ARCHIVED REPORT

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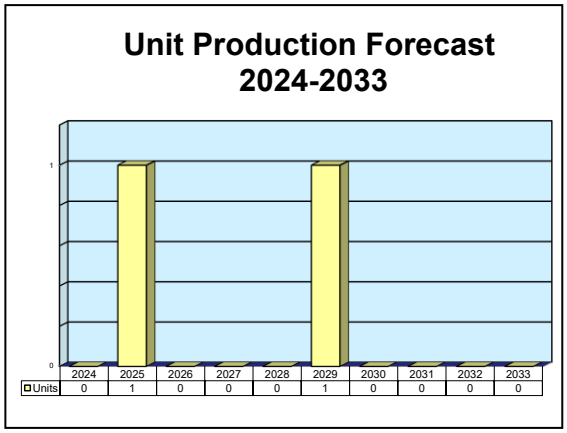
Pegasus XL

Outlook

- Northrop Grumman acquired Orbital ATK in 2018
- Production moving forward is speculative
- Pegasus XL is the standard launch vehicle at this time
- Pegasus XL was utilized in a launch of the U.S. Space Force's Odyssey demonstration satellite in June 2021
- Reportedly, there is one Pegasus XL remaining from the Stratolaunch program



Orientation

Description. The Pegasus XL is a winged, air-launched expendable launch vehicle (ELV).

Sponsor. The Air Force Space and Missile Center, Los Angeles, California, manages Pegasus XL missions for the U.S. Department of Defense. NASA's Goddard Space Flight Center handles space agency launches.

Status. Reportedly in limited production; the first Pegasus launch took place in 1990.

Total Produced. Orbital Sciences Corp / Orbital ATK / Northrop Grumman has conducted 45 Pegasus launches, 40 of which were successful. In February 2015, Orbital ATK was officially formed through the merger of OSC and the aerospace and defense businesses of Alliant Techsystems (ATK). Orbital ATK is now Northrop Grumman.

Application. The Pegasus XL air-launched vehicle can carry small payloads to low-Earth polar or equatorial orbits.

Price Range. For years, a Pegasus XL launch, including the launch vehicle, ground support, and use of a carrier aircraft, cost between $20 million and $25 million. More recently, however, costs have increased. A contract signed in November 2014 to carry the ICON spacecraft is worth $56.3 million.

Pegasus XL Mated to Orbital's L-1011 "Stargazer" Aircraft

Source: OSC

Pegasus XL

Contractors

Prime

Northrop Grumman Space, Space Systems	http://www.northropgrumman.com, 45101 Warp Dr, Dulles, VA 20166 United States, Tel: + 1 (703) 406-5000, Prime Defunct

Subcontractor

Collins Aerospace Systems, Sensors & Integrated Systems	http://www.collinsaerospace.com, 100 Panton Rd, Vergennes, VT 05491-1008 United States, Tel: + 1 (802) 477-4000, Fax: + 1 (802) 877-4111 (Electronic Control)
Northrop Grumman Mission Systems, Navigation Systems Division	http://www.northropgrumman.com, 21240 Burbank Blvd, M/S W8, Woodland Hills, CA 91367-6675 United States, Tel: + 1 (818) 715-2470, Fax: + 1 (818) 715-3368 (Avionics)
Northrop Grumman Space Systems, Defense Systems	http://www.northropgrumman.com, 1700 N Research Park Way, Logan, UT 84341 United States, Tel: + 1 (435) 753-8565 (Composite Components)
Northrop Grumman Space Systems, Space Components	http://www.northropgrumman.com, 7812 West 4100 South, Magna, UT 84044 United States, Tel: + 1 (801) 251-8000 (Orion 50S XL Motor; Orion 50 XL Motor; Orion 38 Motor)
PCC AETC Ltd	http://www.pccairfoils.com, Victoria Ave, Yeadon, Leeds, United Kingdom, Tel: + 44 8700 666060, Fax: + 44 2113 2103006 (Machined Stage 1-3 Compressor Blade; Machined Stage 1 LP Turbine Blade; Machined HP 1 Nozzle Guide Vane; Machined Stage 2 HP Turbine Blade)
Parker Hannifin Aerospace Group	http://www.parker.com, 14300 Alton Pkwy, Irvine, CA 92618 United States, Tel: + 1 (949) 833-3000, Fax: + 1 (949) 851-3277 (Fin Actuator)
Scaled Composites, a Northrop Grumman Subsidiary	http://www.scaled.com, 1624 Flight Line, Mojave Airport, Mojave, CA 93501-1663 United States, Tel: + 1 (661) 824-4541, Fax: + 1 (661) 824-4174 (Composite Delta Wing, Control Fins & Thrust Tube)

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 75 Glen Road, Suite 302, Sandy Hook, CT 06482, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. The Pegasus vehicle's solid rocket boosters use technology borrowed from the Peacekeeper, Pershing II, and Small ICBM missiles. The Pegasus also incorporates advances demonstrated in the solid rocket boosters used on larger ELVs, including the Titan IV and Delta II.

