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Paper Session I-A - Delta Commercial Space Transportation

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DELTA COMMERCIAL SPACE TRANSPORTATION

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Recent Developments

1996 Launches – As of this writing, two launches have taken place in 1996, the NEAR on 17 February and Koreasat-2 on 14 January. NEAR (Near Earth Asteroid Rendezvous) is the first of the NASA Discovery series of spacecraft, and is the fifth under the MELVS contract. The Koreasat-2 satellite was the second satellite launched for the republic of Korea, and was an entirely successful launch. The first satellite, launched on Delta 228 last August, reached orbit successfully but with less than specified lifetime due to a first stage anomaly.

X-ray Timing Explorer Launch/Avionics Upgrade – Delta launch No. 230 took place on 30 December, after numerous weather-related delays. The XTE satellite, the first US x-ray satellite launched in 15 years, will allow scientists to study x-ray-emitting objects within our galaxy and beyond. The launch was the first to carry a new avionics system known as redundant inertial flight control assembly (RIFCA); it also marked the debut of an automated launch control system (ALCS), which routes system status information through a high speed fiber optic computer network linking commercial workstations. Key to the avionics upgrade is the RIFCA, which serves as the brain of the system. Using an array of redundant laser gyros and accelerometers, RIFCA senses the vehicle velocity and attitude movement, which includes its angular position and direction. These data are constantly processed, allowing the RIFCA to set and update a controlled course throughout the flight. The new system is completely redundant, and has two separate power sources.

Additional Motorola Launches – A contract was signed with Motorola's Satellite Communications Division in December to launch an additional 15 satellites to be part of the global wireless Iridium telecommunications network. The satellites will be used in the system's operational and maintenance phase, and will be launched three at a time on Delta 7420 model launch vehicles beginning in April 1998 and continuing through July 2000. The launches will take place from VAFB, as will the 8 Delta launches (5 satellites each) that comprise a portion of the initial system deployment.

Radarsat Launch – On **4 November 1995,** a Delta 7920 successfully placed the Radarsat satellite in a circular polar orbit from SLC-2 at the Vandenberg Air Force Base (VAFB). This was he first Delta II launch from VAFB, and the first launch at that site since Cosmic Background Explorer (COBE) in 1989. The satellite comes under the auspices of the Canadian Space Agency, and is a key element of the Canadian space program. It will be used to monitor ice movements, detect changes in coastal erosion, find productive fishing areas, and numerous other civil and commercial purposes. It was launched by NASA in exchange for access to its data. The flight also carried a secondary payload called the Surfsat.

**New Business Development, Space and Defense Systems.*

History Background

The McDonnell Douglas Delta launch vehicle originated nearly 36 years ago, in May 1960. The so-called interim space launch vehicle proceeded to become a NASA workhorse for many years, through the successful COBE launch of 1989. More recently, it emerged as the Delta II, a reliable vehicle for the USAF, as well as for NASA and the commercial community.

Delta has been launched 232 times, and recorded 219 successes. This includes successful orbital launches for 24 navigation, 81 communication, 38 meteorological, 70 scientific and 6 earth observation satellites. The recent uninterrupted success string of 49 is unprecedented. Since 1977, a total of 96 out of 98 missions (98%) have been successful.

Delta payload capability has increased dramatically through the years by virtue of numerous changes, including new stages, increased capacity, new and larger engines, and addition of solids, etc. Figure 1 indicates many of these changes.

Delta has been launched at an overall rate of nearly seven per year over its 35-year life, or about one every two months. The current nominal launch rate is 12 per year. In both 1990 and 1992 we launched 11 times; in each of two recent twelve-month periods we launched 12 times. In the future a launch rate in excess of twelve is planned, as both of the east coast pads and the west coast pad become activated with scheduled launches for the USAF, NASA and commercial customers.

The Delta story is truly a success story. Along with the 40-fold increase in performance through the years it has increased reliability and improved operability (Figure 2). Today, and in the future, Delta is committed to mission success and continuous improvement.

Delta Configurations/Family

The typical Delta configuration consists of the RP- 1/ LO_2 fueled first stage with RS-27A main engine and nine strap-on solid rocket motors, an isogrid interstage, storable propellant second stage with Aerojet engine, a

