 Ku-Band transponders to provide voice, internet and broadcast digital television services to HELLAS-SAT's customers in Europe. According to International Launch Services (the launch provider), the HELLAS-SAT was “the first telecommunications satellite for Greece and Cyprus.” The spacecraft had an operational life expectancy of 15 years. The HELLAS-SAT was processed at Astrotech's space operations facility in Titusville, Florida. Lockheed Martin

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SpaceHab and chairman of Astrotech's board of directors. The 50,000-square-foot facility was 124 feet tall, and it was designed specifically to process spacecraft and to integrate payload fairings associated with ATLAS V and DELTA IV space missions.

[3] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 96; Summary, Lockheed Martin Space Systems, “Atlas V/EELV Chronology,” undated; “New EELV Launch Ops Spur Astrotech Growth,” *Aviation Week & Space Technology*, 12 Aug 2002.

[4] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 97; “Atlas 5 ready for first launch today,” *Florida Today*, 21 Aug 2002; Fact Sheet, Lockheed Martin, “Atlas V,” 4 Sep 2002; “Lockheed prepares for next mission,” *Florida Today*, 23 Aug 2002; “Atlas V Soars, Market Slumps,” *Aviation Week & Space Technology*, 26 Aug 2002; “Atlas V Flies, But Will It Sell?” *Aviation Week & Space Technology*, 16 Sep 2002; “Wing helps launch new space era,” *45th Space Wing Missileer*, 16 Aug 2002; “Atlas V rumbles to success,” *45th Space Wing Missileer*, 23 Aug 2002.

Astronautics built the ATLAS V (400) launch vehicle chosen for the mission. Lockheed also integrated the ATLAS V with the payload and launched it.[5]

The HELLAS-SAT arrived at Cape Canaveral on 11 February 2003, and technicians transported the spacecraft to Astrotech's facility in Titusville, Florida, shortly thereafter. Engineers encapsulated the satellite in its payload fairing on 30 March 2003. As payload processing continued, technicians transported the ATLAS V launch vehicle from the Vertical Integration Facility (VIF) to the launch pad on Complex 41. Officials completed two Wet Dress Rehearsals (WDRs) on 19 February and 29 April 2003 respectively. Engineers mated the HELLAS-SAT to the launch vehicle on 2 May 2003. Officials completed the Combined Electrical Readiness Test and Launch Readiness Review successfully on 10 May 2003. Though the launch was scheduled for 12 May 2003, it was pushed to 13 May due to a voltage problem in the CENTAUR's remote data unit. Two potentially major instrumentation problems arose during the countdown on the 13th, but they both proved to be minor in nature.[6] As the countdown continued, there was one unscheduled hold lasting 13 minutes, and it involved two separate issues: 1) a range boat in the "one boat contour" (i.e., a fouled range incident) and 2) a faulty hydrogen sensor reading on the launch vehicle. Both conditions cleared, and the ATLAS V lifted off Complex 41 at 2210:00.855Z on 13 May 2003. According to International Launch Services (ILS), the ATLAS V injected the HELLAS-SAT into orbit very close to pre-planned parameters. The mission was successful.[7]

ATLAS V (RAINBOW-1), AV-003, 17 July 2003

The object of the AV-003 mission was to place the 9,445-pound RAINBOW-1 commercial communications spacecraft in a geosynchronous transfer orbit from Complex 41. Lockheed Martin Space Systems Company built the RAINBOW-1 (Model A2100) spacecraft for Cablevision, a direct-to-home broadcast service company. The satellite carried 36 Ku-Band transponders and 26 individually programmable "spot beams." The mission's ultimate goal was to provide Cablevision services to customers in the Continental United States and Canada. The launch contractor, International Launch Services (ILS),[8] chose an ATLAS V (521) vehicle for

[5] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, p 86; News Release, International Launch Services, "ILS Launches Hellas-Sat on Atlas V," 16 Sep 2003.

[6] The first instrumentation problem involved an Advanced Transportable Optical Tracking System (ATOTS) at one of the range's camera sites. The ATOTS was Partially Mission Capable (PMC) due to intermittent "No-Go" alarms. Engineers isolated the problem to a failed time code generator, and the problem cleared. The other problem involved a radar system. Officials declared the radar Non-Mission Capable (NMC) at L minus 216 minutes. The radar was repaired, and it supported the rest of the countdown nominally.

[7] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 86, 88; News Release, International Launch Services, "Successful Launch of the Atlas V for Hellas-Sat," 13 May 2003.

[8] ILS was formed in 1995 as a joint venture by Lockheed Martin and its two Russian partners, RSC Energia and Khrunichev State Research and Production Space Center. Headquartered in McLean, Virginia, ILS marketed and

the mission.[9] The larger fairing was required to shield the RAINBOW-1's "sophisticated" antenna array. According to the flight scenario, the vehicle was launched on a flight azimuth of 86.1 degrees. During the flight, the CENTAUR upper stage accomplished two burns with a 77-minute-long 'coasting' period between them. The RAINBOW-1 spacecraft separated from the vehicle about one hour and 40 minutes after lift-off. The satellite's final geosynchronous orbital location was 61.5 degrees West longitude.[10]

Engineers accomplished initial power-on testing for the RAINBOW-1 launch vehicle at the ATLAS Spaceflight Operations Center (ASOC) in late April/early May 2003. Technicians attached two Aerojet Solid Rocket Boosters (SRBs) to the vehicle on 23 and 24 May, and officials completed a readiness test on 10 June 2003. The Wet Dress Rehearsal was accomplished on 24 June, and the spacecraft was mated to the launch vehicle on 7 July 2003. The launch was scheduled for 17 July 2003, and officials were worried about afternoon thunderstorms before the launch. As the countdown progressed, the T minus 4-minute built-in hold had to be extended for weather as well as a booster helium leak. That delay aside, the countdown continued. The ATLAS V lifted off Pad 41 at 2345:01.000Z on 17 July 2003. The launch was completely successful. According to International Launch Services, the CENTAUR upper stage released the RAINBOW-1 into a nearly perfect transfer orbit.[11]

ATLAS V (AMC-16), AV-005, 17 December 2004

The object of the AV-005 mission was to place the AMC-16 commercial communications satellite in a transfer orbit from Complex 41. Lockheed Martin built the AMC-16 based on the A2100 spacecraft platform. The spacecraft weighed 4,065 kilograms, and it had an operational life expectancy of 15 years. It featured twenty-four 36-MHz Ku-Band transponders and twelve 125-MHz Ka-Band spot beams. The AMC-16 was owned by SES AMERICOM and leased to EchoStar Communications Corporation to enlarge the corporation's fleet of commercial satellites and provide additional high-definition television channels to local U.S. markets. Lockheed Martin Astronautics employed an ATLAS V 521 launch vehicle featuring two Aerojet SRBs and a five-meter payload fairing for the mission.[12]

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managed missions involving the Lockheed-Martin ATLAS and Russian-built PROTON and ANGARA space launch vehicles.

9 The 500 series vehicle chosen for the mission was designated '521' to indicate it carried a '5' meter fairing, '2' Aerojet Solid Rocket Boosters, and '1' RL10A-4-2 engine in its CENTAUR upper stage.

10 45 SW History, 1 Jan – 31 Dec 2003, Vol I, p 88; News Release, International Launch Services, "ILS Launches Rainbow 1 Satellite," 16 Sep 2003.

11 45 SW History, 1 Jan – 31 Dec 2003, Vol I, p 89; News Release, International Launch Services, "ILS Launches Rainbow 1 Satellite," 16 Sep 2003.

12 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 84.

The ATLAS V booster selected for the AMC-16 mission arrived at Cape Canaveral on 25 September 2004, just 24 hours before Hurricane JEANNE made landfall. Though JEANNE did not damage the launch vehicle, erection of the booster was delayed due to the hurricane's impact. Consequently, Lockheed Martin requested a change in the launch date from 6 December to 16 December 2004, and officials approved that change on 5 October 2004. The booster was erected on 19 October, and engineers installed the CENTAUR upper stage on 26 October 2004. Following a slight delay due to a trailer misalignment, engineers finished attaching both Aerojet SRBs to the vehicle on 25 October 2004.[13]

Officials completed the Launch Vehicle Readiness Test on 15 November, and they completed the Wet Dress Rehearsal (WDR) on 23 November 2004. On 3 December, officials slipped the launch date to 17 December 2004. Engineers mated the AMC-16 to the launch vehicle on 6 December, and officials completed an Integrated System Test on 8 December 2004. Preparations continued for the launch on the 17th.[14]

There were two unplanned holds during the countdown on 17 December. The T minus 120 minutes hold was extended to 90 minutes to allow the user time to complete ground support actions. The second unplanned hold occurred at T minus 2 minutes, and it continued for 56 minutes while a redline monitor fault cleared and winds aloft improved. Lockheed Martin entered the terminal countdown with an FAA waiver (with Air Force concurrence) for a CCB Flight Termination System (FTS) battery temperature out of tolerance, but the vehicle lifted off without incident. Lift-off occurred at 1206:59.352Z on 17 December 2004. The launch was successful.[15]

ATLAS V (INMARSAT-4), AV-004, 11 March 2005

The object of the AV-004 mission was to place the first INMARSAT-4 commercial communications satellite in a transfer orbit from Complex 41.[16] The satellite was the first of a new generation of communications satellites built by EADS Astrium (a European company) for Inmarsat, a London-based corporation.[17] The 4-series spacecraft was 60 times more powerful that any of its 3-series predecessors, and it was designed to deliver 3G-compatible broadband data service to mobile users. The 13,138-pound spacecraft was launched on an ATLAS V vehicle

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[13] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 84.

[14] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 85.

[15] *Ibid.*

[16] The AV-004 mission was actually the fifth ATLAS V mission launched from Cape Canaveral. The AV-005 vehicle had been launched from the Cape on the fourth ATLAS V mission on 17 December 2004.

[17] According to Inmarsat's plans for the near future, the first INMARSAT-4 would be complemented with another INMARSAT-4 (F2) to provide services to mobile users in South America, most of North America, in the Atlantic, and portions of the Pacific. It would be launched aboard a Sea Launch (company) rocket. A third INMARSAT-4 (F3) was built as a backup for the two-satellite constellation. It might also serve as an additional operational satellite over the Pacific Ocean.

equipped with a 4-meter diameter payload fairing, three Aerojet SRBs, and a single-engine CENTAUR upper stage. The INMARSAT-4 was touted as the "heftiest commercial communications payload launched from Cape Canaveral," and the ATLAS V selected for the mission was equipped with the largest number of SRBs employed up to that time.[18]

According to the flight scenario, the ATLAS V was launched on a flight azimuth of 90 degrees, and it released the spacecraft over Africa approximately 32 minutes after lift-off. The extremely high transfer orbit (e.g., 56,270 x 274 miles) took advantage of the launch vehicle's great power, and it saved fuel as ground controllers maneuvered the INMARSAT-4 into its final geostationary orbit over the equator at an altitude of 22,300 miles. Positioned at 64 degrees over the Indian Ocean, the INMARSAT-4 provided services to customers in Europe, Africa, the Middle East and Asia.[19]

Technicians erected the booster on Complex 41 on 11 January, and engineers installed the upper stage on 19 January 2005. Initial attempts to install the SRBs were delayed by high winds and minor hardware problems, but technicians completed all SRB attachments by 10 February 2005. Officials accomplished the Launch Vehicle Readiness Test (LVRT) on 10 February, and the Wet Dress Rehearsal (WDR) was completed successfully on 22 February 2005. Engineers mated the INMARSAT-4 payload to the launch vehicle on 2 March, and preparations continued for a launch on 10 March 2005. The first countdown was scrubbed at 2154Z on 10 March for two problems: 1) the Flight Termination System experienced an intermittent pilot tone drop-out, and 2) the upper booster liquid oxygen line Pogo Accumulator indicated wetting as the liquid oxygen tank was pressurized. Both items were resolved quickly, and the launch was rescheduled for 11 March 2005.[20]

The countdown went well. There were no unplanned holds, and the ATLAS V lifted off Complex 41 at 2142:00.280Z on 11 March 2005. The flight was nominal, and the payload was placed in the proper transfer orbit. The $250 million mission was the latest in a string of 76 consecutive ATLAS launch successes dating back to 1993. Lockheed Martin looked forward to even greater accomplishments in the future.[21]

ATLAS V (ASTRA 1KR), AV-008, 20 April 2006

The object of AV-008 mission was to boost the ASTRA 1KR commercial television broadcasting spacecraft into orbit from Complex 41. The satellite was purchased to join Luxembourg's SES ASTRA constellation of 13 direct-to-home broadcast spacecraft. Weighing in at 4,200 kilograms, the ASTRA 1KR was based on Lockheed Martin's popular A2100AX communications platform. The satellite carried 32 active transponders, and it helped bring

[18] 45 SW History, 1 Jan – 31 Dec 2005, Vol I, p 76.

