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The Delta Launch Vehicle- Past, Present, and Future

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INTRODUCTION

The Delta launch vehicle is a medium class expendable booster managed by the NASA Goddard Space Flight Center and used by the U.S. Government, private industry and foreign countries to launch scientific, meteorological, applications and communications satellites. It has been operational since 1960 and currently has launches scheduled through the 1985 time period. This paper presents a summary of Delta history, its current vehicle configuration, the various modifications underway to satisfy ever-increasing payload performance demands and a look into additional uprating possibilities to meet potential future requirements.

HISTORICAL ROLE OF DELTA

On May 13, 1960, the first of what would become the most utilized non-military U.S. launch vehicle lifted off from the Eastern Test Range. Delta's first payload was Echo I, a low-altitude passive communications satellite, weighing 81.6 Kg (179 lbs); however, this launch was not successful. On November 15, 1980, Delta No. 153 placed SBS-A, an active communications satellite weighing 1085 Kg (2388 lbs) into a geosynchronous transfer orbit. During the intervening 20 year period, a remarkable launch record has been established by the Delta launch vehicle in terms of increased vehicle physical size, improved reliability, minimal cost increase and outstanding payload performance improvement.

The origin of Delta dates back to 1955 when the U.S. Air Force initiated development of the THOR Intermediate Range Ballistic Missile (IRBM) and the U.S. Navy was developing the Vanguard launch vehicle to be used during the International Geophysical Year. In 1959 the Douglas Aircraft Company (now the McDonnell Douglas Corporation) was given a contract by NASA's Goddard Space Flight Center to develop, integrate and produce 12 launch vehicles for use as an "interim space launch vehicle." The THOR was to be modified for use as the first stage, the Vanguard second stage propulsion system was used as the Delta second stage and the Vanguard solid rocket motor became Delta's third stage. Following the eighteen month development program and failure to launch its first payload into orbit, a remarkable series of successful missions established the Delta as a highly reliable launch vehicle. A follow-on buy of 14 vehicles of greater boost capability continued the production line. The ensuing years proved to be examples of excellent management and technological skill as the Delta Program flourished. The payload performance capability increased by steady increments to satisfy the ever-increasing weight requirements of new spacecraft. Originally the U.S. Weather Bureau provided the demands for increased orbit energy. The scientific community also demanded an increase in booster capability. Then the communications satellites became, and are presently, the predominant influence in demanding greater payload volume and weight capability from the Delta launch vehicle. By emphasizing a low-cost program philosophy utilizing various cost-effective techniques, the actual increase in cost was only a fraction of the payload performance increase. Simultaneously the emphasis on using previously qualified systems during vehicle uprating and designing redundancy into new systems kept the launch reliability at an unprecedented high level.

A summary of some of the significant modifications to the original Delta is shown in Table I. Figure 1 graphically illustrates the vehicle configuration evolution. Note the numerous examples of the use of "existing" systems and components in this building block approach to uprating. The payload capability growth associated with these vehicle modifications is depicted in Figure 2. Table II illustrates the variety of spacecraft launched to date. Of the 153 Delta launches, 142 have been successful so that the overall reliability is now 92.8 percent (Figure 3).

TABLE I.

GROWTH HISTORY OF DELTA

YEAR	FAIRING	FIRST STAGE	SECOND STAGE	THIRD STAGE	DELTA MODEL DESIGNATION
1960		Modified THOR	Vanguard prop. system	Vanguard X-248	Delta
1962		Uprated MB-3 engine			A
1962			Lengthened tankage Higher energy oxidizer Transistorized guidance elect.		
1963	Bulbous fairing			Scout developed X-258 replaced X-248	C
1964		Augmented thrust using THOR developed strap-on solid rocket motors			D
1965	Larger fairing from USAF Agena stage		Larger diameter propellant tanks from the Able-Star stage. Restart capability	USAF developed FW-4 replaced X-258	E
1968				Surveyor retro-motor modified. TE-364-3 replaced FW-4	J
1968		Lengthened LOX and RP-1 tanks. Increased dia. of RP-1 tanks			L,M.N
1970		Added 3 solid rockets to total 6			M6
1972		Introduced UBT to accommodate 9 solid rockets	Titan transtage engine. Strap-down inertial guidance		903
1972	Increased dia. and length	Increased length of tanks. Isogrid structure	Added interstage and suspended stage within	Increased motor length TE-364-4	1914
1973		Replaced MB-3 engine with more powerful RS-27 engine			2914
1975		Increased size of solid rockets. C-IV replaced C-II			3914

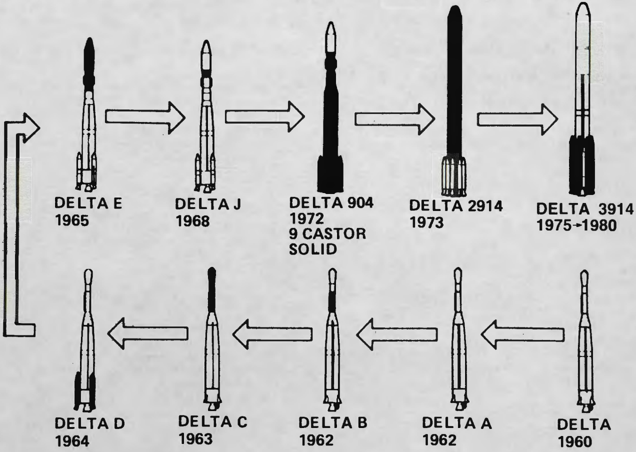

FIGURE 1. DELTA VEHICLE HISTORY

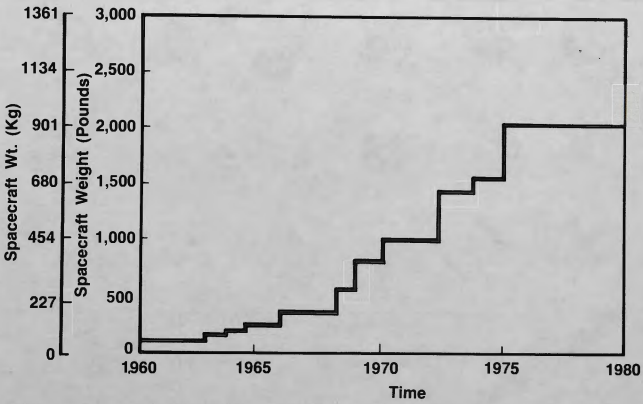

FIGURE 2. DELTA PERFORMANCE HISTORY (GEOSYNCHRONOUS TRANSFER MISSIONS)

TABLE II.