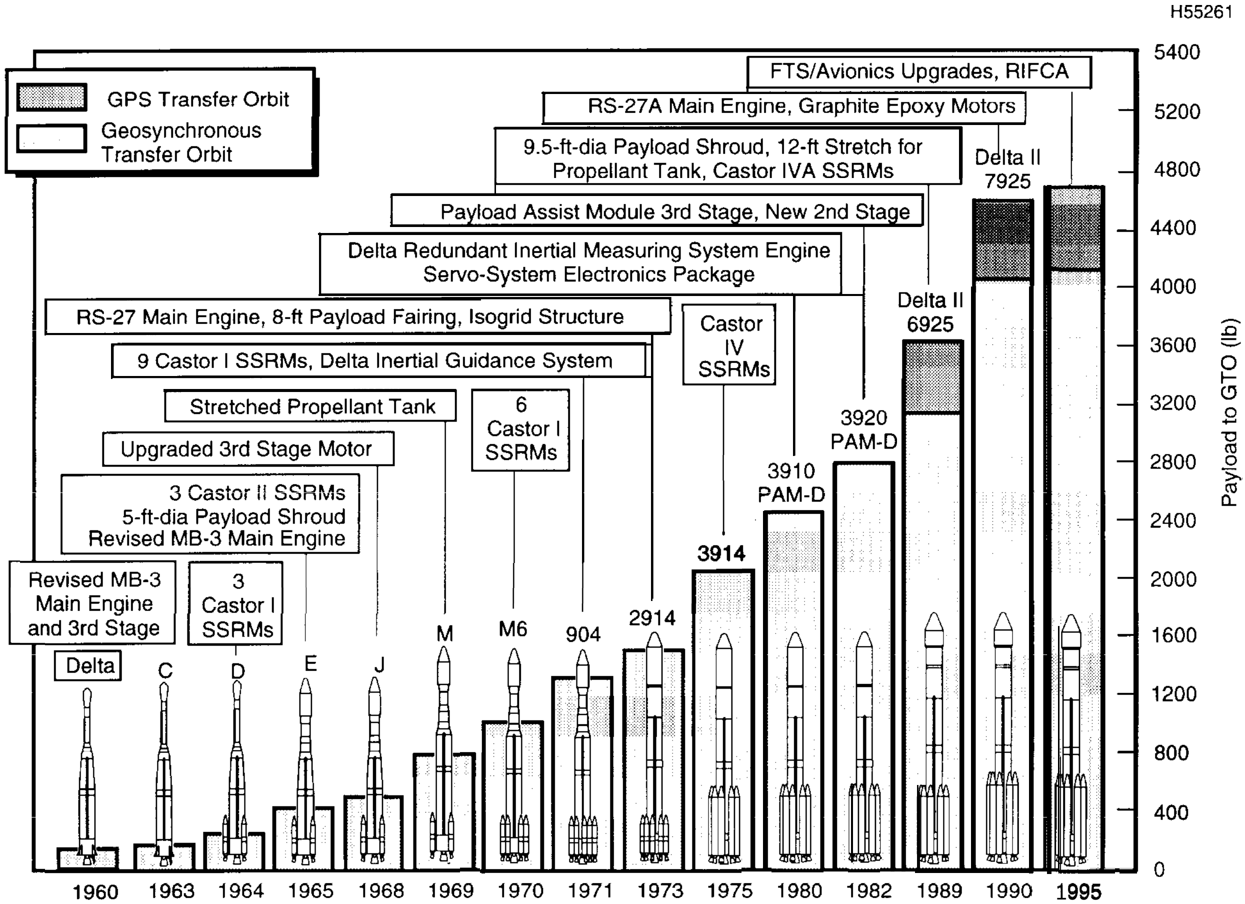

Figure 1. Growth With Enhanced Operability and Reliability

spin table assembly, and a Star-48 solid motor spinning third stage (Figure 3).

There are a number of fairing options available for Delta II: the 2.4-m/8-ft fairing, the standard 2.9-m/9.5-ft model, and a new, composite 3-m/10-ft model. Previous missions requiring additional volume have employed a metal/aluminum 3-m fairing. The new composite fairing has a 3-m/10-ft outside diameter with 2.74-m/108-in static envelope, acoustic blankets, external sparesyl thermal protection, two standard doors, and an available GN2 purge.

Future Delta II missions, starting in mid-1996, will incorporate the newly developed avionics upgrade. This guidance system is located on the second stage. For three-stage missions, the system properly points the third-stage/payload combination, commands the spin-up and separation, after which flight is basically unguided. This upgraded system was checked out on the XTE flight in December 1995.

The major element of the avionics upgrade is the Redundant Inertial Flight Control Assembly (RIFCA), a modernized, single fault tolerant guidance system. RIFCA utilizes six Allied Signal ring laser gyros and six Sundstrand accelerometers to provide redundant three-axis attitude and velocity data. RIFCA is an independent investment of MDA and Allied Signal to incorporate new technology and reliability into the Delta family of launch vehicles.

Currently, the flight profile for all missions involves the ignition of the main engine and six of the solids on the ground. After burnout, the six solids are jettisoned and the remaining three solids ignited and jettisoned after burnout. The main engine continues to burn until MECO. Shortly after second stage ignition, the fairing is jettisoned. Generally, the second stage burns at least twice, depending on the mission, either placing the payload in a final low-Earth orbit (LEO) or burning out of the LEO to start it on a transfer trajectory. The third stage is generally the mechanism to send a communications satellite into GTO.

Current Delta facilities are shown on Figure 4. Most production takes place at the Huntington Beach, CA facility; final assembly is accomplished at Pueblo, CO. The vehicle is transported to either the East or West coast launch site for final checkout and launch.