[19] *Ibid.*

[20] 45 SW History, 1 Jan – 31 Dec 2005, Vol I, p 77.

[21] *Ibid.*

entertainment to approximately 103 million homes in Europe. The ASTRA 1KR was scheduled to replace the ASTRA 1K lost in November 2002 (hence the "KR" designation). The spacecraft's operational life expectancy was at least 15 years.[22]

The ATLAS V that Lockheed Martin chose for the mission was equipped with one SRB, a single-engine CENTAUR upper stage, and a four-meter diameter payload fairing. According to the flight scenario, the vehicle rolled into a flight azimuth of 84.8 degrees shortly after lift-off. The SRB was jettisoned about two and one-half minutes into the flight, and the CENTAUR upper stage fired approximately two minutes later. The payload fairing was jettisoned about four and one-half minutes after lift-off, but the CENTAUR continued to provide thrust for an additional thirteen and one-half minutes. Following a coasting period, the CENTAUR began its second burn at T plus 103 minutes and 56 seconds. The CENTAUR's second burn ended at T plus 105 minutes and 24 seconds, and the payload separated approximately 108 minutes after lift-off. On-orbit, the ASTRA 1KR took up its station at 19.2 degrees East longitude.[23]

Technicians erected the ATLAS V booster on Complex 41 on 1 March 2006, and they added the SRB to the vehicle on 3 March 2006. Engineers mated the upper stage on 8 March, and officials completed the Launch Vehicle Readiness Test (LVRT) between 11 and 21 March 2006. Engineers detected a liquid oxygen leak in the CENTAUR's fill and drain valve during the Wet Dress Rehearsal (WDR) on 29 March, and the vehicle had to be rolled back to the Vertical Integration Facility following de-tanking operations. The valve was replaced, and a proper seal was verified on 3 April 2006. Officials completed the WDR successfully on 4 April, and engineers mated the ASTRA 1KR payload to the launch vehicle on 8 April 2006.[24]

The countdown on 20 April 2006 went well. There were no unplanned holds, and the ATLAS V lifted off Complex 41 at 2027:00.188Z on the same date. The mission was successful. 45th Space Wing officials dedicated the launch to the memory of Major General Jimmey R. Morrell, the first commander of the 45th Space Wing. (General Morrell passed away on 8 February 2006.) General Morrell served as 9th Space Division Commander from 1 October 1990 through 22 September 1991, and he assumed command of the 45th Space Wing on 23 September 1991. He completed his tour as 45th Space Wing Commander on 29 June 1993.[25]

ATLAS V (ICO-G1), AV-014, 14 April 2008

The ATLAS V mission launched from Complex 41 on 14 April 2008 featured ICO Global Communications Limited's ICO-G1 commercial communications satellite. The ICO-G1 was purchased and orbited to deliver wireless voice, data, video and internet services via mobile/portable devices all over the continental United States. The 27-foot-tall spacecraft

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22 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 69.

23 *Ibid.*

24 45 SW History, 1 Jan – 31 Dec 2006, Vol I, pp 69, 70.

25 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 70.

weighed 14,700 pounds, and it carried solar arrays spanning nearly 100 feet on-orbit. It was touted as the largest and heaviest commercial satellite launched on an ATLAS V space vehicle up to that time. For such a large and heavy payload, United Launch Alliance (ULA) employed a 400 Series ATLAS V equipped with two SRBs. According to the flight scenario, the vehicle was launched on a flight azimuth of 93.2 degrees. The flight featured two CENTAUR burn phases. The first burn injected the CENTAUR and payload into a parking orbit. Following a coasting interval, the second CENTAUR burn placed the ICO-G1 in a mission-specific transfer orbit measuring approximately 19,000 x 100 nautical miles. Ultimately, the spacecraft used onboard fuel to reach and maintain geostationary orbit at 92.85 degrees west longitude. The satellite provided services to the United States, Puerto Rico and the U.S. Virgin Islands.[26]

Back in early January 2008, officials approved the ICO-G1 lift-off for 21 March 2008. Processing went well for most of the month of January. Technicians erected the booster on its stand on 18 January, and engineers attached the SRBs to the launch vehicle by the 24th. Erection of the second stage was postponed one day due to high winds, but the procedure was completed successfully on 29 January 2008. Officials completed the Launch Vehicle Readiness Test on 6 February, but payload encapsulation slipped from early March to early April, due in part to the delayed arrival of the spacecraft. The ICO-G1 arrived at Cape Canaveral on 28 February 2008. In the meantime, the launch went into indefinite status in February before officials approved a new launch date of 14 April 2008. Processing went well thereafter, and technicians encapsulated the payload on 31 March before it was moved to the launch pad on 2 April 2008. Officials completed the Spacecraft/Launch Vehicle Integrated Systems Test on 4 April, and final preparations continued for the countdown on the 14th.[27]

The countdown on 14 April 2008 went well. There were no unplanned holds, and the ATLAS V lifted off Complex 41 at 2012:00.244Z (4:12 p.m. Eastern Daylight Time) on the 14th. A "transient" actuator anomaly involving the ATLAS' RD-180 engine was noted during the flight, but it reportedly did not impact the mission. United Launch Alliance and ICO Global Communications both confirmed that the ICO-G1 was launched successfully, and the ATLAS placed the payload in its initial geosynchronous transfer orbit 44 minutes after lift-off.[28]

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[26] 45 SW History, 1 Jan – 31 Dec 2008, p 108; "Atlas launch a record-breaker," *floridatoday.com*, 14 Apr 2008; Press Release, Lockheed Martin Corporation, "Lockheed Martin Successfully Launches ICO G1 Mobile Interactive Media Spacecraft," 14 Apr 2008; "ICO Launches New Era in Mobile Television," *spacedaily.com,* 15 Apr 2008.

[27] 45 SW History, 1 Jan – 31 Dec 2008, pp 108, 109.

[28] 45 SW History, 1 Jan – 31 Dec 2008, p 109; "Atlas V lofts new communications satellite," *45th Space Wing Missileer*. 18 Apr 2008; Amy Butler, "Debris Tied to Atlas V Launch Woes," *Aerospace Daily & Defense Report,* 7 Oct 2008; Press Release, Lockheed Martin Corporation, "Lockheed Martin Successfully Launches ICO G1 Mobile Interactive Media Spacecraft," 14 Apr 2008; "ICO Launches New Era in Mobile Television," *spacedaily.com,* 15 Apr 2008.

ATLAS V (INTELSAT-14), AV-024, 23 November 2009

An ATLAS V 431 launch vehicle equipped with three strap-on Aerojet SRBs was launched from Complex 41 on a flight azimuth of 107.69 degrees on 23 November 2009. The mission was designed to place the INTELSAT-14 spacecraft into geosynchronous transfer orbit. Space Systems/Loral built the 1300-series platform spacecraft as the 44th in a series of satellites sold to Intelsat. The customer was a leading supplier of commercial satellite communications services around the world. INTELSAT-14 was the first satellite to carry an Internet Routing in Space (IRIS) payload,[29] and the spacecraft replaced the INTELSAT-1R at 315 degrees East longitude to provide continued service to companies, governments, and media/service providers on four continents. The spacecraft was delivered to Cape Canaveral Air Force Station around 30 September 2009. Inspectors then examined the satellite and prepared it for launch.[30]

On 14 May 2009, officials approved the INTELSAT-14 launch for 18 September 2009. The schedule slipped about six weeks later. By mid-September, the launch had been rescheduled for 14 November 2009, and technicians finally placed the first stage of the launch vehicle 'on stand' on 25 September 2009. Launch processing continued smoothly thereafter, and milestones were accomplished within a day of their scheduled target dates. Technicians attached the three Aerojet SRBs to the launch vehicle between 28 September and 2 October 2009, and engineers erected the second stage on 5 October 2009. Officials completed a Launch Vehicle Readiness Review on 7 October, and they wrapped up the Wet Dress Rehearsal for the mission on 28 October 2009. The spacecraft was encapsulated on 2 November, and engineers mated the payload to the launch vehicle on 4 November 2009. Following a Spacecraft/Launch Vehicle Integrated Test on 6 November, final preparations got underway for the first launch attempt on 14 November 2009.[31]

Unfortunately, the countdown on 14 November was scrubbed at 0527Z due to an ordnance remote control assembly anomaly. Authorities rescheduled the launch for 23 November 2009. The countdown on the 23rd had to be extended for 65 minutes due to upper level winds, but the ATLAS V lifted off Complex 41 successfully at 0655:00.205Z on 23 November 2009. United Launch Alliance reported the satellite was deployed as planned.[32]

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[29] Cisco Systems provided the IRIS payload, which was designed to enable converged, space-ground network services and more efficient bandwidth utilization than earlier systems. INTELSAT-14's hybrid C- and Ku-Band assets provided data, voice, and video services to customers in Europe, Africa, and the Americas.

[30] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 103, 104; Fact Sheet, Intelsat, "Serving Intelsat customers throughout [the] Americas, Europe & Africa," undated; News Release, Space Systems/Loral, "Space Systems/Loral Delivers the Intelsat 14 Satellite to Florida Launch Base," 30 Sep 2009; James Dean, "ULA: Atlas V Successfully Deploys Satellite," *floridatoday.com*, 23 Nov 2009.

[31] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 104, 105.

[32] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 105; Article, James Dean, "ULA: Atlas V Successfully Deploys Satellite," *floridatoday.com*, 23 Nov 2009; "19th launch on Eastern Range; 20th scheduled Wednesday," *45th Space Wing Missileer*, 27 Nov 2009.

ATLAS V Civil Space Operations

ATLAS V (MARS RECONNAISSANCE ORBITER), AV-007, 12 August 2005

The object of the AV-007 mission was to boost NASA's MARS RECONNAISSANCE ORBITER (MRO) on the first leg of its interplanetary voyage to Mars. According to the flight scenario, the vehicle lifted off Complex 41 on a flight azimuth of 104 degrees. The MRO payload separated from the launch vehicle approximately one hour after launch, and it began its seven-month-long journey to the Red Planet. The MRO was designed to orbit Mars for a full Martian year as it gathered high-resolution imagery and other data on the climate and details of the planet's terrain. The 4,796-pound spacecraft featured six scientific instruments including an imager that could resolve surface features as small as three feet in length. Once the MRO reached Mars, the spacecraft entered a 300 x 45,000-kilometer polar capture orbit. Aero-braking maneuvers over the next six months lowered the spacecraft's orbit to 255 x 320 kilometers to allow a thorough mapping of the planet. NASA expected the $720 million MRO mission to provide important data on safe landing areas for future Mars missions.[33]

Technicians erected the ATLAS V booster on Complex 41 on 6 May 2005. Engineers mated the upper stage on 10 May, and officials completed the Launch Vehicle Readiness Test (LVRT) between 17 and 28 May 2005. The Wet Dress Rehearsal (WDR) was accomplished on 19 July, and engineers mated the MRO payload to the launch vehicle on 28 July 2005. Technicians detected hydrogen vapor around a hydrogen vent fin connection to a ground umbilical during a preliminary WDR in early July, but the problem was resolved during the WDR on 19 July by replacing the disconnect assembly and seals associated with the connection. Preparations continued for a launch on 10 August 2005.[34]

An electrical short on 5 August prompted the contractor to replace a faulty battery on 9 August 2005. In the meantime, NASA asked Eastern Range officials to move the launch from 10 August to 11 August 2005, and the countdown was rescheduled accordingly. Thunderstorm activity early on the 11th delayed the countdown, and there were two unplanned hold during the count. Ultimately, a liquid oxygen tanking software problem prompted officials to scrub the launch at 1251Z on 11 August 2005. Engineers quickly determined the software problem was lightning-induced, and the countdown was recycled for the launch on 12 August 2005.[35]

The countdown on 12 August went well. There were no unplanned holds, and the ATLAS V lifted off Complex 41 at 1143:00.311Z on the same date. By the end of August, the MARS RECONNAISSANCE ORBITER was more than 1,500,000 miles from Earth on a curving 310-million-mile trajectory to Mars.[36]

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33 45 SW History, 1 Jan -31 Dec 2005, Vol I, p 80.