SPACECRAFT LAUNCHED BY DELTA

Meteorological Satellites

- Improved TIROS Operations System (ITOS) series
- Nimbus series
- Synchronous Meteorological Satellite (SMS) series
- ESRO Meteosat
- Japanese Geosynchronous Meteorological Satellite (GMS)
- TIROS-N series
- Geosynchronous Operational Environmental Satellite (GOES) series

Applications Satellites

- Relay series
- Syncom series
- LANDSAT series
- Canadian/U.S. Communication Technology Satellite (CTS)
- Italian SIRIO
- ESRO Orbital Test Satellite (OTS)
- Earth Resources Technology Satellite (ERTS)
- Japanese Broadcast Satellite (BSE)
- ISEE series

U.S. Domestic Communications Satellites

- Telstar series
- Western Union (WESTAR) series
- COMSAT Maritime Satellite (MARISAT) series
- Satellite Business Systems (SBS)
- RCA SATCOM series

Scientific Satellites

- Explorer series
- Pioneer series
- BIOS series
- ESRO-GEOS
- Aeronomy Explorer (AE) series
- Interplanetary Monitoring Platform (IMP) series
- ESRO COS-B
- LAGEOS
- GEOS series (NASA)
- Solar Maximum Mission (NASA)
- Orbiting Solar Observatory (OSO)
- International Ultraviolet Explorer (IUE)
- SCATHA (USAF)

Foreign Communications Satellites

- Canadian TELESAT series
- French/German SYMPHONIE series
- NATO II and III series
- Japanese Communication Satellite (CS)
- United Kingdom Skynet series
- Indonesian (PALAPA) series

International Communications Satellites

- INTELSAT II series
- INTELSAT III series

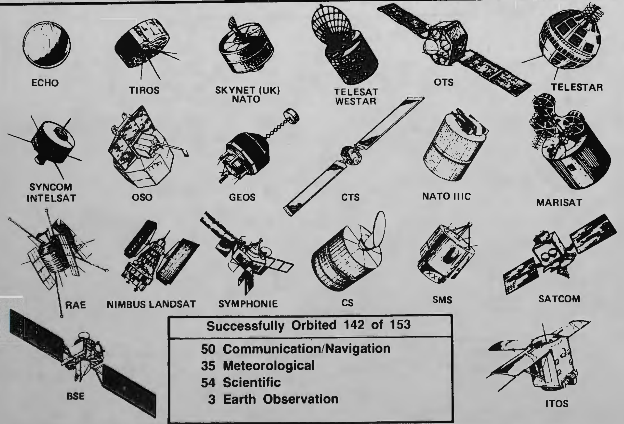

FIGURE 3. DELTA LAUNCH HISTORY 1960 THRU 1980

DELTA TODAY

As in the past 20 years Delta continues to play an important role in NASA's launch vehicle planning activities. The delay of the reusable Space Shuttle has provided an increased importance to the expendable Delta as an alternate NASA back-up launch capability. In addition, due to the continually expanding requirements from the scientific and communications satellite communities Delta is providing dedicated launch opportunities for the overflow from the Shuttle manifests.

The configurations of the Delta which are currently being utilized are primarily the models 3914 and 3910/PAM. The nomenclature used to define Delta configurations is shown in Figure 4. While the PAM has been developed by the McDonnell Douglas Astronautics Corporation and is not part of the Delta, it is used as a third stage of the two-stage 3910 Delta configuration. Overall the vehicle is 116 feet long, 8 feet in diameter, and weighs approximately 422,000 lbs. at liftoff. A brief description of vehicle subsystems is included below, (Reference Figure 5).

Structural Systems

The vehicle consists of five major assemblies: first stage, interstage, second stage, third stage, and fairing. The first stage has an engine compartment which houses the main engine, vernier engines, pressurization and electrical subsystems, and provides the attachments for the strap-on solid propellant motors. A liquid oxygen tank, a centerbody equipment compartment and a fuel tank complete the first stage. The interstage extends from the top of the first stage to the second stage mini-skirt. The second stage includes the main engine, propellant tanks, pressurization and attitude control systems, and guidance and electrical systems. The second stage is entirely encapsulated within the interstage and the lower portion of the payload shroud (referred to as the fairing), and is structurally supported by the mini-skirt and support cone. The mini-skirt houses the main umbilical connector and antennas. The third stage solid propellant motor (if used) is

- **Four-Digit Designator –**

1st Digit – Type of Augmentation/First Stage
2nd Digit – Quantity of Augmentation Motors
3rd Digit – Type of Second Stage
4th Digit – Type of NASA Third Stage

e.g. Delta 3914

Note: When PAM is Used, 4th Digit is Zero and PAM is Added to Designator, i.e, 3910/PAM