USAF MLV Navstar/GPS Competition

The Delta II of today emerged from the MLV-I competition which was won by MDA in 1987. The resulting configurations were the 6925 and the 7925. Both had stretched propellant tanks (3.65-m/l 2-ft longer than the 3920 configuration), and employed the new, 2.9-m/9.5-

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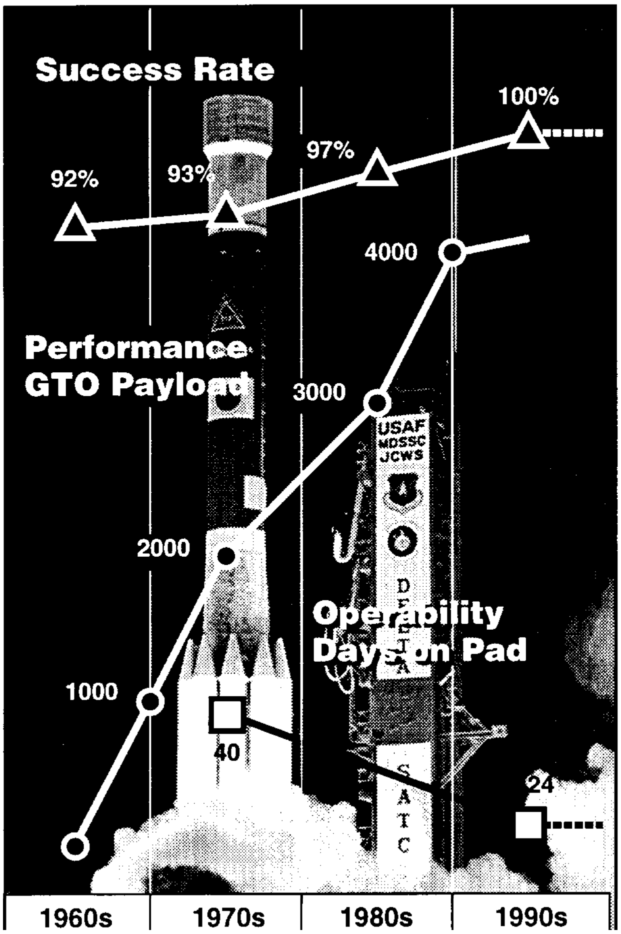

Figure 2. Delta Launch Vehicle Commitment to Mission Success and Continuous Improvement

ft diameter payload fairing. The 6925 used Thiokol Castor-IVA solid motors for the first nine missions.

The 7925 was developed for the heavier GPS satellites. It used Hercules graphite epoxy motors (GEMS) instead of C-IVAs, and had an increased expansion ratio main engine. Another nine missions were flown with this configuration under the original contract. To complete the constellation and provide replenishment satellites for the older ones, a follow-on contract was placed with MDA for 10 additional launches of Block II satellites. To date, six of those have flown. The GPS constellation is now complete and operational, with necessary spares. The remaining four satellites of the follow-on contract are now on a Launch on Need (LON) basis.

MDA was the winner in the 1993 MLV-111 competition to launch the Navstar GPS Block IIR satellites. The contract is for replacement of the current satellites as required. With options, it could involve anywhere from 25 to 32 satellites launched by early in the next century. Launches are to be available on a 60-day call-up basis with up to six launches in a given year. At present, the first launch is scheduled for late 1996

The current performance rating for the 7925 vehicle is 2090-kg/4608-lb for the GPS mission; it will be increased to 2141-kg/4719-lb by early 1996 per the MLV-111 contract. Improvements are summarized on Figure 5; the result is a required 5% payload margin. Increased margin could be achieved by using larger solid motors for the air-lit solids, i.e., increased from 102-cm/40-inches to 117-cm/46-inches in diameter. There will also be launch site improvements, including reductions in personnel, control consoles, and data analysis stations. The aforementioned changes to the RIFCA guidance and control system are also an integral part of the vehicle improvements, as shown on the figure.

NASA MELVs

The Delta remains an important part of the NASA stable by virtue of the award of the 1989 Medium Expendable Launch Vehicle (MELVS) contract. The contract was for three missions (Geotail, Wind and Polar) with options, six of which have been exercised to date (Radarsat, XTE, NEAR, Mars Global Surveyor, Mars Pathfinder and ACE). Geotail, Wind, Radarsat and XTE have flown successfully. In addition to the NASA missions planned from VAFB, two more are scheduled. These are the MSX and the P91-1 Argos.

In an arrangement with the USAF, NASA “borrowed” two of the Deltas from the MLV-I contract to successfully orbit the ROSAT and EUVE satellites in 1990 and 1992.

Commercial Missions

Since the rebirth of Delta in 1987, three configurations—the 4925, 6925 and 7925—have been used to launch a total of 16 commercial communications satellites. Over the years, about 40% of all Delta launches have placed communications satellites into geosynchronous transfer orbits (GTO). The success ratio for these missions is over 93%. The accuracy of these missions, with little exception, has been remarkable.

The performance of the current 7925 configuration for the GTO mission, which is 35,786 x 185-krn/19,323 x 100 nmi, inclined 28.5°, is 1842-kg/4060-lb. This will be increased to 1870-kg/4120-lb by the aforementioned changes available in early 1996.

The addressable market share in the Delta II class continues to be somewhat small as the commercial communications satellite community concentrates on satellites in the 2.5 to 3.5 ton class. The marketplace continues however, as repeat customers, emerging countries and newcomers seek smaller (and less expensive) satellites. A number of launches remain on the manifest: the Thor-IIA for Telenet (Norway), Galaxy-IX for Hughes Communications, and a Skynet-4D for the UK (another Skynet is currently in competition).