34 *Ibid.*

35 45 SW History, 1 Jan -31 Dec 2005, Vol I, pp 80, 81.

36 45 SW History, 1 Jan -31 Dec 2005, Vol I, p 81.

ATLAS V (PLUTO NEW HORIZONS), AV-010, 19 January 2006

The object of the AV-010 mission was to send NASA's PLUTO NEW HORIZONS spacecraft on the first leg of its journey to Pluto, its moon Charon, and two other moons in the Kuiper Belt some 3 billion miles from Earth. The spacecraft was the first of NASA's "New Frontiers" class interplanetary probes, and its journey was expected to take more than nine and one-half years. The project (including the price of the launch vehicle) cost approximately $700 million. The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, led the development of the 1,054-pound spacecraft. The probe carried a suite of seven sensors, two 64-gigabit solid-state tape recorders, and a plutonium-fueled radioisotope thermoelectric generator to supply 200 watts of power for all the spacecraft's electrical needs.[37]

The ATLAS V vehicle chosen for the mission was the first ATLAS V 500 series to carry five SRBs. Lockheed Martin incorporated a Boeing/ATK Thiokol DELTA II spin table and a Star 48B solid-fueled third stage atop the booster's Pratt & Whitney CENTAUR second stage. Fully fueled, the ATLAS V weighed approximately 1,260,000 pounds, and it developed approximately 2.5 million pounds of thrust at lift-off. Flying at approximately 36,000 miles per hour, the spacecraft was expected to reach Jupiter (for a gravity assist) about 13 months after lift-off. If all went well, the probe would reach the vicinity of Pluto in mid-July 2015. Approaching Pluto as close as 6,200 miles and Charon as close as 16,800 miles, the probe was expected to deliver "Landsat quality" images of the surface of Pluto as well as data on the geology of its impact craters. In addition, Charon would be studied by the probe as it orbited Pluto some 12,000 miles away. The spacecraft would begin gathering data on smaller objects in the Kuiper Belt toward the end of 2016.[38]

Technicians erected the ATLAS V booster on Complex 41 on 29 September 2005, and engineers installed the CENTAUR upper stage on 11 October 2005. Solid Rocket Booster stacking began on 19 October, but Hurricane WILMA breached Complex 41's megadoor in early November, and the door touched one of the ATLAS V's SRBs. The SRB was replaced by 4 November, and all five SRBs were attached to the vehicle by 29 November 2005. Officials completed the Launch Vehicle Readiness Test on 1 December, and the Wet Dress Rehearsal was accomplished on 6 December 2005. An ATLAS RP-1 tank isogrid crack prompted a fleet-wide investigation in November and early December 2005, so officials rescheduled the mission from 11 to 17 January 2006 while results were being tabulated. The PLUTO NEW HORIZONS spacecraft arrived at the Kennedy Space Center on 1 December 2005, and engineers mated the payload to the ATLAS V on 17 December 2005.[39]

NASA cleared flight constraints associated with the isogrid crack on 13 January 2006. The launch did not go off as planned on the 17th, and officials scrubbed the countdown on 18

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37 45 SW History, 1 Jan -31 Dec 2006, Vol I, p 66.

38 *Ibid.*

39 45 SW History, 1 Jan -31 Dec 2006, Vol I, pp 66, 67.

January at 1530Z due to a power failure at the Applied Physics Laboratory Mission Operations Center. Nevertheless, the countdown on the 19th went well, and the ATLAS V lifted off safely at 1900:00.221Z on 19 January 2006. The launch was reportedly “flawless,” and the PLUTO NEW HORIZONS spacecraft was 6 million miles closer to Pluto by 27 January 2006.[40]

ATLAS V (LRO/LCROSS), AV-020, 18 June 2009

The purpose of the ATLAS V launch from Complex 41 on 18 June 2009 was to insert the Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS) spacecraft on pre-planned trajectories to the Moon. Though launched at the same time, each spacecraft had its own mission.[41] The LRO spacecraft separated from the $79 million LCROSS and the CENTAUR upper stage about one hour after the launch, and the LCROSS continued on its own trajectory still attached to the spent CENTAUR upper stage to guide the latter into a permanently shadowed crater near the Moon’s south pole. The LCROSS mission was designed to search for water and hydrogen on the Moon. After orbiting the Moon with the LCROSS spacecraft for nearly four months, the CENTAUR was scheduled to separate from the spacecraft and crash into the crater at high speed on 9 October 2009. Considerable lunar debris would be ejected from the crater in the process. Four minutes later, the LCROSS spacecraft would follow the CENTAUR’s path into the crater and descend through the debris plume to analyze the latter’s content with special instruments. Engineers expected the LCROSS to continue collecting and sending data back to Earth before the spacecraft’s own inevitable impact. Additional data from the two impacts would be picked up the LRO and the Hubble Space Telescope.[42]

On 31 July 2008, officials approved 9 December 2008 for the LRO/LCROSS launch. Unfortunately, the launch was delayed almost immediately by other ATLAS V missions on the manifest. Consequently, the mission went into indefinite status in early August 2008. Officials approved a new launch date of 25 April 2009 in early January 2009, but the launch date eventually settled on 17 June 2009 as processing continued. Engineers and technicians erected the ATLAS V booster on its stand on 27 April 2009. The CENTAUR was added to the launch

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40 45 SW History, 1 Jan -31 Dec 2006, Vol I, p 67.

41 The $504 million LRO mission was designed to place LRO spacecraft in an elliptical orbit (e.g., 136 x 1,926 miles) above the Moon’s surface about four and one-half days after lift-off. Once on-orbit, the spacecraft would accomplish four rocket firings to pull its orbit down to a low point of 18.5 miles above the Moon’s south pole and 134 miles above the Moon’s north pole. Over the next two months, the LRO’s orbit would be circularized 31 miles above the lunar surface so it could begin using seven state-of-the-art cameras to look for favorable landing sites for future manned lunar expeditions. The 4,200-pound spacecraft was solar-powered to ensure its longevity, since it would spend one year scouting landing sites and three additional years gathering data on solar and cosmic radiation, surface topology, and the Moon’s chemical composition.

42 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 99, 100; Article, James Dean, “Live: NASAS Probe Set to Swing Past Moon,” *floridatoday.com,* 23 Jun 2009; Article, William Harwood, “NASA’s lunar mapper goes into orbit around the moon,” *spaceflightnow.com,* 23 Jun 2009.

vehicle on 30 April, and officials completed the Launch Vehicle Readiness Test on 9 May 2009. The Wet Dress Rehearsal followed on 15 May. Engineers and technicians encapsulated the payloads and mated them to the launch vehicle on 18 May and 28 May 2009 respectively. Officials wrapped up the Spacecraft Launch Vehicle Integrated Test on 1 June 2009.[43]

Last-minute delays pushed the launch to 18 June 2009, and the Eastern Range was 'Red' for weather between 2000Z and 2117Z on that date. Additionally, there was a 20-minute unplanned hold in the countdown for weather (ending at 2128Z). Despite those problems, the ATLAS V lifted off Complex 41 without incident at 2132:00.191Z on 18 June 2009. ULA was proud to announce the successful launch shortly thereafter.[44]

As the mission continued, the LRO spacecraft fired its main thrusters four and one-half days after the launch to enter elliptical orbit around the Moon. Over the next few hours, the LCROSS approached to within 2,000 miles of the Moon and completed its initial 'swing-by' to prepare itself (together with the CENTAUR) for the impact mission on 9 October 2009. The spent CENTAUR upper stage impacted the Moon's Cabeus crater at 7:31 a.m. Eastern Daylight Time (EDT) on Friday, 9 October 2009. The 'Diviner' instrument aboard the LCROSS orbiting spacecraft observed the impact site during eight orbits, and it collected data for a series of thermal maps and images beamed to Earth approximately three days later.[45]

ATLAS V Military Space Operations

ATLAS V (STP-1), AV-013, 9 March 2007

The ATLAS V flight launched from Complex 41 on 9 March 2007 had two objectives: 1) deploy the Autonomous Space Transfer and Robotic Orbiter (ASTRO) and the NEXTsat serviceable spacecraft for the "Orbital Express" orbital refueling demonstration, and 2) utilize the launch vehicle's excess launch capacity to deploy four smaller satellites from the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA). Taken together, the objectives constituted the Defense Department's Space Test Program-1 (STP-1) mission. The Defense Advanced Projects Research Agency (DARPA) was responsible for acquisition and operation of the Orbital Express portion of the mission. Orbital Express was designed to validate technologies crucial to extending the on-orbit operational life expectancy of satellites via orbital

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[43] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 100; Stephen Clark, "Lunar mapper and military vehicle swap launch slots," *spaceflight Now*, 30 Jul 2008.

[44] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 101.

[45] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 101; Article, James Dean, "Live: NASAS Probe Set to Swing Past Moon," *floridatoday.com,* 23 Jun 2009; Article, William Harwood, "NASA's lunar mapper goes into orbit around the moon," *spaceflightnow.com,* 23 Jun 2009; "United Launch Alliance Successfully Launches Moon Missions for NASA," *prnewswire.com,* 18 Jun 2009; "45th Space Wing supports NASA's Dual Lunar Exploratory Missions," *45th Space Wing Missileer,* 26 Jun 2009; "Moon Orbiter Beams Home Images of Lunar Crashes," *space.com,* 12 Oct 2009.

refueling and parts replacements. The four smaller satellites — MidSTAR 1, FalconSat 3, STPSat 1 and CFESat — were sponsored by a variety of agencies including the Space Development and Test Wing at Kirtland AFB, New Mexico, the United States Air Force Academy, the United States Naval Academy, and the Los Alamos National Laboratory. The DoD Space Test Program at Detachment 12, Space and Missile Systems Center, Kirtland AFB, was responsible for overall integration of the STP-1 mission. Boeing served as the prime integrating contractor. The STP-1 mission was significant as the first "military" (Department of Defense) ATLAS V mission.[46]

The STP-1 mission was scheduled to lift off Complex 41 on 3 November 2006. Technicians erected the ATLAS V booster on Complex 41 on 18 September, and engineers installed the CENTAUR upper stage on 20 September 2006. Unfortunately, the launch date slipped to 8 December 2006, and the integration of the various payloads was delayed somewhat due to the tardy arrival of the final two spacecraft on the manifest. Nevertheless, spacecraft testing at the launch hub was completed by 7 December 2006. Final spacecraft integration took a bit longer than anticipated, but the stacking operation was completed successfully on 11 January 2007. Officials approved a new launch date of 31 January 2007 for the STP-1 flight.[47]

Following payload fairing installation toward the end of January, engineers erected and mated the STP-1 payload to the ATLAS V launch vehicle on 31 January 2007. The precise lift-off date remained in doubt due to a recent – but, fortunately, unrelated – launch failure in the Pacific Ocean involving a ZENIT rocket. (The ZENIT design had many components in common with the ATLAS V launch vehicle.) Though officials completed the STP-1's Integrated Systems Test in early February, the AV-013 launch date slipped to 9 March as assessments of Sea Launch's ZENIT mission failure continued.[48]

The countdown on 9 March 2007 went well. Though there was one 33-minute-long delay to the scheduled 10-minute hold at T minus 4 minutes for Radio Frequency (RF) interference, the ATLAS V lifted off Complex 41 at 0310:00.244Z. The flight was successful. All satellites were deployed properly, and the Orbital Express spacecraft (ASTRO and the NEXTsat) underwent several weeks of system checks before they became operational.[49]

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[46] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 77; Article, Eric Brian, "STP-1 atop first AF-sponsored Atlas V," *45th Space Wing Missileer*, 2 Mar 2007; "Air Force Selects ILS' Atlas V for Space Test Program Mission," *spacedaily*.com, 11 Jun 2004.

[47] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 78.

[48] *Ibid*.

[49] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 79; News Release, Kim Irving, Director of Marketing of AeroAstro, Inc., "AeroAstro-Built STPSat-1 Satellite Successfully Launched By the U.S. Air Force," 9 Mar 2007.