- **Numbers Used as Designators**
  - **First Digit:** **2 – Castor II Augmentation, Extended Long Tank**; **3 – Castor IV Augmentation, Extended Long Tank**
  - **Second Digit:** **3 – Three Motors**; **9 – Nine Motors**
  - **Third Digit:** **1 – Standard 2nd Stage (10,000 Lb Prop., TRW LEM-D Engine)**; **2 – Uprated 2nd Stage (13,200 Lb Prop., AJC ITIP Engine)**
  - **Fourth Digit:** **0 – No NASA Third Stage**; **3 – TE-364-3 Third Stage (1,440 Lb Propellant)**; **4 – TE-364-4 Third Stage (2,300 Lb Propellant)**

FIGURE 4. DELTA LAUNCH VEHICLE DESIGNATIONS

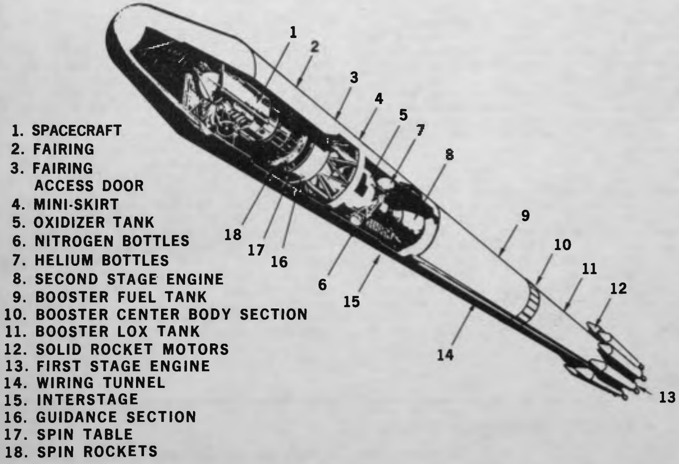

FIGURE 5. DELTA LAUNCH VEHICLE

mounted on the spintable and the spacecraft is connected to the third stage motor using any one of several spacecraft attach fittings. For two-stage configurations the spintable and third stage are not required and either the spacecraft attach fitting or the PAM spintable mounts directly onto the forward end of the second stage. The payload fairing encloses the spacecraft, third stage assembly and a portion of the second stage during the flight through the sensible atmosphere. It is jettisoned shortly after second stage ignition.

Propulsion Systems (Ref. Figure 6)

The first stage includes as its main engine the Rocketdyne RS-27 single start liquid bipropellant (RP-1 and liquid oxygen) rocket with a thrust rating of 207,000 lbs. at sea level. Two vernier engines provide roll control. Thrust augmentation solid rocket motors attach to the lower part of the structure which is designed to accommodate up to nine Castor II or Castor IV motors. Each Castor IV motor develops 85,000 lbs. average thrust at sea level. The second stage uses the pressure-fed TRW TR-201 liquid bipropellant rocket with fixed calibrated thrust and multiple restart capability. The engine is rated at 9,825 lbs. thrust; propellants are N_2O_4 as oxidizer and a mixture of 50 percent UDMH/50 percent Hydrazine as fuel. Gaseous helium is used for pressurization. A nitrogen cold gas jet system provides pitch, yaw and roll control during coast periods and roll control during powered flight. The main engine thrust chamber assembly is gimballed for pitch and yaw control during powered flight.

The third stage uses the Thiokol TE-364-3 or TE-364-4 solid propellant rocket motor delivering nominal thrusts of 10,000 and 15,000 lbs., respectively. Total impulses of 418,000 lb-sec and 654,000 lb-sec are delivered by these motors. The third stage and spacecraft are spin stabilized during third stage powered flight and coast phases. Spin rockets in combinations up to a total of eight (depending on spacecraft roll moment of inertia) are used to impart the desired spin rate.

■ **Third Stage**	
• **Motor**	**Thiokol TE-364-4 (Solid Propellant)**
• **Control**	**Spin-Up**
• **Fairing**	**8-Ft (2.44 M) Diameter**
■ **Second Stage**	
• **Airframe**	**8 Ft (2.44 M) Diameter**
• **Tankage**	**4.5 Ft (1.39 M) Diameter**
• **Engine**	**TRW TR-201** **9,825 Lb Thrust**
• **Propellants**	**N_2O_4/Aerozine 50**
• **Control**	**Gimbal/Cold Gas**
• **Guidance**	**Inertial**
■ **First Stage**	
• **Airframe**	**8 Ft (2.44 M) Diameter**
• **Engine**	**Rocketdyne RS-27** **207,000 Lb Thrust**
• **Propellants**	**LOX/RP-1**
• **Control**	**Gimbal/Verniers**
• **Guidance**	**Inertial**
• **Solid Augmentation**	**9 Thiokol Castor IV Motors (85,000 Lb Thrust Each)**

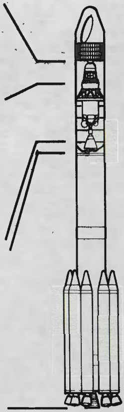

FIGURE 6. DELTA 3914 VEHICLE PROPULSION AND G&C SYSTEMS

The PAM stage uses the Thiokol STAR-48 solid propellant rocket motor which delivers 15,000 lbs. of nominal thrust and 1,268,500 lb-sec of total impulse.

Guidance and Control Systems

Guidance and control equipment is housed in the forward section of the second stage and provides guidance, sequencing and stabilization signals for both first and second stages. The guidance system is a strap-down all-inertial unit consisting of a Delta Redundant Inertial Measurement system (DRIMS) which contains three gyros, four accelerometers and conditioning electronics, and a guidance computer (GC). The computer processes the DRIMS data to obtain attitude reference and navigation (position and velocity) information, and it provides continuous guidance correction signals based on a comparison of the instantaneous orbit to the desired mission orbit. The computer also issues pre-programmed sequence commands and provides control system stabilization logic for both powered and coast phases of flight.

First and second stage electronic packages receive the guidance commands from the guidance computer in the second stage and in turn drive the servo amplifier for engine gimbal and the swtich amplifier for control jet (vernier or gas jet) operations.