On the other hand, a significant marketplace is emerging based on the numerous parties interested in development and operation of mobile communication systems, as well as positioning and messaging systems. All of these involve smaller satellites placed into low-Earth orbits. Two kinds of service are required: 1) to put constellations in place, and 2) to replenish failed satel-

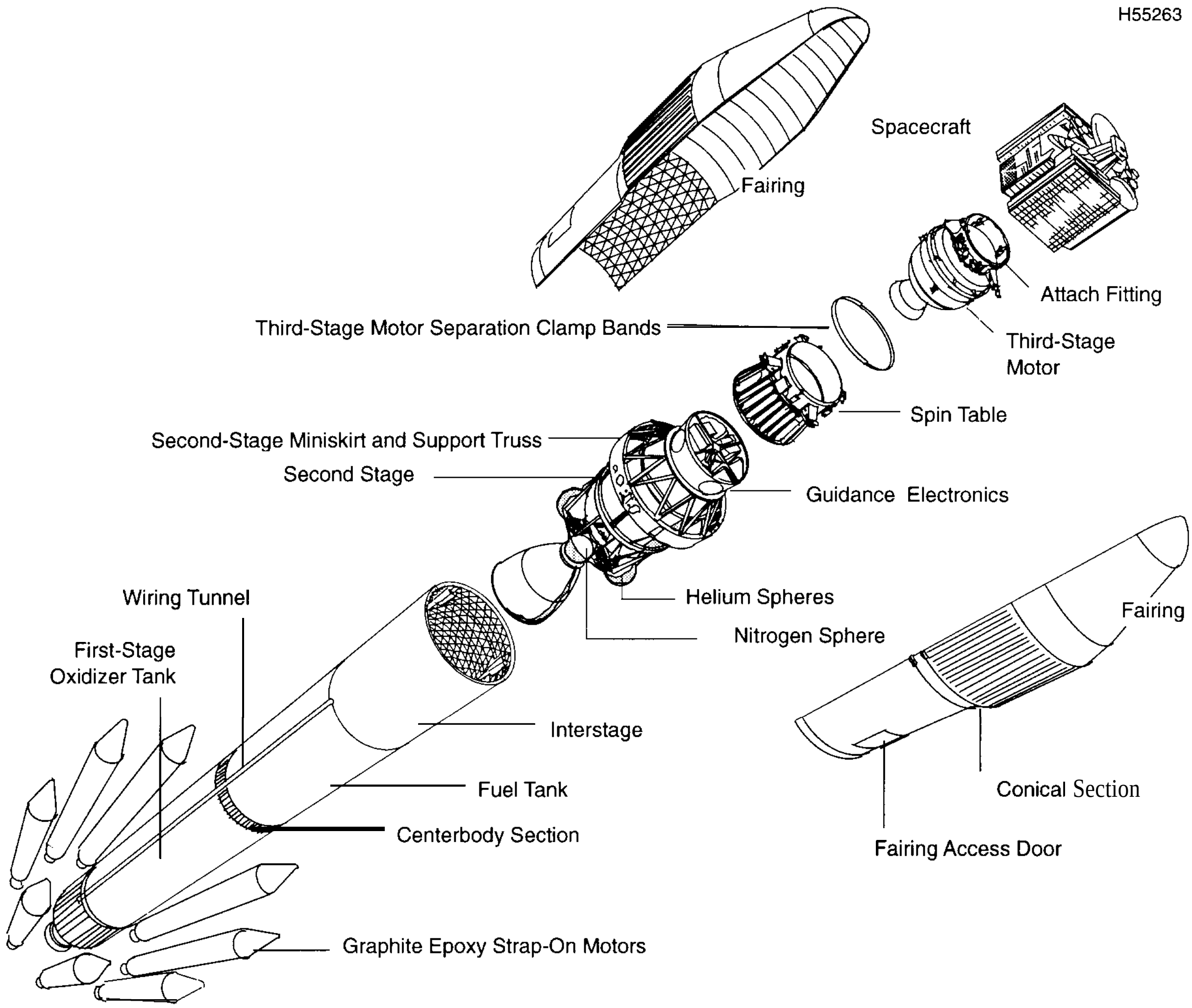

Figure 3. Delta II 7925 Launch Vehicle

lites, as necessary. In many cases, Delta-II can serve both markets.

MDA signed a contract with Motorola in March 1994 to launch the majority of the satellites needed to form the global wireless Iridium telecommunications network. The multi-billion dollar system will provide global, wireless hand-held telecommunications services, including voice, facsimile, data, and paging via 66 lightweight satellites in low earth orbit. The satellites will be placed in six orbital planes consisting of 11 satellites each, positioned about 778-km 1420-nmi above the Earth, and interconnected via cross links to provide complete coverage of the Earth's surface. Under the agreement, MDA will launch 8 Delta II vehicles with 5 satellites each, thus positioning 40 of the constellation's satellites in orbit.

We have also reached agreement with Space Systems/Loral to orbit a part of the Globalstar systems constellation. Two Delta 7420-10 vehicles launched from VAFB in 1997 will position eight of the required satellites in orbit.

Delta III Program

There is a continuing trend toward heavier, more capable spacecraft and it seems to have leveled off in the 3-3.5-ton category. Although there continues to be a need for the smaller spacecraft (equal to or less than 1.8-ton class), it has diminished, being perhaps 10-15% of commercial communications satellites. Capability up to about 3600-kg/8000-lb enables one to address at least 80% of the world market.