ATLAS V (NROL-30), AV-009, 15 June 2007

The purpose of the ATLAS V launch on 15 June 2007 was to place the NROL-30 classified payload in the proper transfer orbit. The mission was sponsored by the National Reconnaissance Office (NRO). United Launch Alliance (ULA) produced the ATLAS V (vehicle number AV-009) and provided mission integration and launch services.[50] A separate launch services integration contractor transported the payload to the Cape. According to the flight scenario, the vehicle was launched on a flight azimuth of 46.85 degrees from Complex 41.[51]

On 29 January 2007, Air Force officials approved the NROL-30 launch for 4 May 2007 (figured in Greenwich Mean or "Z" time). On 21 March, the customer requested a slip in the launch date to 18 May 2007, and both the ATLAS V booster and CENTAUR upper stage were erected close to the revised schedule's processing dates on 28 March and 30 March 2007 respectively. Following completion of the Launch Vehicle Readiness Test on 11 April, officials adjusted processing milestones once again to meet a new Initial Launch Capability (ILC) of 14 June 2007. The new launch date was approved on 19 April, and processing continued on schedule thereafter. Technicians encapsulated the payload on 30 May, and the spacecraft was mated to its launch vehicle on 1 June 2007. Officials completed an Integrated Systems Test successfully on 4 June, and preparations continued for the first launch attempt on 14 June 2007. Unfortunately, the first countdown was scrubbed on the 14th due to a range instrumentation problem, but the second countdown on 15 June 2007 was successful. After one six-minute-long unplanned hold for a brief vehicle anomaly, the ATLAS V lifted off Complex 41 without incident at 1512:00.182Z on 15 June 2007.[52]

Though several public media sources reported that the NROL-30 payload was injected in the wrong orbit, official Air Force sources explained the results of the mission in more precise terms. The ATLAS V performed well within performance expectations during powered flight, but the second CENTAUR RL-10 engine 'burn' ended a few seconds early. Consequently, the spacecraft's orbital perigee was somewhat lower than expected. Ultimately, there was some loss in performance during the second stage burn, but the payload was launched successfully.[53]

ATLAS V (WGS-2 [F-1]), AV-011, 11 October 2007

The first in a series of new Wideband Global SATCOM spacecraft, WGS-2 (F-1), was launched from Complex 41 on an ATLAS V (Model 421) vehicle on 11 October 2007. The

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[50] The reference to ULA rather than Lockheed Martin underlined a change in marketing policy prompted by the formation of Boeing and Lockheed's ULA partnership on 1 December 2006. Strictly speaking, the ATLAS V was still a Lockheed Martin launch vehicle under ULA auspices.

[51] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 80, 81.

[52] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 81.

[53] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 81; News Release, SMC and NRO, "NRO satellite successfully launched aboard Atlas V," 15 Jun 2007.

WGS was built by Boeing, and it was designed to complement the nation's aging constellation of Defense Satellite Communications System (DSCS) spacecraft. Each WGS satellite weighed approximately 13,000 pounds at launch and 7,600 pounds on-orbit. Each new spacecraft was designed to provide more than 10 times the communications capacity of the previous generation's DSCS III satellites.[54] The first three WGS spacecraft would be positioned over the Pacific, Indian, and Atlantic oceans. Additionally, two Block I and three Block II WGS satellites were being prepared to provide a radio frequency bypass capability. The new military communications spacecraft also supported airborne intelligence, surveillance, and reconnaissance platforms at the data rates required by unmanned aerial vehicles.[55]

In late February, officials approved the launch for 2 July 2007, but shipment of the spacecraft was delayed. Consequently, the launch date slipped to late August 2007 before it moved into indefinite status in mid-July 2007. Range officials approved a new launch date of 1 September 2007 two weeks later, but the launch schedule continued to move to the right until the end of August. In the meantime, ULA erected the ATLAS V booster on 11 July, and two SRBs were mated to the launch vehicle on 13 and 25 July 2007 respectively. The spacecraft arrived on 20 July, and officials conducted a successful spacecraft/CCAFS Payload Processing Facility compatibility test on 26 July 2007. Engineers mated the CENTAUR upper stage to the ATLAS V on 30 July, and a flight simulation was completed on 9 August 2007. Engineers encapsulated the spacecraft on 25 September, and technicians transported the payload to Complex 41 on 27 September 2007. The spacecraft/launch vehicle integrated test was completed on 1 October, and final preparations continued for a launch attempt on 10 October.[56]

The ATLAS V and DELTA IV flew variants of the same RL-10 engine in their CENTAUR upper stages, so officials decided to delay the launch 24 hours to review some last-minute data on earlier DELTA IV missions. That delay aside, the countdown the following day went well. There were no unplanned holds during the count, and the ATLAS V lifted off the pad at 0022Z on 11 October 2007. Officials deemed the launch vehicle's performance "outstanding

[54] Boeing Satellite Systems received a contract for the first three WGS spacecraft and their ground-based command and control systems in January 2001. The WGS spacecraft was based on Boeing's 702 spacecraft. A wide variety of ground terminals and modulation schemes were anticipated, and each satellite could support between 2.1 and 3.6 gigabytes per second (Gbps). The DSCS III satellite had a maximum data rate of 0.25 Gbps. In 2006, United States Air Force Space Command's MILSATCOM Systems Wing authorized Boeing to produce two more WGS satellites under a Block II contract.

[55] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 84, 85; Fact Sheet, Boeing, "Boeing Satellites, Transformational Wideband Communication Capabilities for the Warfighter," undated; SMC Public Affairs, "New satellite arrives at Cape," *45th Space Wing Missileer*, 27 Jul 2007.

[56] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 85.

on all parameters," and the payload's apogee and perigee were even better than predicted. The mission was highly successful.[57]

ATLAS V (NROL-24), AV-015, 10 December 2007

The purpose of the ATLAS V launch on 10 December 2007 was to place the NROL-24 classified payload in the proper transfer orbit. The mission was sponsored by the National Reconnaissance Office (NRO). United Launch Alliance (ULA) produced the ATLAS V 401 launch vehicle (designated AV-015) used for the mission, and ULA also provided mission integration and launch services. According to the flight scenario, the vehicle was launched on a flight azimuth of 47.07 degrees from Complex 41. The payload was released approximately one hour after lift-off.[58]

In mid-April 2007, Air Force officials scheduled the NROL-24 launch for 6 September 2007. The launch dated slipped to 5 October 2007 in early May. Then it moved to 18 October a few weeks later, before settling into indefinite status in mid-July 2007. Officials approved a new launch date of 7 November 2007 on 11 August, but it slipped to 15 November before returning to 7 November 2007 at the end of August. The mission went into indefinite launch status again on 5 September 2007, but officials selected 10 December 2007 for the launch date at the end of September, and, this time, the schedule held.[59]

Engineers reported the booster 'on stand' on 28 October 2007, and they erected the CENTAUR upper stage on 4 November 2007. Following the Launch Vehicle Readiness Test on 6 November, officials completed a successful Wet Dress Rehearsal (WDR) on 20 November 2007. Technicians encapsulated the spacecraft on 27 November, and technicians completed propellant loading operations on 28 November. The payload was transported to Complex 41 on 30 November, and the spacecraft/launch vehicle integrated test went ahead successfully on 3 December 2007. Final preparations were completed, and all items were placed in readiness for the countdown on 10 December 2007.[60]

Apart from a single one-minute-long unscheduled hold during the opening minute of the launch window, the countdown on 10 December 2007 went forward seamlessly. The ATLAS V lifted off Complex 41 at 2205:00.228Z on the same date. The flight was successful. The mission

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[57] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 85, 86; Article, Patrick Peterson, "Air Force holds off on Atlas launch," *Florida Today,* 9 Oct 2007; Article, Patrick Peterson, "Atlas cleared for launch Wednesday night," *Florida Today,* undated; Article, Patrick Peterson, "Atlas lights up Brevard night sky," *Florida Today,* 11 Oct 2007; "Wideband Global SATCOM Satellite Launched," *Space,* 13 Oct 2007.

[58] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 86, 87; News Release, ULA, "United Launch Alliance Atlas V Successfully Launches NRO Satellite," 10 Dec 2007.

[59] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 87.

[60] *Ibid*.

marked the Cape's fourth ATLAS V mission of 2007 and the 12th ATLAS V mission since the program's inception in 2002.[61]

ATLAS V (WGS-2), AV-016, 4 April 2009

On 4 April 2009 (8:31 p.m. on 3 April 2009 in local time), an ATLAS V 421 launch vehicle equipped with a four-meter-diameter payload fairing, two SRBs, and a single-engine CENTAUR upper stage lifted off Complex 41 successfully. The mission was designed to place the second Wideband Global SATCOM spacecraft (WGS-2) in a geosynchronous transfer orbit. Boeing Satellite Systems was under contract to build a total of six WGS spacecraft based on the Boeing 702 satellite platform.[62] The new satellites were built and orbited to offset the eventual decline of America's Defense Satellite Communications System III (DSCS III) constellation. They also complemented DSCS III Service Life Enhancement Program (SLEP) spacecraft. Each of the newer WGS-2 satellites supplied more than 10 times the capacity of instantaneous bandwidth (e.g., 4.875 gigahertz) than the older DSCS III SLEP spacecraft. According to the flight scenario, the ATLAS V rolled into a flight azimuth of 93.17 degrees. The flight featured two CENTAUR burn phases, and the spacecraft separated successfully approximately half an hour after lift-off. The WGS-2 weighed approximately 13,000 pounds at lift-off, but a considerable amount of onboard fuel was expended getting the satellite into its 22,300-mile-high geosynchronous orbit. Consequently, the spacecraft's mass dropped to just 7,600 pounds on-orbit. Following a transition period, the constellation of six, new, fully-operational WGS spacecraft would replace the old DSCS III constellation around 2013.[63]

On 9 April 2008, Eastern Range officials approved the WGS-2 launch for 6 August 2008, but the mission moved into indefinite status shortly thereafter. A new launch date of 11 October 2008 was requested on 27 May 2008, and officials approved it in early June 2008. The mission continued to see-saw back and forth between indefinite status and new launch dates over the next nine months as planners continued to wrestle with technical issues. In the meantime, however, technicians and engineers managed to erect the ATLAS V booster on its stand on 27 June 2008. The two SRBs were attached to the ATLAS V on 2 July 2008, and engineers erected the CENTAUR upper stage one week later. Officials completed a Launch Vehicle Readiness Test on 14 July, and they wrapped up a Wet Dress Rehearsal on 8 October 2008. The spacecraft

[61] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 88; News Release, ULA, "United Launch Alliance Atlas V Successfully Launches NRO Satellite," 10 Dec 2007.

[62] The first WGS-2 satellite was designated WGS-2 (F-1), and it was launched aboard an ATLAS V from Complex 41 on 11 October 2007. Each satellite cost approximately $350 million. Those satellites launched on ATLAS V vehicles were designated WGS-2 spacecraft. Other WGS satellites – earmarked for DELTA IV missions – were designated WGS-3 spacecraft.

[63] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 95, 96; Justin Ray, "Atlas 5 rocket successfully launches military satellite," *spacefightnow.com,* 3 Apr 2009; 45 SW Public Affairs, "New satellite will grow warfighter capabilities," *45th Space Wing Missileer,* 10 Apr 2009; News Release, Boeing, "Boeing-Built Satellite WGS-2 Sends 1st Signals From Space," 6 Apr 09; Fact Sheet, "Wideband Global SATCOM Satellite," *afspc.af.mil,* Feb 2010.

was encapsulated on 25 February 2009, and engineers mated the spacecraft to the launch vehicle on 4 March 2009. Officials completed the Spacecraft/Launch Vehicle Integrated Test on 6 March 2009. They anticipated a tentative launch date of 17 March 2009, assuming the Space Shuttle *Discovery's* STS-119 countdown went on 15 March 2009.[64]

Following *Discovery's* successful lift-off from Complex 39A, preparations for the WGS-2 flight got underway on 17 March 2009. Unfortunately, a valve on the CENTAUR upper stage sprang a leak during fueling operations, and the ATLAS V launch was scrubbed at 2349Z on 18 March 2009. Officials approved a new launch date of 1 April 2009, pending determination of the root cause for the valve malfunction and proper corrective action. The countdown slipped to 3 April 2009 a few days later. There were no unplanned holds during the countdown, and the ATLAS V lifted off without incident at 0031:00.233Z on 4 April 2009. The mission was successful.[65]

An Additional U.S. Government ATLAS V Mission

ATLAS V (PAN), AV-018, 8 September 2009

On 8 September 2009, an ATLAS V 401 launch vehicle equipped with a four-meter-diameter payload fairing and no SRBs lifted off Complex 41 successfully at 2135:00.202Z. The countdown went smoothly, and no safety actions were required during the flight. There was considerable speculation in the media as to which agency – civil, military or commercial – sponsored the mission, but United Launch Alliance (ULA) Vice President of Atlas programs Mark F. Wilkins would only admit that it was a "United States Government customer." The 45th Space Wing reportedly described the payload as a "U.S. Government communications satellite," and Brigadier General Edward L. Bolton, Jr., as 45th Space Wing Commander, was quoted by the *Orlando Sentinel* as declaring: "This launch helps ensure that vital communications will continue to bolster our nation's capabilities and showcases why the 45th Space Wing is the world's premier gateway to space." The PAN spacecraft was built by Lockheed Martin under a commercial contract.[66]

In early May 2009, Eastern Range officials approved the PAN flight for 17 July 2009. The launch date slipped to 12 August about one month later, and engineers placed the booster 'on stand' on 8 July 2009. The CENTAUR upper stage was erected on 10 July 2009, but a

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[64] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 96.