Electrical Power Systems

A battery supplied DC power system is used in both the first and second stages. Separate batteries are used for the control and guidance systems, the engine and ordnance systems, and the instrumentation systems.

Telemetry Systems

S-band telemetry systems are similar for the first and second stage, each combining the use of pulse duration modulation and frequency modulation (PDM/FM/FM and FM/FM). Frequency assignments may be varied to provide system compatibility for individual range operations. The second stage telemetry also provides one PCM/FM/FM channel for input and monitor of guidance parameters. When a third stage is employed, a telemetry set is used on the payload attach fitting for monitoring third stage parameters.

Range Safety and Tracking Systems

Command destruct receivers on the first and second stages are tuned to the same frequency and respond to the same RF modulated signal from the ground transmitting station. Dual command destruct systems are installed in the second stage. A C-band beacon is provided for range tracking.

Operational Capability

With respect to mission operational capability Delta is extremely versatile. Single burn or multiple restarts of the second stage permit using direct ascent or Hohmann transfer flight modes for two-stage missions, or provide the flexibility required to locate injection at any specific geographic location for three-stage missions. The second stage separates the payload from a three axis stabilized platform. A low spin rate can be imparted at separation if desired. Attitude maneuvers may be performed during coast phases to accommodate spacecraft restraints such as solar heating or sensor viewing limitations. Also, liftoff time may be precisely controlled to meet specific mission objectives. Much of this versatility was developed as a result of spacecraft user demands as the Delta evolved during its long history.

PAYLOAD ASSIST MODULE

Origin

The advent of Shuttle promises an economical capability to carry large and heavy payloads into low-earth orbit; the problem remaining is to transfer and circularize the satellites in their final geostationary orbit. This need for upper stages prompted a wide-ranging series of studies during the Shuttle conceptual phase, covering the adaptation of existing stages and the development of new stages and systems. One of these candidates was the PAM (also called the Spinning Solid Upper Stage, or SSUS), which was initially conceived by McDonnell Douglas Astronautics Company to provide an orderly transition from the Delta ELV to the Shuttle for medium-class payloads. This system, known as PAM-D for Delta-class missions, was originally proposed for the Tracking and Data Relay Satellite system. Although this proposal was not successful, it did lead to an agreement with the National Aeronautics and Space Administration for McDonnell Douglas to develop the system on a commercial basis and provide it to users in this payload class. This system had the additional advantage of being adaptable to either an STS or a Delta launch, thereby providing the users with a backup capability in case the Shuttle was not available to support their launches.

A larger PAM system, designated PAM-A, is also currently under development to support larger (Atlas/Centaur) class payloads.

Systems Description

The PAM-D system elements are shown in Figure 7, along with their assembled configuration for the respective ascent vehicles. The PAM-D can be employed with either the Shuttle or the Delta ELV as the ascent vehicle. For Shuttle use, each system has a deployable (expendable) stage consisting of a spin-stabilized solid-rocket-fueled motor, a payload attach fitting (PAF) to mate with the spacecraft, and the necessary timing, sequencing, power, and control assemblies mounted on the PAF. The reusable Airborne Support Equipment consists of the cradle structure for mounting the deployable system in the Shuttle, a spin system to provide the

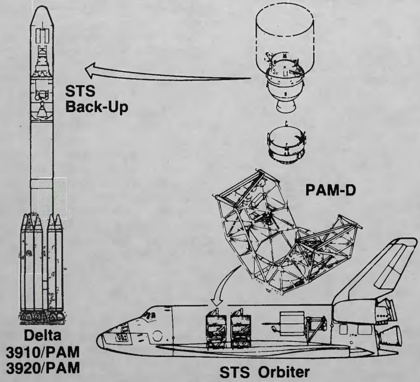

FIGURE 7. MDAC PAYLOAD ASSIST MODULE

stabilizing rotation, a separation system to release and deploy the stage and spacecraft, and the necessary avionics to control, monitor, and power the system. The PAM-D will also provide a sun-shield for thermal protection while the Orbiter bay doors are open.

The PAM-D stage is supported through the spin table at the base of the motor and through forward restraints at the PAF. The forward restraints are retracted before deployment.

When the PAM-D is used with a Delta ELV, the spacecraft interface remains the same and certain changes are made to the PAM-D stage. The forward restraint fittings are removed, the standard Delta confined detonating fuze (CDF) is employed for sequencing, and the spin table is configured to mount to the Delta second stage and accommodate spin rockets for rotation. The common hardware is shown in Figure 8.

The PAM-D expendable vehicle hardware consists of the Thiokol STAR-48 solid rocket motor, the payload attach fitting, and its functional systems. The STAR-48 motor, shown in Figure 9, features a titanium case, 89 percent solids HTPB propellant, a toroidal pyrogen ignition system, a 3-D carbon-carbon throat insert, and a carbon-carbon exit cone. Fully loaded (4400 lb. propellant) and off-loaded (3833 lb. propellant) configurations are being qualified. Total impulse of the motor is 1,268,500 lb-sec with an action time of 85.3 sec.

Figure 10 depicts how the PAM-D stage is interchangeable with the existing standard 3914 TE-364-4 third stage. By removing the TE-364-4, the two stage Delta is referred to as the 3910 configuration. Addition of the PAM creates the 3910/PAM configuration.