There is considerable world-wide competition in this category, although the domestic competition is limited to the Atlas Centaur. Estimates of the future market vary somewhat widely, as was demonstrated by the 1995 COMSTAC update to the projected GEO commercial mission model, which considered both modest growth and ambitious, vigorous growth models. As reported therein, the world-wide average addressable market varies from about 22 to 35 commercial communications satellites per year.

In early 1995, MDA decided that this marketplace was sufficient to enter with a Delta III candidate. The vehicle would be based on the existing Delta II to the maximum extent possible, and use the same philosophy

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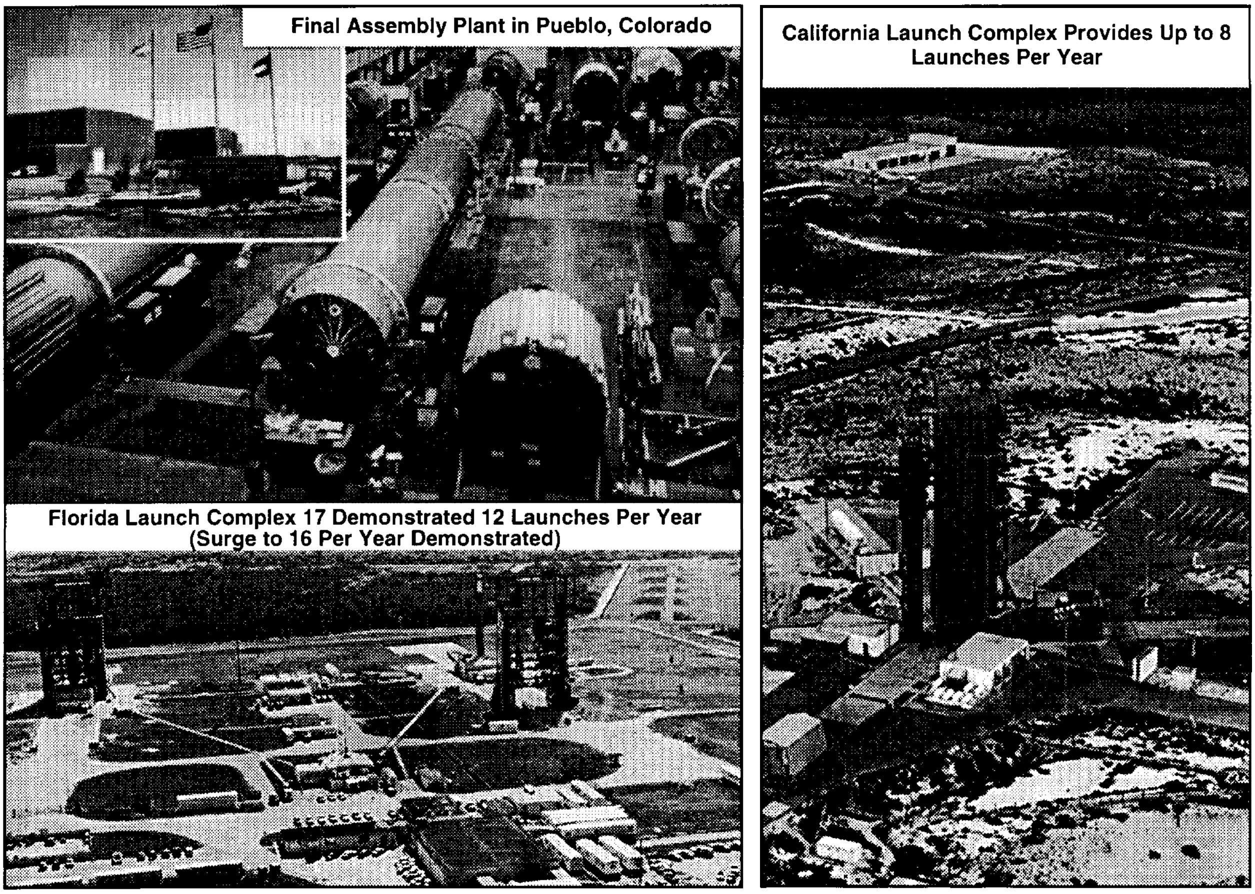

Figure 4. Delta Facilities

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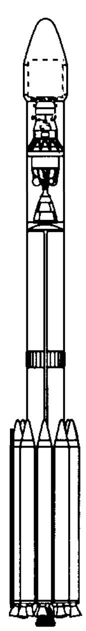


Improvement	Benefits
❑ Redundant Inertial Flight Control Assembly (RIFCA)	Modernized guidance system increases operability and reliability
❑ Flight Termination System (FTS)	Improved range safety compliance, security, and reliability
❑ Telemetry (PCM)	Additional capability to monitor range safety functions and ground station compatibility
❑ Ordnance Thrusters	Improved operability
❑ Extended Nozzles for Air-Lit Motors	Improved performance