[65] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 97; Aricle, Todd Halvorson, "Valve failure delays Atlas launch," *Florida Today,* 18 Mar 2009; Article, James Dean, "Atlas V rockets satellite to orbit," *Florida Today,* 4 Apr 2009; "ULA and USAF Launches WGS-2 –Enhanced Communications for Warfighters," 5 Apr 2009; Article, William Graham, "LIVE: ULA Atlas V launches WGS-2 for USAF," *nasaspaceflight.com,* 3 Apr 2009.

[66] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 102; Fact Sheet, ULA, "Atlas V Launches PAN," undated; Robert Block, "Atlas V blasts off from the Cape with its top secret payload," *orlandosentinel.com,* 8 Sep 2009; ULA Release via Reuters, "United Launch Alliance Atlas V Successfully Launches PAN Satellite," 8 Sep 2009.

booster hydraulic leak delayed milestones following the Launch Vehicle Readiness Test on 11 July. A new launch date of 21 August 2009 was selected and approved. Spacecraft encapsulation, mate, integrated testing, and launch dates remained “TBD” (To Be Determined) through much of August. Nevertheless, technicians completed the spacecraft encapsulation on 22 August, and engineers mated the spacecraft to the ATLAS V on 27 August 2009. Officials completed the Spacecraft/Launch Vehicle Integrated Test on 31 August, and the flight was launched on 8 September 2009 as mentioned earlier.[67]

[67] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 103.

CHAPTER III

DELTA IV LAUNCH OPERATIONS

DELTA IV Commercial Space Operations

DELTA IV Medium-Plus (4,2) [EUTELSAT W5], 20 November 2002

The object of the first DELTA IV mission was to place the EUTELSAT W5 commercial communications satellite in a geosynchronous transfer orbit (e.g., 291 x 19,323 nautical miles, inclined 13.5 degrees). Alcatel built the 7,000-pound EUTELSAT W5 spacecraft for the Eutelsat Corporation. The satellite was equipped with 24 wideband Ku-Band transponders to provide digital television, internet, and information technology services to Eutelsat's customers in the Far East. According to the flight scenario, the mission's DELTA IV Medium-Plus (4,2) vehicle lifted off Pad 37B on an initial flight azimuth of 95 degrees. On orbit, the EUTELSAT W5 offered "direct connectivity" from the Far East into Western Europe via Eutelsat's constellation of HOT BIRD satellites.[1] The EUTELSAT W5 was processed at Astrotech's space operations facility in Titusville, Florida. The 45th Space Wing's Wing Safety Team oversaw the DELTA IV mission for flight analysis and systems safety purposes. Boeing built the launch vehicle, integrated it with the payload, and launched it.[2]

The 'first flight' DELTA IV upper stage arrived at Complex 37 on 10 September 2001. The *Delta IV Mariner* delivered the first flight CBC to Port Canaveral on 4 October 2001. Engineers "soft mated" the two stages on 29 November, and they followed up the process with a hard mate on 13 December 2001. The launch site team completed umbilical retraction tests on 4 January, and technicians completed encapsulation of a simulated payload on 15 January 2002. The two GEM-60 Solid Rocket Motors (SRMs) assigned to the vehicle arrived at the Cape on 23 January 2002. The DELTA IV team accepted the solids on 27 March, and they declared the DELTA IV "ready to move to the pad" on 28 March 2002. [3]

In passing, it should be noted that the DELTA IV Heavy's Launch Mate Unit (LMU) was delivered to the Complex 37 Horizontal Integration Facility on 7 April 2002. The rather large

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[1] The EUTELSAT W5 was worth approximately $100 million, and it had an on-orbit life expectancy of more than 12 years. Eutelsat reportedly received substantial "inaugural price discounts" for flying the HOT BIRD 6 on the first ATLAS V and the EUTELSAT W5 on the first DELTA IV.

[2] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 107; "Delta IV Thrusts Boeing Against Atlas V, Ariane," *Aviation Week & Space Technology*, 25 Nov 2002; "Eutelsat W5 Payload To Bridge Europe, Asia," *Aviation Week & Space Technology*, 25 Nov 2002; "New EELV Launch Ops Spur Astrotech Growth," *Aviation Week & Space Technology*, 12 Aug 2002.

[3] 45 SW History, 1 Jan -1 Dec 2001, Vol I, pp 26, 27; 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 107.

(e.g., 56 x 24 x 7.5-foot) structure weighed more than 64 tons. Though unrelated to the mission at hand, it was a significant milestone for future DELTA IV operations.[4]

Engineers erected the first flight DELTA IV Medium-Plus booster on Pad 37B on 30 April 2002. The DELTA IV team mated the GEM-60 Graphite Epoxy Motors on 22 May, and they verified electrical interfaces between the launch vehicle and its command/monitoring systems on 28 May 2002. Technicians performed a successful demate and retraction test of the Tail Service Mast (TSM) system on 10 June 2002. Engineers placed a simulated payload atop the vehicle in early July, and officials approved a new launch date (e.g., 9 October versus 31 August 2002) on 9 July 2002. Electromechanical and radio frequency checks were performed in mid-July, and a Wet Dress Rehearsal (WDR) was completed in early September 2002. A software issue surfaced during the WDR in September, so Boeing opted to reschedule the launch from 9 October to 3 November 2002. Boeing requested an additional delay that pushed the lift-off to 16 November shortly thereafter.[5]

The EUTELSAT W5 was delivered to Complex 37 from Astrotech's space operations facility on 5 November 2002. It was mated to the vehicle shortly thereafter. Vehicle guidance control checks were completed successfully on 13 November, and it looked as though the 16 November 2002 launch date might be achievable. Unfortunately, officials decided to slip the date from 16 to 19 November 2002 after they discovered a cracked rotor in a factory engine in West Palm Beach. The defect proved to have no bearing on the DELTA IV Medium-Plus or its components, so the countdown was allowed to proceed on 19 November. Nevertheless, weather conditions and vehicle anomalies led to three unplanned holds during the countdown, and the user eventually scrubbed the launch at 2333Z on the 19th.[6]

The second (and final) countdown for the mission got underway on 20 November 2002, and the DELTA IV Medium-Plus (4,2) lifted off Pad 37B at 2239:00.278Z on that date. The flight went well, and the payload was injected into the proper orbit about 37 minutes after launch.[7]

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[4] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, pp 107, 108.

[5] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 108.

[6] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, p 108; News Release, Boeing, “Boeing Delta IV Stands Ready on Launch Pad… Points to the Future,” 1 May 2002; News Release, Boeing, “Boeing Gives First Glimpse of Fully Integrated Delta IV,” 17 Jul 2002; “Delta IV Payload Set," *Aviation Week & Space Technology*, 11 Nov 2002.

[7] 45 SW History, 1 Jan – 31 Dec 2002, Vol I, pp 109, 110; “Rocket puts its 1st satellite into orbit,” *Florida Today*, 21 Nov 2002.

DELTA IV Civil Space Operations

DELTA IV Medium-Plus (4,2) [GOES-N], 24 May 2006

The object of Boeing's DELTA IV Geostationary Operational Environmental Satellite N (GOES-N) mission was to place the spacecraft in an 18,994 x 3,576 nautical-mile transfer orbit from Complex 37B. Boeing built and launched the DELTA IV Medium-Plus used to carry GOES-N into space, and Boeing Satellite Systems (formerly Hughes Corporation) designed and manufactured the spacecraft and integrated the payload with its launch vehicle.[8]

Boeing received a contract in January 1998 for three next-generation weather-monitoring spacecraft designated GOES-N, GOES-O and GOES-P.[9] The National Oceanic and Atmospheric Administration (NOAA) sponsored the effort, and all three satellites were based on the highly popular and successful Boeing-601 spacecraft design. The GOES-N and each of its siblings weighed 7,035 pounds at lift-off, but the satellites expended a lot of fuel to get into geostationary orbit. Consequently, the GOES-N's mass dropped to around 4,924 pounds by the time it became operational. (The spacecraft employed a liquid-fueled apogee kick motor and an array of bi-propellant thrusters for station-keeping purposes.) The GOES-N had S-Band, L-Band and UHF uplinks and downlinks, and the spacecraft was designed to track severe storms, hurricanes and cyclones. Boeing Satellite Systems (BSS) included a Search and Rescue (SAR) package in the satellite's communications suite to detect distress signals from ships and airplanes. Data collected by GOES satellites were routinely transmitted to NOAA's ground station on Wallops Island, Virginia, for retransmission to NOAA's Satellite Operations Control Center in Suitland, Maryland. Each of the new GOES satellites had an operational life expectancy of 10 years.[10]

According to the flight scenario, the launch vehicle lifted off Pad 37B and rolled into a flight azimuth of 95 degrees. The vehicle's two Graphite Epoxy Motors completed their burns about one minute and 34 seconds after lift-off. They were jettisoned about six seconds later. Following main engine cut-off, Stage 1 separated from the launch vehicle about four and one-half minutes into the flight. The payload fairing separated after Stage 2 began its first burn, and the vehicle entered a coasting period about 12 minutes and 37 seconds after lift-off. Stage 2 restarted approximately 23 minutes into the flight, and it continued firing for about four minutes. Following a lengthy coasting period, Stage 2 fired again, completing a one-minute-long burn about 4 hours and 11 minutes after lift-off. The GOES-N satellite was released from the launch vehicle a little less than 4 hours and 22 minutes after lift-off.[11]

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[8] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 90.

[9] Boeing also built five earlier GOES satellites (D, E, F, G and H). GOES-D, E and F were launched in 1980, 1981 and 1983 respectively. GOES-G was launched in 1986, but that mission failed. GOES-H was launched in 1987.

[10] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 90; Fact Sheet, Boeing, "Goes N, O, P, Next-Generation Weather Satellites," *boeing.com*, undated.

[11] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 90.