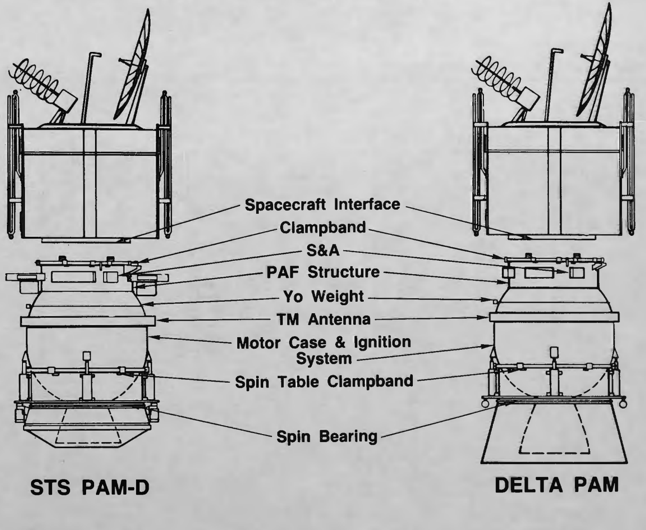

FIGURE 8. COMMON HARDWARE — STS PAM-D AND DELTA PAM

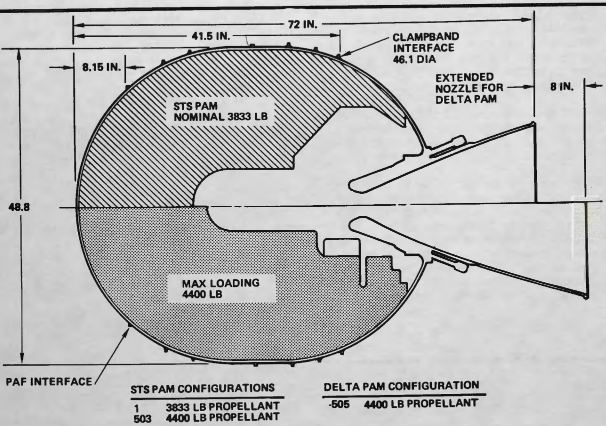

FIGURE 9. PAM-D MOTOR CONFIGURATIONS

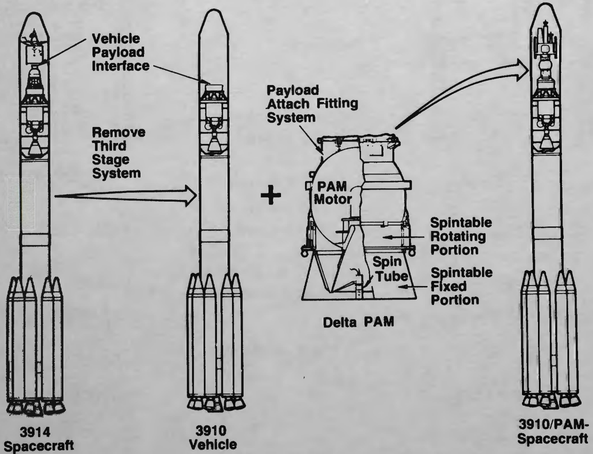

FIGURE 10. STANDARD DELTA AND 3910/PAM RELATIONSHIPS

3920 IMPROVED SECOND STAGE

Origin

In mid-1979 it became apparent that the expendable-to-Shuttle transition time would increase over that previously planned. This required not only more Delta launches, but improved performance for the communications and scientific satellites then being designed to take advantage of the Shuttle payload capability. Additionally, the LANDSAT-D project was having increasing difficulties meeting the 3910 payload capability, thereby creating a need for additional Delta performance. LANDSAT-D, with a scheduled launch date of mid-1982, therefore served as the impetus to increase the Delta performance again in a timely and economical manner.

Aerojet Services Company had designed and developed a new second stage for the Japanese N-II launch vehicle, utilizing the Titan transtage engine with increased tankage delivering more optimum performance. Additionally, the Air Force had funded a development program to increase the performance of the F injector called the Improved Transtage Injector Program (ITIP). It was decided to utilize the improved ITIP engine and adapt it to the existing N-II stage tanks along with usage of Delta 3910 second stage common components where possible. This was the basis for the new Delta 3920 Improved Second Stage (ISS). The resulting Delta launch vehicle configuration, when used with the PAM, is referred to as the 3920/PAM (Figure 11).

Systems Description

The new stage has the same overall length, 19.6 feet, with structural mounting provisions within the existing interstage. The tank diameter was increased from 54.5 in. to 68.8 in., and the guidance section and mini-skirt assemblies have been strengthened to accept the greater loads. The equipment panel has been redesigned to an isogrid configuration attached to the aft tank section with the helium spheres moved inboard and forward. As can be seen in Figure 12, the propellant capacity was increased from 10,072 lbs. to 13,200 lbs., and the total impulse was increased from 3.04×10^6 lbs. sec. to 4.2×10^6 lbs. sec. Both engines are pressure fed.