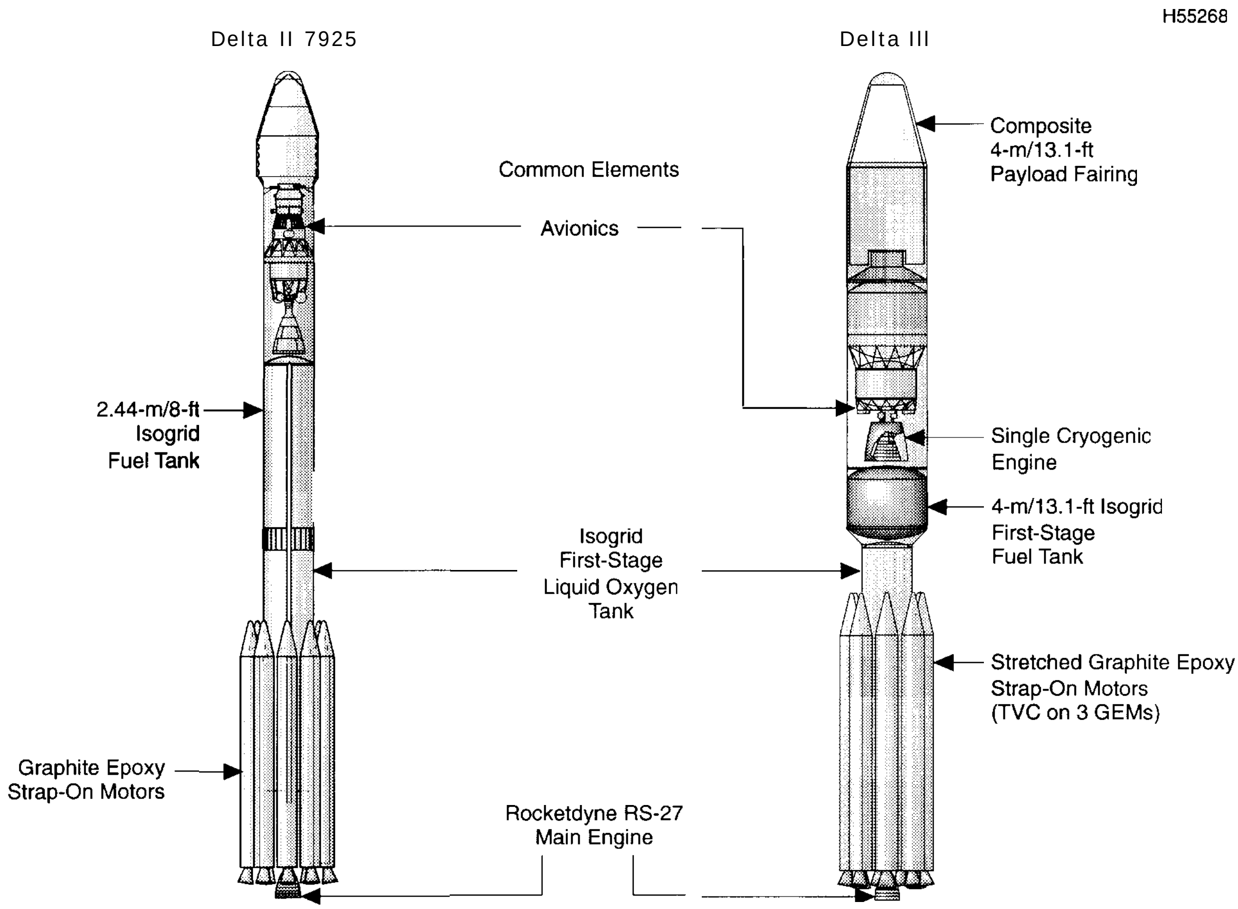
Figure 5. Delta H Improvements Being Implemented

for improvements/upgrades that has been so successful over the years, i.e., maximum use of proven systems and concepts. The heart of the vehicle would be a new, cryogenic second stage. A comparison of the two vehicles is made on Figure 6.

The first stage engine is still the Rocketdyne RS-27A, and nine solids will still be employed, although they will be stretched, larger diameter GEMs, with three of the six ground-lit motors having thrust vector control to aid in controlling the vehicle during flight through the atmosphere. This TVC was demonstrated during GEM static firing in March 1994. The $L0_2$ tank remains virtually the same, but a new fuel tank will be built at the 4-meter diameter, which is the same as the second stage and payload fairing. The new fuel tank will also be of an isogrid construction and will use existing external insulation.

The second stage will be based on existing components and technology; it will use a single Pratt & Whitney RL1OB-2 engine, with extendable exit cone for increased expansion ratio/performance, as well as existing propulsion system components. There will be separate aluminum isogrid tanks, and an existing external insulation will be used to protect the liquid hydrogen. The guidance and control system will be the fully redundant system now being employed on the Delta II, and will be located on a platform below the LO_2 tank as shown on the figure.

A new, 4-meter diameter composite fairing will be employed to protect the payloads during flight through



Delta II 7925	
GTO Payload (kg/lb)	1870/4120
LEO Payload (kg/lb)	5140/11,330

Delta III	
GTO Payload (kg/lb)	3810/8400
LEO Payload (kg/lb)	8160/18,000

Figure 6. Delta III Configuration

the atmosphere. This fairing is based on the same technology developed for the current Delta II 3 composite fairing. It provides a dynamic envelope of 3750-mm/ 147.6-in.