Fuselage. Most of the Pegasus fuselage consists of the first- and second-stage graphite composite rocket motor cases connected by interstage extensions. A two-piece composite payload fairing covering the payload and the third-stage motor and avionics assembly completes the basic fuselage.

The Pegasus' graphite composite delta wing, control fins, and thrust tube are built by Scaled Composites LLC.

During hypervelocity flight, additional layers of graphite composite on the wings and fins are designed to ablate, providing thermal protection. Scaled Composites also supplies the pylon adapter. Other contractors involved in structural development of the Pegasus included Alliant Techsystems (two-piece composite payload fairing), Parker Aerospace (fin actuators), and Davison Engineering (pylon adapter tubing). In designing the aluminum saddle that attaches the wing to the booster body, Hercules Inc borrowed the design used for the SRAM II short-range attack missile, which transmits the Pegasus' weight to the carrier aircraft pylon attachment hook.

Control fins at the rear of the vehicle provide attitude control during first-stage burn, eliminating the need for a vectorable nozzle on the first-stage solid rocket motor. Thrust vector control for pitch and yaw steering during second- and third-stage flight is provided by gimbaled nozzles. Roll control during powered flight is provided by a nitrogen cold-gas reaction control system, which also provides three-axis control during the final coasting period.

Pegasus XL

Propulsion System. The heart of the Pegasus winged vehicle is the solid-fuel rocket propellant system developed and produced by Alliant Techsystems. Technology for producing propellants, cases, insulators, and nozzles developed for the Peacekeeper, Trident D5, Pershing II, and Small ICBM programs has found its way into the vehicle's rocket motors.

The three composite motor cases are made of wound IM7 graphite fibers on an HBRF-55A matrix. Each case is filled with the same non-detonating, slow-burn-rate, polybutadiene-based propellant used in the Pershing II missile. All three-stage motors feature low-erosion carbon-carbon integral throat inserts and carbon-phenolic nozzles with graphite epoxy overwraps. Glass/silicone rubber flex seals and two-axis electromechanical actuators provide thrust vectoring for the second and third stages.

Avionics. The avionics architecture of the Pegasus takes full advantage of recent advances in computers and electronics, especially in areas such as microprocessors and ring laser gyros. Fourteen microprocessors provide onboard computations, and the vehicle's telemetry system can also perform ground checkout, forgoing the need for special connectors for final system checkout. Guidance and navigation are provided by a ring laser inertial measurement system. Pegasus avionics contractors are Northrop Grumman (inertial measurement unit), Aitech Systems Ltd (flight computer), and Aydin-Vector (telemetry transmitter).

The subcontractors involved in the Pegasus ordnance and flight termination system include Teledyne McCormick (safe and arm devices), Ensign-Bickford Aerospace Co (ordnance devices), and Aydin-Vector (flight termination system receiver).

Ground Support. Unlike the larger expendable launch vehicles, which require hundreds of support personnel before each launch, the Pegasus is assembled, checked out, and made ready for flight by a small ground crew of about 10. Checkout occurs at the departure field and uses a single ground support trailer. Contractors involved in ground and air support equipment are Balzer (pylon adapter frame, assembly integration trailer, and support) and Intertex (VAB construction and modifications).

Engineering Support. Besides Orbital Sciences Corp and Alliant Techsystems, seven subcontractors have provided engineering support: Nielsen Engineering & Research Inc (aerodynamics analysis), Acurex Aerotherm (aerothermal analysis), Interferometrics (avionics design), Matrix (structural dynamics analysis), Systems Technology Inc (flight dynamics and control analysis), Dynamic Engineering (flutter analysis), and SELF (carrier aircraft analysis). Antenna testing and payload support are provided by Physical Sciences Lab and EER Systems, respectively.

Flight Profile. For the first mission, the Pegasus was attached to the NASA Dryden Flight Research Facility NB-52 aircraft and launched over the Pacific Ocean in the Western Test Range near Vandenberg Air Force Base. Missions now use a Lockheed L-1011 commercial transport as a dedicated Pegasus carrier.