The GOES-N mission was scheduled to launch in December 2004, but an insufficient number of Flight Termination System (FTS) batteries compelled officials to delay the mission until at least 4 May 2005. The DELTA IV booster was placed ‘on stand’ on 16 February 2005, but the contractor noted a detached line in a gaseous helium bottle in the Common Core Booster. The defective helium bottle was replaced with a good one, and Boeing re-inspected Stage 2 for possible thermocouple boss-weld distortions on 23 March. As the matter progressed, the contractor decided to remove three bottles from the CCB and four bottles from Stage 2. Boeing convened an Engineering Review Board (ERB) on 13 April 2005 to draft a “go-forward” plan. Officials placed the GOES-N mission in indefinite status on 8 April 2005.[12]

All Type I defective bottles were removed and replaced with new bottles on the 26th, and technicians began fitting gas lines for the new bottles and making new welds on 27 April 2005. X-ray scans of the bottles confirmed the welds were acceptable in early May, and engineers re-mated Stage 2 to the CCB on 7 May 2005. The Stage 1 helium bottle leak check was completed successfully on 18 May, and officials accomplished a simulated flight test on 24 May 2005. Though a root cause for the defective bottles could not determined at that time, borescope inspections of all the bottles were completed by 22 June 2005. The anomaly was not expected to impact the launch. Engineers erected the spacecraft on 8 June 2005.[13]

On 30 June, officials rescheduled the launch for 18 July 2005. Unfortunately, technicians detected a data transfer error in the launch vehicle’s Redundant Inertial Flight Control Assembly (RIFCA), and the contractor’s Engineering Review Board recommended replacing the faulty RIFCA with a new one on 8 July 2005. Consequently, officials declared the launch date indefinite on 6 July, and they rescheduled it for 28 July 2005 after the new RIFCA was installed as planned. The new RIFCA and its flight program were verified on 14 July, and the issue was closed on 22 July 2006. In the meantime, concern arose over the “potential susceptibility” of the GOES-N spacecraft to ground-based “non-nominal” uplink signals. The spacecraft contractor requested and received approval in early August for a new launch date of 12 August 2005.[14]

As NOAA and the spacecraft contractor continued their ruminations over the uplink issue on 10 August, officials pushed the GOES-N launch to 13 August, then 14 August, and (finally) 15 August 2005 to allow NOAA more time to review spacecraft data. Though the issue was finally closed on the 16th, a Stage 2 helium bottle pressure loss prompted officials to delay the launch 24 hours. The countdown on 16 August 2005 almost succeeded, but officials scrubbed the launch at T minus 4 minutes and 22 seconds for multiple indications of low battery voltage in the booster. The GOES-N launch went into indefinite status once again on the 17th. Though the contractor later determined the indications (e.g., launch telemetry parameters) did not reflect the

[12] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 91.

[13] *Ibid*.

[14] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 92.

actual flight-worthiness of the components, the launch remained indefinite for the balance of August and most of September. Ultimately, Range Safety cleared the GOES-N as flight-worthy on 26 September 2005.[15]

Connector insert retention snap rings were yet another bone of contention in September 2005. The snap rings were manufactured by Deutsch, and they were used throughout the DELTA IV launch vehicle. In mid-September 2005, technicians found at least one of the snap rings "not fully engaged." An investigation at the vendor's plant led to the cause of the anomaly: incorrect use of a pneumatic press. The follow-up revealed 24 out of 1115 connectors (found in 8 out of 34 batches of connectors) would not snap properly. Boeing's analysis of the potential problem was submitted to Range Safety experts at the 30th Space Wing and 45th Space Wing. 45th Range Safety officials accepted Boeing's findings and assurances of connector quality, and they determined no waiver was required. The issue was closed on 31 October 2005.[16]

No sooner had the connector issue been settled than the International Association of Machinists and Aerospace Workers (IAM) Union went on strike on 2 November 2005. The strike ended in early February 2006.[17] During the dry spell, range officials labeled some 1-AMP Hour Flight Termination System batteries "non-flight-worthy" in late December 2005. On 3 January 2006, a government/contractor team met to discuss battery alternatives, but subsequent visual inspections of some candidate Orbital Sciences Corporation batteries revealed a higher rate of defects than some of the existing DELTA "Plan A" batteries considered earlier. Officials concluded they needed to find an alternate vendor or, failing that, rework the Plan A batteries to make them more flight-worthy. They eventually found an alternate vendor.[18]

At the customer's request, Boeing de-mated the spacecraft on 20 February 2006 to allow the customer a chance to clear up some spacecraft maintenance issues. The GOES-N was delivered to a subcontractor's maintenance facility on 22 February, and technicians de-encapsulated it the next day. The spacecraft re-mate was scheduled for 27 April, and officials rescheduled the launch for 18 May 2006.[19]

Within a couple of weeks of the projected launch, the lift-off slipped to 20 May 2006. Then, on 10 May, a Thrust Vector Control (TVC) actuator snubbing ring anomaly surfaced that posed potentially disastrous consequences: a piece of beryllium copper was found in the TVC's

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[15] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, pp 92, 93.

[16] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 93.

[17] The IAM membership voted to accept a three-year contract that provided lump sum bonuses and wage increases, lower monthly premiums on some medical plans, and a pension increase for employees who retired on or after 1 March 2006. At least three DELTA missions, including the GOES-N, were affected by the strike.

[18] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, pp 93, 94; Article, Justin Ray, "Boeing prepares to reunite its fractured Delta team," *Spaceflight Now*, 5 Feb 2006.

[19] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 94.

main control valve area. When technicians disassembled the actuator, they found the actuator and its snubbing ring were damaged. If undetected or left untreated, the defect could have ruined the mission. Fortunately, the anomaly was detected, and the contractor replaced all the TVC actuators on 13 and 14 May 2006. Retesting was completed successfully on 17 May, and officials rescheduled the countdown for 24 May 2006.[20]

The countdown went well. There were no unplanned holds, and the DELTA II lifted off Complex 37B without incident at 2211:00.213Z on 24 May 2006. The GOES-N payload was placed in the proper geosynchronous parking orbit, and the mission was successful. The flight marked the fifth time Pratt & Whitney's Rocketdyne RS-68 boosted a DELTA IV into orbit. The Rocketdyne RL-10 upper stage engine performed as expected.[21]

DELTA IV Medium-Plus (4,2) [GOES-O], 27 June 2009

The DELTA IV GOES-O flight was sponsored by the National Oceanic and Atmospheric Agency (NOAA) as the latest in a series of three next-generation weather-monitoring spacecraft missions into space.[22] Like its siblings, the GOES-O spacecraft featured a body-stabilized design that allowed the satellite to "stare" at Earth and monitor surface temperatures, cloud formations, severe storms, hurricanes and cyclones. The GOES-O provided real time coverage of short-lived severe weather phenomena. The manufacturer (Boeing Satellite Systems) also provided each spacecraft with a communications subsystem to detect distress signals from vessels and aircraft. Data collected by GOES satellites were transmitted routinely to NOAA's ground station on Wallops Island, Virginia, for retransmission to NOAA's Satellite Operations Control Center in Suitland, Maryland. Each of the three new weather satellites had an operational life expectancy of 10 years.[23]

According to the flight scenario, the DELTA IV Medium-Plus carrying the GOES-O lifted off Complex 37B and rolled into a flight azimuth of 95 degrees. The vehicle's two GEMs completed their burn in about a minute and a half, and they were jettisoned approximately one minute and forty seconds after lift-off. Following main engine cut-off, the second stage and payload separated about four and one-half minutes into the flight. The payload fairing dropped

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[20] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 94.

[21] 45 SW History, 1 Jan – 31 Dec 2006, Vol I, pp 94, 95; News Release, Pratt & Whitney, "Pratt & Whitney Rocketdyne's RS-68 and RL10 Power GOES-N Launch," 24 May 2006.

[22] The GOES-N, GOES-O and GOES-P spacecraft were designed and built by Boeing Satellite Systems (formerly the Hughes Corporation) for NOAA. A DELTA IV Medium equipped with two SRMs lifted the first spacecraft in the series, GOES-N, into orbit from Complex 37B on 24 May 2006. All three satellites were based on the highly popular and successful Boeing-601 spacecraft, and each came equipped with S-Band, L-Band and UHF uplinks and downlinks. Each spacecraft weighed 7,035 pounds at lift-off, but residual mass dropped to approximately 4,924 pounds as each satellite expending onboard fuel to reach geostationary orbit. Each satellite featured a liquid-fueled Apogee Kick Motor (AKM) and an array of bi-propellant thrusters for station-keeping purposes.

[23] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 132; 45 SW History, 1 Jan – 31 Dec 2006, Vol I, p 90.

off early in the second stage's first burn, which lasted about eight minutes. Following a coasting period of nearly 12 minutes, the second stage restarted for about four minutes. The next coasting period was following by a brief (46-second-long) burn approximately four hours after lift-off. The spacecraft was injected in its pre-planned 18,994 x 3,576 nautical-mile transfer orbit approximately four hours and 22 minutes after lift-off.[24]

Range officials approved the GOES-O launch for 28 April 2009 in late January 2009, and contractors placed the DELTA IV on its stand on 25 February 2009. The GEMs were added to the launch vehicle by the end of February, and officials conducted the Simulated Flight on 27 March 2009. Technicians encapsulated the payload between 6 and 9 April 2009, but an oxygen leak was detected in the main engine of the first stage during the DELTA IV's Wet Dress Rehearsal on 8 April 2009. Troubleshooting began immediately to detect the source of the problem, but officials announced publicly that the leak would delay the launch at least "a couple of weeks." A new launch date of 20 May 2009 was approved for the GOES-O mission, and the second Wet Dress Rehearsal on 21 April 2009 was successful. Nevertheless, later milestones were delayed while officials addressed a flight safety ordnance issue toward the end of April. Officials approved a new launch date of 26 June 2009 for GOES-O in mid-May 2009. Engineers mated the spacecraft to the launch vehicle on 9 June 2009. Officials completed a successful Flight Program Verification test on 11 June 2009, and the vehicle was readied for launch.[25]

The countdown on the 26th was scrubbed at 2259:00Z due to thunderstorms, high winds and lightning strikes in the local area, but the second countdown on 27 June 2009 went well. There was a 37-minute-long unplanned hold due to foul weather during the second countdown, but the DELTA IV Medium-Plus lifted off Complex 37B without incident at 2251:00.244Z on 27 June 2009. The launch was successful.[26]

DELTA IV Military Space Operations

DELTA IV Medium (DSCS III-A3), 11 March 2003

The object of Boeing's first "military" DELTA IV mission was to place the DSCS III-A3 spacecraft in a highly elliptical (e.g., 19,196 x 127-nautical-mile) transfer orbit. The spacecraft weighed approximately 2,700 pounds. Together with other spacecraft in the Defense Satellite Communications System (DSCS) constellation, it was designed and built by Lockheed Martin to

[24] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 132, 133.

[25] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 133; Article, Justin Ray, "Weather satellite launch delayed to repair rocket leak," *spaceflightnow.com,* 10 Apr 2009.

[26] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 133, 134; Article, Todd Halvorson, "Rocket launches weather satellite," *floridatoday.com,* 28 Jun 2009; News Release, "Pratt & Whitney Rocketdyne Helps Boost Satellite Monitoring Severe Weather Into Space," *prnewswire.com,* 28 Jun 2009; Article, William Harwood, "Delta 4 deploys an advanced weather observatory," *spaceflightnow.com,* 27 Jun 2009; Article, Eric Brian, "GOES-O launch goes successfully," *45th Space Wing Missileer,* 3 Jul 2009.

provide secure voice and data communications for U.S. military forces worldwide.[27] According to the mission scenario, the DELTA IV Medium vehicle chosen for the mission lifted off Pad 37B on an initial flight azimuth of 95 degrees. Following the typical series of Stage 1 and Stage 2 sequences, the spacecraft was released from the vehicle approximately 40 minutes after lift-off. As the mission continued, the spacecraft's Integrated Apogee Boost Subsystem (equipped with two 110-pound thrust rocket engines) fired to circularize the DSCS III-A3's orbit. Detachment 8, Space and Missile Systems Center provided Air Force oversight for the vehicle and its payload. The 45th Space Wing's Wing Safety Team oversaw the mission for flight analysis and systems safety purposes. Boeing built the launch vehicle, integrated it with its payload, and launched it. [28]

The Common Booster Core for the mission arrived at Cape Canaveral on 12 September 2002. The flight was scheduled to take place in December 2002, but it was delayed for a variety of reasons. The launch continued to slip until 7 February 2003, when Boeing requested a firm launch date of 8 March 2003. Unfortunately, officials scrubbed the countdown on 8 March for technical reasons, and they scrubbed a second launch attempt on 9 March 2003 due to a 70 percent chance of unacceptably high winds at the Cape. The countdown on 10 March went well, though officials had to extend a built-in hold to handle a range instrumentation system anomaly before the lift-off. The DELTA IV Medium lifted off Pad 37B at 0059:00.228Z on 11 March 2003. The DSCS III-A3 was inserted in the proper orbit. The flight marked America's first use of an Evolved Expendable Launch Vehicle (EELV) in a military space mission.[29]

DELTA IV Medium (DSCS III-B6), 29 August 2003

The object of this DELTA IV mission was to place the DSCS III-B6 spacecraft in a highly elliptical transfer orbit. Like its predecessors, the spacecraft was designed to provide secure voice and data communications for U.S. military forces worldwide. While the mission was virtually a 'carbon copy' of the DSCS III-A3 flight launched five months earlier, it had the distinction of featuring the last of 14 DSCS III spacecraft placed on-orbit over a period of 22 years. As such, it was a major milestone in the history of the Cape. Detachment 8, Space and Missile Systems Center provided Air Force oversight for the vehicle and its payload, and the

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[27] The Defense Communications Agency managed the DSCS III program for the Air Force. The DSCS III-A3 carried two major subsystems: 1) a primary system consisting of eight antennas and six independent SHF transponders, and 2) a secondary system featuring an Air Force Satellite Communications single-channel transponder.