The planned production flow for the Delta III (Figure 7) is much the same as that for the current Delta II. Production will take place primarily at Huntington Beach, CA with some at the Monrovia facility. Assembly will be done at the Pueblo, CO facility. Integration of systems and system checks will be done at the launch site. The payload will be encapsulated in the fairing, and the entire assembly transmitted to the pad for installation on the erected vehicle. One of the two pads at Launch Complex 17 will be modified for Delta II/III dual use. A new liquid hydrogen tank farm will be required, as well as a modified fixed umbilical tower (FUT) and a modified mobile service tower (MST). The resulting facility will be capable of both Delta II and Delta III launch operations.

The planned encapsulation concept will provide increased payload security, physical safety and contamination control. It will also minimize on-pad operations and timelines, provide enhanced launch-on-need and launch-on-demand capabilities, and provide rapid payload changeout capability. Based on single shift operations, the processing plan is anticipated to involve 25 work days on the pad, from the initiation of vehicle erection to launch.

The mission sequence for the Delta IIII vehicle will be quite similar to that of the Delta II. A lofted flight profile will be used to reduce aerodynamic flight environment. The thrust-time history of the GEM LDXL solid rocket motors has been designed to reduce the Delta II flight environment (dynamic pressure, aero heating, and axial acceleration) to levels at or below those of the Delta II. At maximum GTO payload weight, an axial acceleration at MECO of just under 7 g's is expected.

The initial Delta III customer is Hughes Space and Communications International Inc. In March 1995, we entered into a commercial launch services contract with Hughes for ten firm launches plus options. The launch period was specified as 1998 to 2002, with an option period extending until 2005. The first launch is programmed for the first half of 1998.

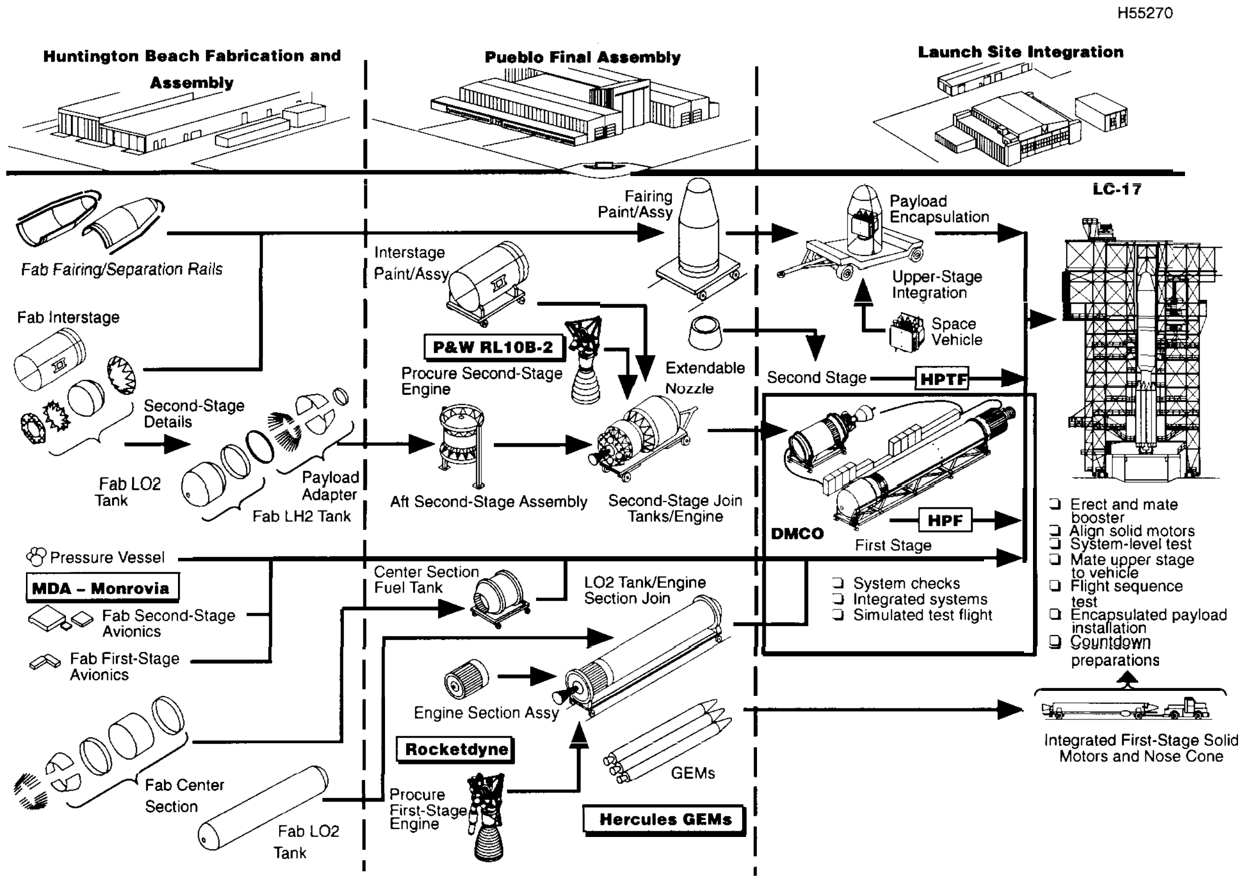


Figure 7. Delta III Production Flow

Med-Lite

Another market need is to create capability between that of the Pegasus XL and the Delta vehicles. This constitutes a substantial gap. NASA saw a pressing need in that range, and initiated the Medium-Light Expendable Launch Vehicle, or Med-Lite, procurement late last year. In this way space science and planetary spacecraft could be reduced in size and cost. They could be built “faster, better, cheaper.” The procurement was targeted for five missions, beginning in 1998, with options for up to nine additional flights. The first three missions were planned to be the Far Ultraviolet Spectroscopic Explorer (FUSE), a Mars Orbiter and a Mars Lander. The contract would be for launch services, but would also involve NASA oversight of the payload interface, integrated tests, and launch. A standard order would be 30 months leadtime. Launches would be required from both coasts.