The L-1011 carries the Pegasus directly underneath its fuselage, rather than under a wing, as it is carried by a B-52.

A typical Pegasus launch takes place at an altitude of about 12 kilometers, with the carrier aircraft traveling at Mach 0.8. At this altitude, atmospheric drag is greatly reduced.

First-stage ignition occurs five seconds after the Pegasus is released from the carrier aircraft. During first-stage burn, the vehicle's fins provide attitude control and the rocket motor powers the vehicle to Mach 8.7 and 63 kilometers. At this point, the flight proceeds much like a conventional ELV mission. Second-stage burnout occurs at 168 kilometers and a velocity of 5,425 meters per second. Third-stage burn lasts for about 65 seconds, with orbital insertion at 463 kilometers.

Pegasus XL

	Metric	U.S.
Dimensions (Pegasus XL)		
Vehicle Overall Length	17.5 m	57.5 ft
Vehicle Diameter	1.27 m	4.2 ft
Vehicle Wingspan	6.7 m	22 ft
Payload Fairing Length	4.4 m	14.5 ft
Weight		
Vehicle Launch Weight (excluding payload)	24,000 kg	52,000 lb
Stage 1 Rocket Motor Total Weight	15,014 kg	33,105 lb
Stage 2 Rocket Motor Total Weight	3,925 kg	8,655 lb
Stage 3 Rocket Motor Total Weight	770 kg	1,697 lb
Performance		
Stage 1 Thrust	726 kN	163,247 lbst
Stage 2 Thrust	196 kN	44,060 lbst
Stage 3 Thrust	36 kN	8,093 lbst
Payload to Polar Orbit (200 km)	345 kg	760 lb
Payload to Low-Earth 28° Equatorial Orbit (200 km)	460 kg	1,105 lb
Stage 1 Burn Time	68 sec	
Stage 2 Burn Time	69 sec	
Stage 3 Burn Time	68 sec	

Propulsion

Stage 1: (1) Orbital ATK Orion 50S XL solid-propellant booster motor, 726 kN (163,247 lbst) maximum vacuum thrust

Stage 2: (1) Orbital ATK Orion 50 XL solid-propellant booster motor, 196 kN (44,060 lbst) maximum vacuum thrust

Stage 3: (1) Orbital ATK Orion 38 solid-propellant booster motor, 36 kN (8,093 lbst) maximum vacuum thrust

Variants/Upgrades

Standard Pegasus. Original version; last launch took place in 1996.

Pegasus XL. Stretched version with a greater payload capacity.

Hyper-X. NASA developed three X-43 hypersonic research vehicles under the agency's Hyper-X program. Each vehicle, designed to reach speeds between Mach 7 and Mach 10, comprises a ramjet/scramjet engine module attached to a Pegasus first-stage booster. The X-43 is released at operating altitude by NASA's B-52 carrier aircraft, after which the vehicle flies as high as 36,575 meters (120,000 ft).

The first mission, in June 2001, ended in failure shortly after launch over a Pacific Ocean test zone. The Pegasus XL booster ignited normally after it – along with an X-43A – was dropped from a B-52 carrier aircraft. However, the vehicle combination began corkscrewing moments later and was ordered to self-destruct.

Program Review

Background. Development of the Pegasus began in 1987. The first vehicle rolled out two years later at Edwards Air Force Base, California. In 1990, the booster took part in captive flight tests involving NASA's B-52 carrier vehicle. After numerous delays, the first Pegasus launch took place in 1990, carrying the Pegsat mini-satellite into low-Earth orbit. Starting in 1992, the Pegasus was carried aboard a Lockheed L-1011 TriStar aircraft acquired by Orbital Sciences for that use.

Spectrum Astro Chooses Pegasus. Spectrum Astro Inc chose the Pegasus rocket to launch its Communication/Navigation Outage Forecasting System spacecraft in November 2004. Spectrum built the C/NOFS for the U.S. Air Force Space Test Program. The satellite, launched in 2008, serves as an advanced warning system and detects irregularities within the ionosphere and atmosphere that may disrupt military space-based communications.

HESSI Launched. NASA's HESSI spacecraft, whose launch was repeatedly delayed, was finally placed into low-Earth orbit aboard a Pegasus XL vehicle in February 2002.