[28] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 120, 121; "Delta IV to launch first military payload," *45th Space Wing Missileer*, 7 Feb 2003; "First military payload launched on EELV," *45th Space Wing Missileer*, 14 Mar 2003; "DSCS Deployed," *Aviation Week & Space Technology*, 8 Sep 2003; "45th Space Wing, Det. 8 launch DSCS," *45th Space Wing Missileer*, 5 Sep 2003.

[29] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 121, 122; "Delta IV to launch first military payload," *45th Space Wing Missileer*, 7 Feb 2003; "First military payload launched on EELV," *45th Space Wing Missileer*, 14 Mar 2003; "Delta IV, Atlas V Conduct EELV Launch Pad Tests," *Aviation Week & Space Technology*, 23 Dec 2002.

45th Space Wing's Wing Safety Team oversaw the mission for flight analysis and systems safety purposes. Boeing built the launch vehicle, integrated it with its payload, and launched it.[30]

The launch was scheduled for 1 July 2003. Unfortunately, unspecified "spacecraft issues" emerged in mid-May, and officials requested a new launch date of 11 July 2003. Launch vehicle issues caused another slip in the schedule to 3 August 2003, and the mission was placed in indefinite status in early August due to a problem with the vehicle's Flight Termination System (FTS). The mission was back on the schedule toward the end of August with a launch date of 28 August 2003. Following the Launch Readiness Review (LRR) on 27 August 2003, final preparations were completed for the countdown on 28 August 2003.[31]

The countdown got underway on 28 August as planned, but officials declared the Eastern Range 'Red' for unacceptable weather conditions at 1630Z. The range remained Red until officials scrubbed the launch for weather at 2032Z on the same date. The count was recycled for 29 August, and the second countdown began on that date.[32]

The second countdown was successful. There were no unplanned holds during the countdown, and no safety actions were required. According to the 45th Space Wing Command Post, the DELTA IV Medium lifted off Pad 37B at 2313:00.022Z on 29 August 2003. The DSCS III-B6 was injected in the proper orbit approximately 40 minutes later.[33]

DELTA IV Heavy Demo, 21 December 2004

The object of Boeing's DELTA IV Heavy Demo (Heavy Demonstration) mission was to verify the proper operation of the DELTA IV Heavy Launch System by placing a satellite simulator into a 19,623-nautical-mile-high geosynchronous orbit.[34] The 6.6 x 4.5-foot cylindrical satellite simulator weighed 13,213 pounds, and its primary function was to record flight characteristics of critical importance to the success of future DELTA IV Heavy missions. Two NanoSat spacecraft were carried as well, and they were scheduled to separate from the launch vehicle during the second stage's coasting period to enter an orbit of 102 x 136 nautical miles. The DELTA IV Heavy was equipped with a Common Booster Core (CBC) and two strap-on CBCs to provide approximately 1,986,000 pounds of thrust at lift-off. The simultaneous operation of those three boosters was a key feature of the mission.[35]

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[30] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 122, 123; "DSCS Deployed," *Aviation Week & Space Technology*, 8 Sep 2003; "45th Space Wing, Det. 8 launch DSCS," *45th Space Wing Missileer*, 5 Sep 2003.

[31] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, p 123.

[32] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 123, 124.

[33] 45 SW History, 1 Jan – 31 Dec 2003, Vol I, pp 125.

[34] According to *Aviation Week & Space Technology*, the Air Force requirement for a DELTA IV Heavy Demonstration arose as part of the official restructuring of the EELV program in 2001.

[35] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 109; "The Ready Heavy," *Aviation Week & Space Technology*, 8 Sep 2003; "Heavy lifting for the new millennium," *The Space Review*, 26 Apr 2004.

According to the flight scenario, the DELTA IV Heavy lifted off Pad 37B and rolled into a flight azimuth of 95 degrees. The left and right strap-on CBCs were programmed to complete their burns about four minutes after lift-off. They would be jettisoned about three seconds later. The remaining CBC completed its burn about five and one-half minutes after lift-off, and the first stage separated from the launch vehicle about eight seconds later. The payload fairing was jettisoned following second stage ignition, and the second stage's cut-off heralded a coasting period, beginning about 13 minutes after lift-off. The NanoSats were programmed to release approximately 16 minutes after lift-off. Two more second stage burns set the vehicle up for payload separation about six hours into the flight.[36]

Officials scheduled the DELTA IV Heavy Demo flight for 23 September 2003, but they decided to place the launch in indefinite status on 19 May 2003 to allow additional time for launch pad modifications and vehicle processing. The DELTA Launch Team joined the Launch Mate Unit (LMU) to the vehicle's three CBCs on 30 October 2003, and the team completed a "hard mate" of the three-booster assembly on 6 November 2003. On 12 November, technicians and engineers mated the second stage to the central CBC, and workers transported the launch vehicle to Pad 37B on 10 December 2003. Upon its arrival, the vehicle was placed on the Fixed Pad Erector and elevated to its upright position in just 20 minutes. As processing and testing continued, officials projected the DELTA IV Heavy launch for July 2004, but it slipped to 10 September 2004 a few months later. In the meantime, officials completed an integrated vehicle test on 18 March and a Simulation Flight on 19 April 2004. Engineers erected the spacecraft on 24 July 2004.[37]

A problem with the second stage's liquid hydrogen drain valve surfaced toward the end of July 2004. On 4 August, Boeing requested another indefinite launch date for the DELTA IV Heavy to give the company time to resolve technical issues associated with the Tail Service Mast (TSM). By 25 August, technicians and engineers had eliminated all outstanding problems, and officials established a new launch date of 20 October 2004. During Hurricane FRANCES (4-5 September 2004) all three CBC engine covers blew off, and the port and starboard throat plugs were ejected. Fortunately, the engine purges remained intact, eliminating concern for flight hardware. Technicians reinstalled the throat plugs, and they used portable Environmental Control System (ECS) units to reestablish airflow to the booster while ECS control cards were replaced and booster and payload environmental control systems were brought back online. Officials reported "no apparent damage" to the DELTA IV Heavy booster following the hurricane. Nevertheless, the launch slipped back into indefinite status on 13 September 2004.[38]

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[36] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, pp 109, 110.

[37] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 109; "Heavy lifting for the new millennium," *The Space Review*, 26 Apr 2004; Summaries, Joy Bryant, Boeing Director, Launch Sites Expendable Launch Systems, 7 Nov 2003 and 17 Nov 2003.

[38] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, pp 110, 111.

As hurricane recovery efforts and launch processing continued, Air Force Headquarters asked the launch contractor to perform inspections to detect any contamination that may have been caused by: 1) the loss of liquid hydrogen (LH2) purge on the DELTA IV's second stage, and 2) the loss of gaseous nitrogen (GN2) and air conditioning to the payload fairing. Negligible levels of contaminants were detected in the interstage compartment, and no contamination was discovered in the RL10B-2 engine's gear train and bearings. Officials closed out the issue on 12 October 2004. In the meantime, engineers de-mated and lowered the spacecraft on 5 October to replace six transducers. They re-mated the spacecraft on 9 October 2004. On 7 October, officials rescheduled the DELTA IV Heavy launch for 18 November 2004. Further hurricane-related inspections around the end of October revealed some wind-blown sand damage to the DELTA IV first stage thermal blankets, so Boeing decided to replace all twelve blankets in November 2004. The launch, once again, went into indefinite status. [39]

Following a DELTA II RIFCA failure during testing elsewhere on the Cape, Boeing convened an Engineering Review Board (ERD) on 5 November 2004 to clear the DELTA IV's Redundant Inflight Controller Assembly (RIFCA) for flight. Technicians completed the second stage Attitude Control System (ACS) propellant load on 23 November, and officials rescheduled the DELTA IV Heavy launch for 10 December 2004. Technicians completed thermal blanket installations on all three CBC main engines on 2 December 2004. Boeing convened another Engineering Review Board on 2 December to clear the DELTA IV Heavy's RS-68 engines following an RS-68 test failure (e.g., early cut-off) at Boeing's Stennis facility. That issue was closed on 2 December 2004. The loss of the tracking beacon during the DELTA II SWIFT flight on 20 November 2004 prompted Boeing to remove the DELTA IV Heavy's C-Band beacon on 29 November 2004 and have it shipped back to the vendor for testing. The beacon was tested and returned, and Boeing completed C-Band transponder checks successfully on 8 December 2004.[40]

As the latest launch date approached, the weather outlook worsened. Consequently, officials decided on 9 December to reschedule the countdown for 11 December 2004. An electrical problem with the Terminal Count Sequencer compelled authorities to scrub the DELTA IV Heavy Demo launch on the 11th, and an Environmental Control System (ECS) fault caused another scrub on 12 December 2004. As engineers dealt with the latest problem, the user requested a new launch date of 21 December so as not to conflict with the ATLAS V (AMC-16) launch on 17 December 2004. Troubleshooters rewired the ECS circuit breakers to resolve the ECS problem on 15 December, and the Launch Readiness Review on 20 December cleared the DELTA IV Heavy for launch on 21 December 2004.[41]

There were two unplanned holds during the countdown on 21 December 2004, but the DELTA IV Heavy lifted off Pad 37B at 2150:00.241Z on the same date. Though the vehicle's

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[39] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, pp 111, 112.

[40] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 112.

[41] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 113.

RS-68 and RL10B-2 engines performed properly, the first stage's strap-on CBC engines shut down approximately 8 seconds earlier than planned, and the center CBC engine shut down nine seconds early. The upper stage performed all three of its burns successfully, but the first stage velocity deficit could not be overcome, and the upper stage simply ran out of fuel before the vehicle could place the satellite simulator in the proper orbit. The two NanoSats carried on the second stage also failed to achieve their proper orbits.[42]

Boeing, together with the Air Force and the Aerospace Corporation, established an Anomaly Investigation Team to determine the root cause of the flight anomaly. The team's preliminary "fault tree" analysis pointed to a disturbance in the first stage's liquid oxygen flow that prompted engine cut-off sensors to initiate shutdown sequences when there was still plenty of fuel in the tanks. As the investigation continued into February 2005, Boeing planned to make timing and software changes to eliminate a repeat of the anomaly once the investigation concluded.[43]

In the meantime, Boeing and the Air Force could take some satisfaction in knowing that the DELTA IV Heavy Demo flight achieved the following important milestones: [44]

- Activation and launch of the first heavy version of the DELTA IV
- First flight of three CBCs in tandem
- Successful separation of strap-on CBCs from the vehicle's central CBC
- First flight and successful separation of the five-meter composite payload fairing
- First flight of the cryogenic upper stage with a three-burn flight profile for the RL10B-2 engine

DELTA IV Heavy (DSP-23), 11 November 2007

The object of Boeing's DELTA IV Heavy DSP-23 mission was to place the 23rd and final Defense Support Program (DSP) spacecraft in a geosynchronous transfer orbit from Complex 37B.[45] The DSP-23 weighed approximately 5,200 pounds. If its earlier siblings'

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[42] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 113; "Early engine shutoff blamed," *Florida Today,* 23 Dec 2004.

[43] 45 SW History, 1 Jan – 31 Dec 2004, Vol I, p 113; "Early engine shutoff blamed," *Florida Today*, 23 Dec 2004; "Heavy Changes," *Aviation Week & Space Technology*, 3 Jan 2005; "Delta IV Heavy test mission provides engineers invaluable data," *45th Space Wing Missileer*, 14 Jan 2005; "AF/Boeing investigation team to identify cause of Delta IV Heavy main engine cut-off in February," *45th Space Wing Missileer*, 28 Jan 2005.

[44] "Delta IV Heavy test mission provides engineers invaluable data," *45th Space Wing Missileer*, 14 Jan 2005; "AF/Boeing investigation team to identify cause of Delta IV Heavy main engine cut-off in February," *45th Space Wing Missileer*, 28 Jan 2005.