MDA was selected for award in March 1995; contract negotiations were initiated shortly thereafter. The concept proposed would use a Taurus vehicle for the lower end of the mission spectrum, and a down-sized Delta II vehicle for the upper range (see Figure 8). This latter configuration would only employ three strap-on solid motors instead of the usual nine. In this way the family will cover the entire range of NASA requirements.

The first launch under the Med-Lite contract is the FUSE mission scheduled for October 1998 on a Delta 7325. The Mars Orbiter-2 and the Mars Lander- 1 missions are programmed for December 1998 and January 1999, respectively, on Delta 7325 vehicles. We are proposing an initial operational capability (IOC) date of second quarter 1998, so commercial missions could precede the NASA missions if an opportunity arises.

Summary

McDonnell Douglas Aerospace is now in a position to offer launch services over a wide range of capabilities through its Med-Lite, Delta II and Delta III. The Delta II has an unsurpassed record of providing reliable service. This heritage has been used to the maximum extent possible to assure similar service from the other members of the family.

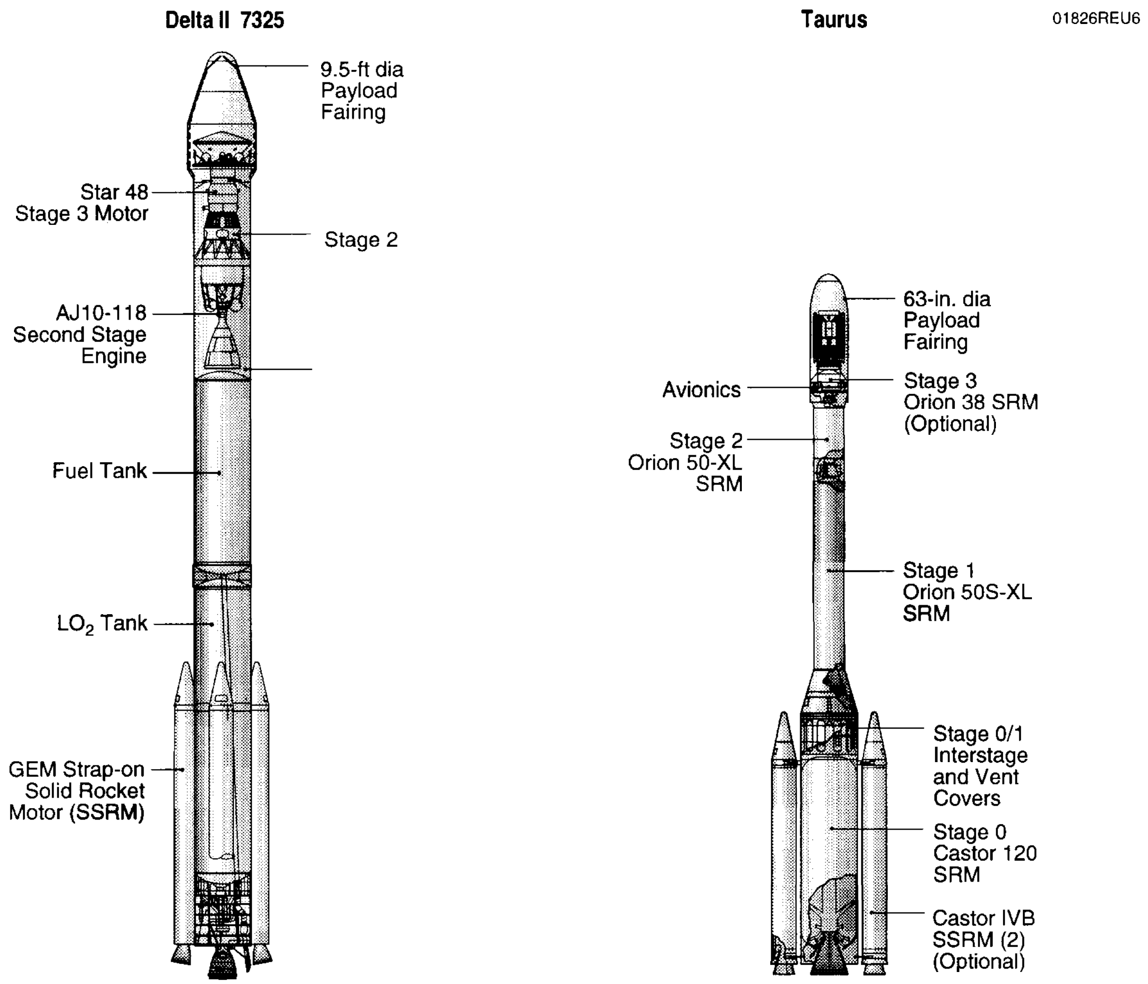


Figure 8. Med-Lite Launch Vehicles