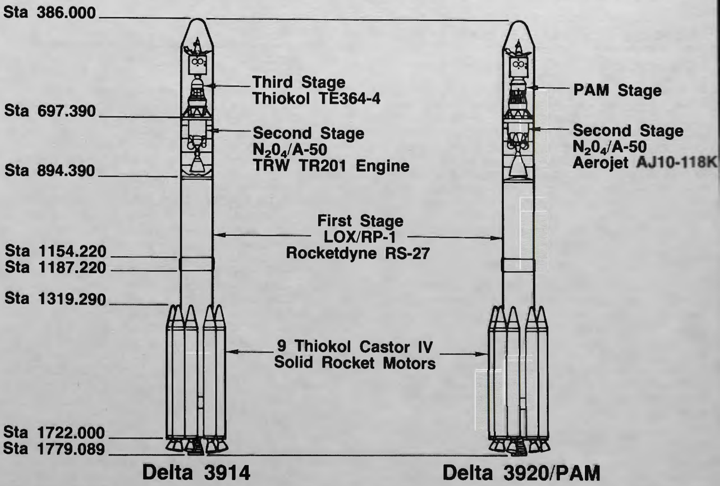

FIGURE 11. DELTA LAUNCH VEHICLES COMPARISON

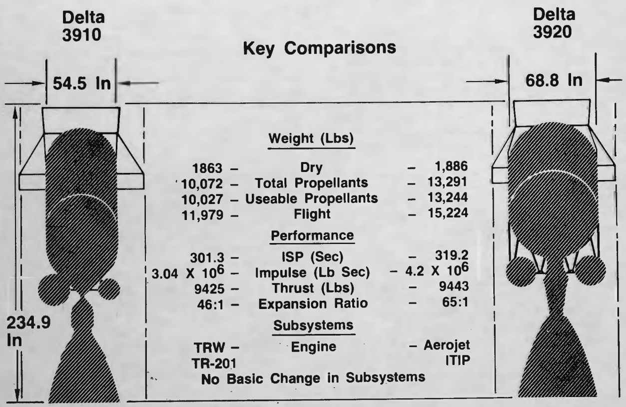

FIGURE 12. DELTA 3920 CONFIGURATION IMPROVED SECOND STAGE

Stage Description

An isometric cutaway view of the 3920 ISS is shown in Figure 13. As in all past Delta upgrades previously qualified subsystems have been used, where possible, in the interest of economy and reliability. The RACS, hydraulic system, and pneumatic system are as used on the 3910 second stage. Additionally, redundant features previously developed were employed; e.g., dual coil TSPV and actuator pots. The Aerojet supplied new hardware are the tank, ITIP engine, and the nitrogen and helium pressure vessels.

Program Status

The 3920 Improved Second Stage development is on schedule with a launch readiness date of April 30, 1982. The first mission is LANDSAT-D, presently scheduled for July 1982. The critical engineering release and structural subassembly fabrication dates have been met. As shown by Figure 14, the first tank and first engine delivery has slipped, but work-arounds have been developed, and the remaining milestones are expected to be met.

OTHER PERFORMANCE IMPROVEMENTS

In addition to the current major vehicle modifications described above, two other operational changes have been introduced to further enhance performance capability.

Suborbital Flight Mode

During the 3910/PAM development it was recognized that the full capability of the third stage could not be utilized if the second stage was injected into transfer orbit as is the case for the 3914 configuration. Payload performance optimization studies indicated that a sub-orbital second stage flight mode was more efficient than flying the third stage with a significant propellant offload. The flight profile results in a second-stage re-entry into the Atlantic Ocean off the West Coast of Africa. For this type of flight mode, payload capability to various geosynchronous transfer orbits is extremely sensitive to both vehicle and Range Safety constraints, thereby necessitating parametric optimization studies for each mission to maximize payload. When the Improved Second Stage is used (i.e., the 3920/PAM configuration) with its additional impulse capability, the optimum payload is again obtained by injecting the second stage into parking orbit as is done with the 3914 configuration.

Solid Motor Firing Sequence

Another payload performance increase is obtained by an alternate sequencing of firing of the solid rocket boost assist motors. Rather than igniting only 5 of the 9 motors at liftoff and then 4 "at altitude," the sequence change ignites

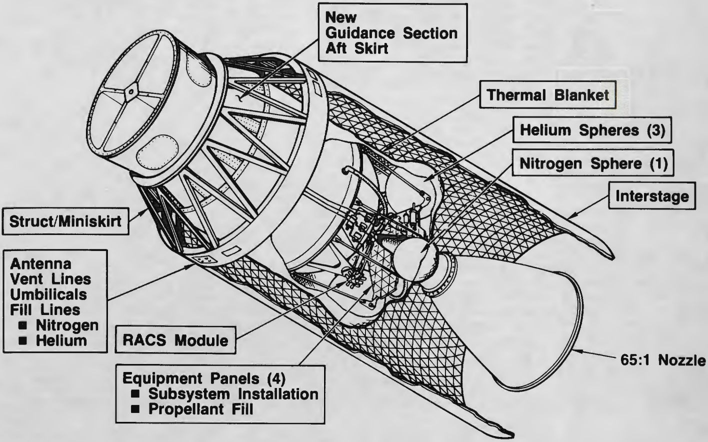

FIGURE 13. DELTA 3920 IMPROVED SECOND STAGE

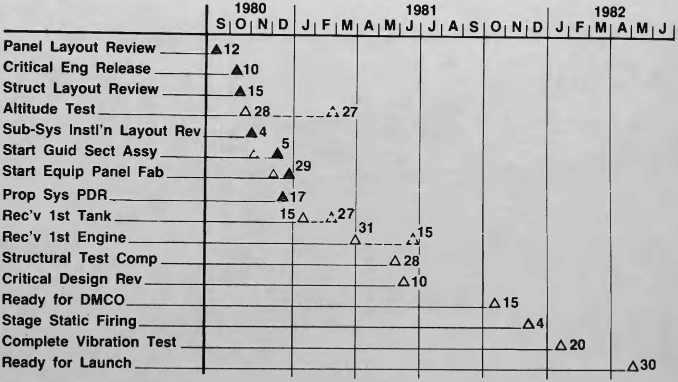

FIGURE 14. 3920 IMPROVED SECOND STAGE PROGRAM MILESTONES

6 motors on the pad and 3 at altitude. The increase in allowable spacecraft weight to geosynchronous transfer orbit resulting from this change is shown in Figure 15. These values incorporate the slight increase in launch vehicle weight required to accommodate the sequence change. Primarily, additional thermal insulation was required in the booster boattail section and solid motors due to increased base heating. This heating increase results from stronger plume interaction and change in firing and drop sequences.