[45] The DSP constellation began with the first launch of a DSP satellite in 1970. The constellation underwent four major upgrades to increase its capabilities, and it used infrared sensors aboard each station-keeping spacecraft to detect strategic missile attacks against the United States and/or its allies. Put simply, DSP spacecraft sensed the number and direction of the missiles' heated exhaust 'plumes' in flight, and they provided early warning to U.S.

longevity was any guide, the DSP-23 could be expected to function much longer than its nominal three-year operational lifespan. Northrop Grumman managed the DSP program and integrated the spacecraft and its sensors. The Space Based Infrared Systems Mission Control station at Buckley AFB, Colorado, operated the DSP constellation on an around-the-clock basis every day. Though the DSP-23 spacecraft was the last of a long line, it would eventually become part of a "blended" constellation of DSP and Space Based Infrared System (SBIRS) satellites.[46]

According to the flight scenario, the DELTA IV Heavy lifted off Pad 37B and rolled into a flight azimuth of 95 degrees. The first stage, consisting of three CBCs attached together side-by-side, completed its burn about five and one-half minutes after lift-off. The CBCs separated from the launch vehicle about six seconds later. The second stage fired about six minutes into the flight, and the payload fairing dropped off six seconds later. The second stage shut down, and the vehicle entered a coasting period about 13 minutes after lift-off. Following a lengthy coasting period punctuated with two more second-stage burns, the DSP-23 spacecraft was released more than six hours after lift-off.[47]

Back in May 2005, the mission had been placed in indefinite status after the launch vehicle's RL-10B-2 engine developed elevated harmonics during ground testing. The launch was back on the schedule in August 2005, but its status see-sawed back and forth until officials approved a new launch date of 31 January 2007 on 20 July 2006. In the meantime, the spacecraft was shipped to the Cape in May 2005, and launch vehicle processing operations continued. Officials eventually approved a new launch date of 1 April 2007. Engineers encapsulated the spacecraft by the end of February 2007, but inspections (following a tanking dress rehearsal on 28 February 2007) revealed cracks in the launch table. Analysis suggested a liquid oxygen leak from feed lines used to tank the booster probably caused the cracks by thermal shock. Consequently, the vehicle had to be powered down to determine the extent of damage to the launch vehicle. The launch remained indefinite until officials took it off the schedule at the end of April 2007. The vehicle was taken down on 29 March 2007.[48]

Technicians had to replace liquid oxygen and liquid hydrogen feed lines to correct the problem mentioned earlier, so the DELTA IV remained in storage in the Horizontal Integration Facility (HIF) while the work continued in early May 2007. On 28 April 2007, technicians

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command centers primed to retaliate in kind. They could also detect nuclear bursts, making them an integral part of the United States' attack assessment system.

[46] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 106, 107; "Northrop Grumman's Defense Support Program Wins 2007 Aviation Week Program Excellence Award," *CNN Money.com,* 30 Oct 2007; "United Launch Alliance Successfully Completes First Operational Delta IV Heavy Launch," *spacetravel.com,* 11 Nov 2007; Article, Ken Warren, "Final DSP mission marks five launches in less than 50 days," *45th Space Wing Missileer,* 16 Nov 2007; Article, Justin Ray, "Delta 4-Heavy rocket fires away from Cape Canaveral," *Spaceflight Now,* 11 Nov 2007.

[47] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 107, 108.

[48] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 108.

moved the DSP-23 to the North Integration Cell of the Spacecraft Processing and Integration Facility (SPIF) for battery reconditioning and cleaning. The mission was back on the launch schedule in mid-July with a lift-off anticipated as early as 28 August 2007. (To some observers, October seemed more likely.) Engineers encapsulated the spacecraft for a second time on 10 July 2007. The spacecraft was mated to the launch vehicle on 25 September 2007, but the launch dropped back into indefinite status. In late September, officials selected a launch planning date not earlier than 3 November 2007. They completed a spacecraft/launch vehicle verification integrated test on 6 October 2007. They approved a new launch date of 9 November on 24 October 2007, but the countdown ultimately slipped to 10 November 2007 EST (11 November 2007 GMT).[49]

There was one 11-minute-long unplanned hold at T minus 5 minutes during the countdown on 10/11 November 2007. It was prompted by the loss of an instrumentation link. That incident aside, the DELTA IV Heavy lifted off Complex 37B at 0150Z on 11 November 2007. The launch and flight went very well,[50] and the satellite separated from the launch vehicle as planned on the same date. Orbital parameters were nominal, and the data confirmed that the first launch of a DELTA IV Heavy with an operational payload[51] was successful.[52]

DELTA IV Heavy (NROL-26), 18 January 2009

The object of Boeing's DELTA IV Heavy mission launched from Complex 37B on 18 January 2009 was to place the National Reconnaissance Office's NROL-26 spacecraft in a pre-determined orbit using a descending node transfer orbital injection technique. According to the flight scenario, the DELTA IV Heavy lifted off the launch pad and rolled into a flight azimuth of 95 degrees. The first stage, consisting of three CBCs attached together side-by-side, complete its burn about five and one-half minutes after lift-off. The CBCs separated from the launch vehicle about eight seconds later. The second stage fired for about seven minutes initially, and the vehicle and its payload entered the first of two coasting periods shortly thereafter. Two more second stage burns led to spacecraft separation approximately six hours after lift-off.[53]

Officials approved the NROL-26 launch for 25 July 2008 in mid-March of that year, but the spacecraft was delayed. Consequently, the lift-off slipped to 8 September 2008 by the end of May 2008. The spacecraft's arrival was delayed further in early June 2008, so the launch

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[49] 45 SW History, 1 Jan – 31 Dec 2007, Vol I, pp 108, 109.

[50] This was the first time that a NASA WB-57 Wave aircraft supported an EELV launch. The aircraft provided IR imaging to monitor debris and observe critical staging events during the flight.

[51] As noted earlier in this chapter, the first DELTA IV Heavy was launched from Complex 37B on 21 December 2004 as a demonstration launch. The payload on that mission was a 6.6 x 4.5-foot cylindrical satellite simulator weighing 13,213 pounds.

[52] 45 SW History, 1 Jan -31 Dec 2004, Vol I, pp 109, 113; 45 SW History, 1 Jan – 31 Dec 2007, Vol I, p 109.

[53] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 127.

contractor (ULA) requested a new launch date of 26 September 2008. In the meantime, engineers and technicians placed the DELTA IV Heavy on its stand on 27 March 2008. Officials completed the Simulated Flight on 17 June 2008. Then Tropical Storm FAY approached Central Florida and dumped as much as 26 inches of rain in some local areas between 18 and 22 August 2008. Having witnessed such heavy rainfall, local officials were concerned about water damage to the launch vehicle. However, the DELTA IV Heavy was in a sheltered modern facility, and it remained unharmed. Nevertheless, officials selected a new launch date of 31 October 2008 for planning purposes in mid-September 2008, and vehicle milestones were shifted to later dates accordingly.[54]

Once again, there were delays. By early October 2008, the new launch date for planning purposes slipped to 17 November 2008 despite payload encapsulation on 17 September 2008. In mid-December 2008, officials approved a new launch date of 14 January 2009. Engineers mated the spacecraft to its DELTA IV Heavy launch vehicle on 24 November 2008, and officials completed the Flight Program Verification and Spacecraft/Launch Vehicle Integrated Test on 19 December and 20 December 2008 respectively. The Mobile Service Tower's roll (and the NROL-26's launch) was delayed 24 hours while technicians: 1) reapplied foam on four interstage access doors and 2) repaired a leaking pneumatic valve and a tear in an environmental control system duct's protective cover. Finally, the first countdown was scrubbed on 14 January 2009 at 2309Z due to gaseous nitrogen (GN2) system problems. The next countdown got underway on 17 January 2009.[55]

There were three unplanned holds during the countdown on 17/18 January 2009. They involved user or launch vehicle alarm problems, but each anomaly cleared in less than one hour. Those incidents aside, the DELTA IV Heavy lifted off Complex 37B at 0247:00.327Z on 18 January 2009. The launch was successful.[56]

DELTA IV Medium-Plus (5,4) [WGS-3], 6 December 2009

A DELTA IV Medium-Plus (5,4) carried the Wideband Global SATCOM-3 (WGS-3) spacecraft into orbit from Complex 37B on 6 December 2009. The 6.5-ton spacecraft was the third in a series of high-capacity satellites in the Defense Department's new WGS communications system. Boeing built the $300 million WGS-3 satellite under government contract, and the spacecraft was designed to complement current-generation Defense Satellite Communications System III (DSCS III) Service Life Enhancement Program (SLEP) and GBS payloads. It also offset the inevitable decline in DSCS III capabilities. A total of six WGS

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[54] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 127, 128.

[55] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 128; Article, Craig Covault, "NRO Delays Delta IV Heavy Launch," *aviationweek.com,* 10 Dec 2008; Article, Todd Halvorson, "Top-Secret Mission Delayed Until Wednesday," *Florida Today,* 13 Jan 2009.

[56] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 128, 129; "First ULA Delta IV Heavy NRO Mission Successfully Lifts Off From Cape Canaveral," *space-travel.com,* 20 Jan 2009.

spacecraft were planned for the new WGS constellation. Each spacecraft offered 4.875 gigahertz (GHZ) of instantaneous switchable bandwidth, and each satellite could downlink 2.4 Gbits of data to tactical users. (As noted earlier in Chapter II of this study, the WGS-2 spacecraft was launched successfully from Complex 41 on an ATLAS V in early April 2009.) According to the scenario for this mission, the DELTA IV Medium-Plus was launched on an initial launch azimuth of 100.97 degrees. The four GEMs were jettisoned in pairs approximately two minutes after lift-off. The spacecraft separated from the launch vehicle approximately 40 minutes into the flight in a highly elliptical orbit (e.g., roughly 220 x 36,000 nautical miles).[57]

On 9 April 2009, officials approved the WGS-3 launch for 26 August 2009. Unfortunately, the launch date slipped to 30 September in mid-May before moving into indefinite status toward the end of July 2009. Nevertheless, technicians erected the DELTA IV booster on Complex 37B on 29 August, and the four GEMs were added to the launch vehicle between 31 August and 7 October 2009. The Simulated Flight and Wet Dress Rehearsal went well on 15 October and 23 October 2009 respectively. Low levels of monomethylhydrazine (MMH) were detected at the Payload Processing Facility during spacecraft transport preparations on 6 November, but the suspected leak turned out to be a false reading. The spacecraft was moved to the launch pad on 7 November 2009, but high winds prevented mating operations. The launch moved into indefinite status once again on 11 November 2009.[58]

Officials approved a new launch date of 3 December 2009 on 18 November, and engineers mated the spacecraft to the DELTA IV Medium-Plus on 15 November 2009. A Flight Program Verification was completed on 17 November 2009, and final preparations got underway for the launch. The launch slipped one day to the right two weeks later, and the first countdown had to be scrubbed at 0131Z on 4 December due to false alarms from a Ground System Command and Control Unit. The next launch attempt got underway for a lift-off on 6 December 2009.[59]

The countdown on 5/6 December went well. Though there was a one-hour and 14-minute unscheduled hold for upper level winds, the launch vehicle lifted off Pad 37B at 0147:00.276Z on 6 December 2009. Major Mark Hadley, mission manager for the spacecraft, confirmed the

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[57] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 136, 137; New Release, 45 SW, "AF Successfully Launches Satellite to Enhance Military Communications," 5 Dec 2009; "USAF launches telecom satellite," *United Press International,* 6 Dec 2009; Article, Todd Halvorson, "Satellite is a 'game changer' for US troops," *Florida Today,* 6 Dec 2009.

[58] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, pp 137, 138; Featured Photo, "On The Rise…" *45 SW Missileer,* 4 Sep 2009; Article, Todd Halvorson, "Live At The Cape: High Winds Delay Delta Launch," *floridatoday.com,* 9 Nov 2009.

[59] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 138.

launch was a success. United Launch Alliance (ULA) reported the spacecraft separated from the launch vehicle as planned.[60]

[60] 45 SW History, 1 Jan – 31 Dec 2009, Vol I, p 138; New Release, 45 SW, "AF Successfully Launches Satellite to Enhance Military Communications," 5 Dec 2009; "USAF launches telecom satellite," *United Press International,* 6 Dec 2009; Article, Todd Halvorson, "Satellite is a 'game changer' for US troops," *Florida Today,* 6 Dec 2009.