SORCE Launched. In January 2003, a Pegasus XL rocket was air-launched from a TriStar carrier aircraft at Cape Canaveral and placed NASA's Solar Radiation and Climate Experiment spacecraft into low-Earth orbit. Orbital Sciences built the satellite under an $85 million contract from NASA's Goddard Space Flight Center, which manages the SORCE.

GALEX Launched. Launch of NASA's GALEX spacecraft took place in April 2003 following a delay of almost a year.

OrbView-3 Launched. Orbital Sciences launched the OrbView-3 satellite for its former affiliate Orbimage in June 2003.

Canadian SCISAT Launched. The SCISAT-1, the first new Canadian scientific satellite since 1971, was launched by NASA on a Pegasus rocket in August 2003. The Canadian government sponsors the 150-kilogram spacecraft, which carries the Atmospheric Chemistry Experiment to monitor the ozone layer. The SCISAT orbits at an altitude of 650 kilometers.

In October 2003, Orbital Sciences received a contract from NASA to supply two Pegasus and two Taurus launch vehicles. The orders were placed under the Small Expendable Launch Vehicles contract that was awarded to Orbital in 1998. One Pegasus vehicle was to be used to launch the satellite designated for NASA's Space Technology-8 (ST-8), which was later canceled; the other vehicle carried the Small Explorer-10 (named the Interstellar Boundary Explorer, or IBEX) on October 19, 2008.

In February 2009, NASA selected Orbital Sciences to provide launch services for the NuSTAR satellite, which Orbital also built. A Pegasus XL carried the NuSTAR spacecraft into orbit on June 13, 2012.

On June 28, 2013, a Pegasus XL launched carrying NASA's IRIS spacecraft.

Although production of the Pegasus has been threatened in recent years, Orbital Sciences was awarded two launch services contracts for the vehicle in 2014. The first was awarded in April, and covered the launch of eight small Cyclone Global Navigation Satellite System (CYGNSS) satellites, which launched on December 15, 2016. Under the second agreement, Orbital's Pegasus carried NASA's Ionospheric Connection Explorer (ICON) mission to orbit. Originally scheduled to lift off in 2017, the mission was delayed until 2018 while a problem with the vehicle's separation system was resolved.

In October 2016, Orbital ATK and Stratolaunch systems announced a deal to work jointly on launching Pegasus XL rockets from Stratolaunch's giant six-engine carrier aircraft. While the announcement indicated the first step toward a more involved partnership, details about the number of Pegasus rockets included or a specific timeframe were not disclosed.

Some reports suggest that two Pegasus XL rockets were produced for use in conjunction with Stratolaunch. One of these launch vehicles was used to launch a U.S. Space Force demonstration satellite in June 2021. This means that there is one left, but does not preclude the production of more in the future.

Forecast Rationale

The Pegasus and Pegasus XL have enjoyed a relatively good success rate since the former first launched in 1990; 40 of 45 launches have been successful. Despite this success, costs for launching payloads are proving to be a shortfall for the program – the latest contract had a price tag of $56.3 million. Northrop Grumman is reportedly increasing efforts to mitigate costs on the Pegasus XL mission; however, price is hurting Pegasus XL. In July 2019, NASA awarded a contract to SpaceX for a mission that was originally slated for Pegasus. The decision reportedly came down to price.

The Pegasus XL is designed to launch small payloads into low-Earth orbit (LEO). Smaller satellites are becoming more popular, and the way in which they are orbited has become more diverse. There are myriad options available to potential customers. For example, smaller satellites can be a secondary payload or can even be launched by a smaller rocket, such as Rocket Lab's Electron. As technology advances, even more options will become available.

Pegasus XL

Reportedly, two Pegasus XL launch vehicles were produced for the Stratolaunch program. In 2019, Stratolaunch stopped development and is now focusing on using its massive aircraft for flight test services.

The last Pegasus mission supposedly utilized one of the Pegasus XLs earmarked for Stratolaunch, leaving one remaining. Production moving forward will likely be sporadic as more competitive rockets come on line. The rocket is still advertised by Northrop Grumman. This is not to say the Pegasus XL is finished, there might be some production moving forward; however, this is highly speculative.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION												
Designation or Program		High Confidence				Good Confidence			Speculative			
	Thru 2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
Northrop Grumman Space Systems												
Pegasus XL Note: Orbital ATK Acquired by Northrop Grumman in 2018; Does not include Launch Vehicles produced under Orbital ATK												
	3	0	1	0	0	0	1	0	0	0	0	2
Total	3	0	1	0	0	0	1	0	0	0	0	2