Performance Capability Comparison

Summarizing the results of the recent vehicle modifications described in the foregoing paragraphs, it is seen that significant gains have been made in Delta's performance capability. The introduction of PAM increased the synchronous transfer weight capability by 174 Kg from 937 Kg (2065 lbs) to 1111 Kg (2450 lbs.). Using the improved second stage provided another significant increase of 159 Kg bringing total capability to 1270 Kg (2800 lbs.). (See Figure 16) The payload weights shown are all based on using a 6-3 solid rocket firing sequence. Incorporating these values into the performance history curve of Figure 2 shows the continuing growth of the 1960 era "interim space launch vehicle." (Figure 17)

Launch Operations

In addition to the launch vehicle developments underway, modifications to the launch facility at the Eastern Test Range have been initiated. As will be described in the following section, the schedule for Delta is based upon a rate of 10 launches per year. This increased demand has prompted NASA to authorize the reactivation of the second Delta launch pad (Pad 17B). The modifications required are primarily directed toward the accommodation of the Castor IV solid motor strap-ons, strengthening decks, enlarging cutouts and increasing lifting hoist capacity. These changes, currently underway, are scheduled for completion by January 1982.

	Spacecraft Weight*			
	5-4 Sequence		6-3 Sequence	
	Kg	Lbs	Kg	Lbs
Delta 3914	916	2020	937	2065
Delta 3910/PAM	1084	2390	1111	2450
Delta 3920/PAM	–	–	1270	2800

*Standard Geosynchronous Transfer Orbit

FIGURE 15. EFFECT OF SOLID ROCKET FIRING SEQUENCE

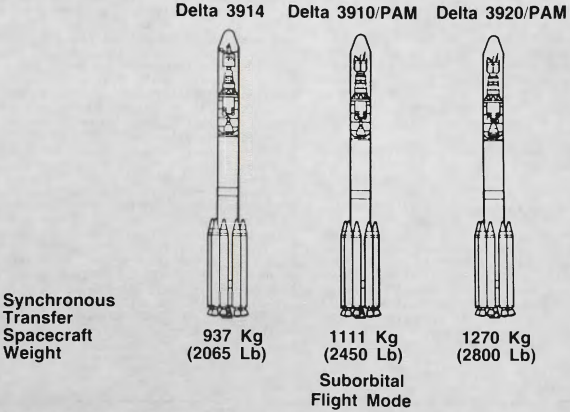

FIGURE 16. COMPARISON OF CAPABILITY-UPRATED CONFIGURATIONS

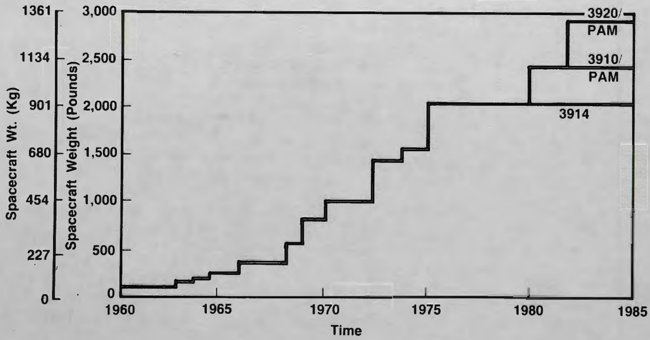

FIGURE 17. DELTA PERFORMANCE HISTORY (GEOSYNCHRONOUS TRANSFER MISSIONS)

THE FUTURE OF DELTA

The near term future of the Delta launch vehicle is best shown by the current NASA launch schedule illustrated in Figure 18. Of the 43 missions presently planned, 67% are firm Deltas and 33% are Space Shuttle backups. It should also be noted that 33 of the planned 43 missions include the use of the PAM upper stage. In addition to the current baseline schedule shown, several potential users have been identified and are listed in Figure 19. The primary future utilization of Delta is in the field of geosynchronous communication satellites.

Looking further into the future, it is anticipated that as spacecraft grow in weight for the next generation of satellites, they may also require a larger spacecraft envelope. To date there are no firm requirements by the government or commercial users to upgrade the Delta capability to meet any projected weight and volume requirements. There are several options available, however, to provide additional Delta capability. (See Figure 20). Combinations of these "building blocks" are also possible. Take, for example, a vehicle growth concept which has been recently evaluated by MDAC which incorporates a larger payload volume for the spacecraft with additional transfer orbit throw weight capability up to 3000 pounds. This concept, designated the Delta 4920 configuration (Figure 21) utilizes the MDAC produced Titan IIIC 10-foot diameter fairing design and a 12-foot lengthening of the booster to provide additional propellant loading. All other elements of the vehicle are essentially the same as the current 3920/PAM configuration with some minor structural modifications to accept the higher loads. The 10-foot diameter fairing (Figure 22) uses a Titan IIIC nose module, two Titan IIIC intermediate modules, and a new base module which adapts to the 8-foot diameter interface. The internal dynamic envelope available to the user is 108 inches in diameter and 156 inches in height. Missions which are designed for the STS using a PAM-D are required to maintain a maximum vertical height of 101 inches. As seen in the Figure, this height is easily accommodated in the fairing design for STS missions requiring a Delta backup. Spacecraft flying a dedicated Delta mission can use the additional vertical height for larger antenna configurations.

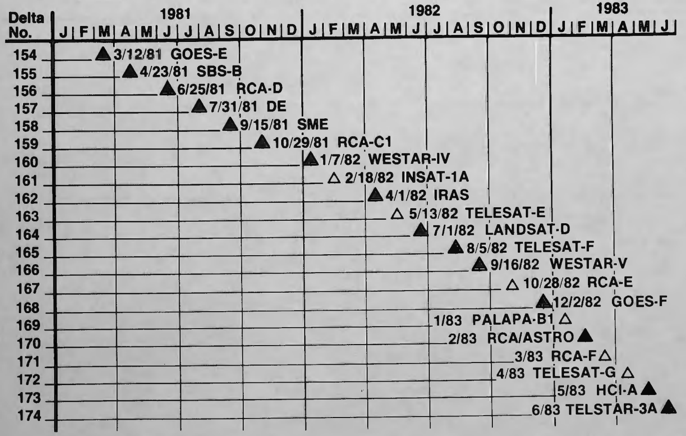

FIGURE 18. DELTA PROJECT MASTER SCHEDULE FEBRUARY 1981 (1 of 2)

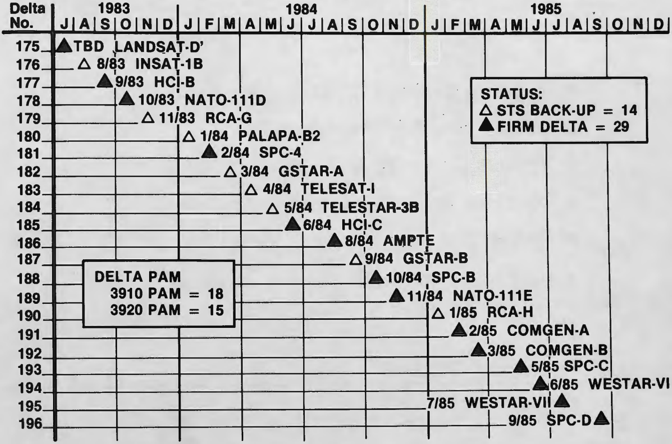

FIGURE 18. DELTA PROJECT MASTER SCHEDULE FEBRUARY 1981 (2 of 2)

Arab League Australia Brazil Columbia, S.A. Luxembourg Mexico PRC (China) Switzerland	Domestic Communications
NOAA GOES-G GOES-H GOES-I	Meteorological
NASA (Open Satellite)	Scientific

FIGURE 19. POTENTIAL USERS OF DELTA

- Upgrade Booster RS-27 Engine Performance
- Stretch Booster Propellant Tanks
- Stretch Castor IV Solid Motors
- Upgrade Second Stage Performance
- Larger Diameter Payload Fairing
- Upgrade PAM Solid Motor Performance

FIGURE 20. FUTURE DELTA GROWTH OPTIONS

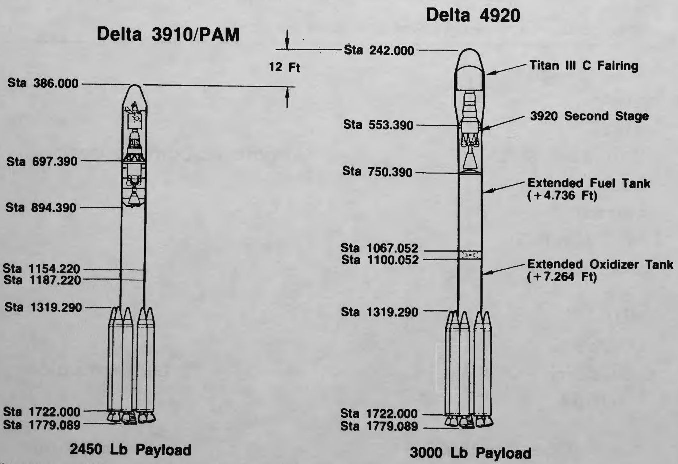

FIGURE 21. DELTA 4920 CONFIGURATION (CONCEPTUAL)

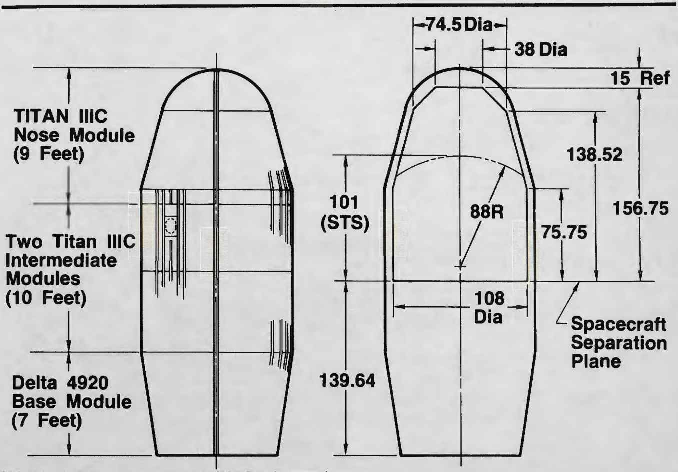

FIGURE 22. DELTA 4920 FAIRING (10 FT DIAMETER)

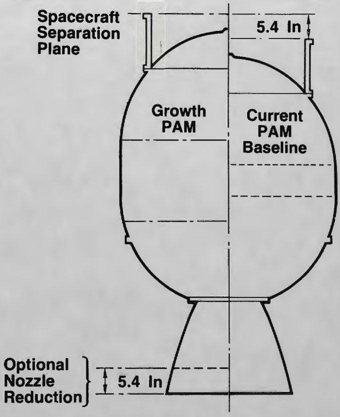

FIGURE 23. PAM GROWTH

Another example of growth potential exists within the PAM stage itself. By increasing the length of the motor case an increase in propellant capacity of approximately 15% is possible. With the existing PAM nozzle, the spacecraft separation plane would be relocated approximately 5.4 inches forward (Figure 23). To maintain the existing separation plane the nozzle could be foreshortened similar to the STS PAM application. An increase in booster performance would be required in conjunction with this change.

Other Delta options such as engine uprating and stretched augmentation solids are also feasible and could be employed if the expendable launch vehicles are to be continued in the STS era.

In summary, the Delta vehicle has always maintained a highly reliable positive growth trend as government and user needs have evolved. Additional growth potential exists to support future user needs throughout the expendable launch vehicle-Shuttle transition period. Delta can be ready to meet these needs with an improved capability STS backup launch vehicle to support government and commercial users for a large variety of future space missions.

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