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Taurus

Outlook

- NASA investigation fails to pinpoint root cause of launch failures
- Taurus faces competition from the likes of the Falcon 9 and the Antares
- Orbital Sciences will not market the Taurus anymore, instead focusing on the Antares and Minotaur
- This report will be archived next year

Orientation

Description. Taurus is a four-stage, solid-propellant, expendable ground-launched vehicle.

Sponsor. Taurus was developed for the Defense Advanced Research Projects Agency (DARPA).

Status. Orbital Sciences Corp launched its first Taurus vehicle in 1994. The Taurus has launched nine times, with three failures.

Total Produced. Nine vehicles.

Application. Taurus was developed as part of DARPA's Advanced Space Technology Program. ASTP is geared toward developing the technology to enable production of Lightsats – smaller, lightweight satellites – for military commanders. The Standard Small Launch Vehicle, or SSLV (the official name for the new booster), developed for this program has commercial and scientific applications.

Price Range. OSC charges about $23 million for a Taurus Standard launch and $24 million for a Taurus XL mission.

Contractors

Prime

Orbital Sciences Corp, Space Systems Group	http://www.orbital.com, 45101 Warp Dr, Dulles, VA 20166 United States, Tel: + 1 (703) 406-5000, Prime

Taurus

Subcontractor

ATK Aerospace, Space Launch	http://www.atk.com, PO Box 160362, Clearfield, UT 84015 United States, Tel: + 1 (763) 712-7700, Email: businessdevelopment@atk.com (Castor 120 First Stage Motor)
Engelhard Corp	http://www.engelhard.com, 101 Wood Ave, PO Box 770, Iselin, NJ 08830 United States, Tel: + 1 (732) 205-5000, Fax: + 1 (732) 205-6711, Email: info@engelhard.com (Oxidation Catalyst)
Ingersoll-Rand Engine Starting Systems	PO Box 1776, Liberty Corner, NJ 07938 United States, Tel: + 1 (908) 647-6000, Fax: + 1 (908) 647-6007 (Pneumatic Starter)
Micro Power Electronics Inc	http://www.micro-power.com, 22995 NW Evergreen Pkwy, Hillsboro, OR 97124-7165 United States, Tel: + 1 (503) 693-7600, Fax: + 1 (503) 648-9625, Email: powerexpert@micro-power.com (Battery Packs)
Pacific Scientific Energetic Materials - Valencia	http://www.psemc.com, 24908 Kearney Ave, Valencia, CA 91355 United States, Tel: + 1 (661) 600-1100, Fax: + 1 (661) 600-1101, Email: BRitchie@psemc.com (Arming System and Stage Separation)
Vosper Thornycroft (UK) Ltd	Woolston Shipyard, Victoria Rd, Woolston, SO9 5GR Southampton, United Kingdom (Control)

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Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. To date, the Taurus expendable launch vehicle has been offered in four versions: the DARPA model, developed for the Defense Advanced Research Projects Agency and the first model launched; the Taurus Standard; and the Taurus XL and XLS, which are available for customers seeking additional payload capability.

The DARPA Taurus' 0 stage uses the ATK Thiokol Castor 120 Solid Rocket Motor, a commercial variant of the Peacekeeper ICBM's first-stage solid-propellant motor. The rocket's first stage is powered by an ATK Thiokol Orion 50S solid-propellant motor. This is the same unit, with modifications, used on OSC's Pegasus air-launched winged booster. An Orion 50 solid-propellant motor, with gimbaled nozzle, provides thrust for the third stage. The fourth stage of the DARPA Taurus is powered by an Orion 38 motor.

The Taurus Standard replaces the Peacekeeper motor with an ATK Thiokol Castor 120 solid-propellant rocket motor. The first, second, and third stages incorporate Orion 50S-G (or 50SXLG), Orion 50 (or 50XL), and Orion 38 motors, respectively. The optional upper stage may use any one of several upper stage systems, including the Orion 38, which features a vectorable nozzle, the spin-stabilized Star 37, or the Rafael AUS-51, which is also spin-stabilized.

The Taurus XL uses the same motors as the standard Taurus, but the first and second stages are stretched. The Taurus XLS is basically a Taurus XL with the addition of two ATK Thiokol Castor IVB strap-on rocket motors.

Avionics. The Taurus employs an all-digital avionics suite with distributed processors. At the center of the Taurus avionics system is the flight computer, which communicates with all vehicle subsystems, and the Launch Support Equipment (LSE), using standard RS-422 digital serial datalinks. All avionics on the vehicle feature microprocessors to perform local processing and to handle communication with the flight computer.

Vehicle guidance, navigation, and control are performed through the use of Honeywell's SIGI navigator and Northrop Grumman's LN-200 rate gyro. The SIGI is a space-qualified navigator that has also flown on Pegasus missions and on a number of Orbital's target and interceptor vehicles.

The LN-200 is a space-qualified rate gyro located in the Stage 1 motor raceway. The LN-200, used during Stage 0 flight, provides an additional measurement of vehicle attitude rates for use by the autopilot. The LN-200 has flown on all previous Taurus missions except the very first.

The Taurus can be launched from Cape Canaveral Air Force Station, Florida, for low-inclination orbits or high-energy missions (28.5° to 38°); from Wallops Flight Facility, Virginia, for mid-inclination orbits (38° to 55°); or from Vandenberg Air Force Base, California, for high-inclination missions (60° to 140°). Missions that require polar or sun-synchronous orbits are also performed from VAFB.

	Metric	U.S.
Dimensions		
1.6-meter payload fairing		
Payload envelope length	3.9 m	13 ft
Payload envelope diameter	1.4 m	4.5 ft
2.3-meter payload fairing		
Payload envelope length	5.7 m	18.7 ft
Payload envelope diameter	2.0 m	6.7 ft
Dual payload fairing		
Payload envelope length	5.8 m	19 ft
Payload envelope diameter	2.0 m	6.7 ft
Performance		
Payload to 463 km (290 mi) with Orion 38 upper stage		
DARPA Taurus	1,114 kg	2,450 lb
Taurus Standard	1,250 kg	2,750 lb
Taurus XL	1,389 kg	3,055 lb
Taurus XLS	1,770 kg	3,895 lb
Payload to GTO with Star 37 perigee kick motor		
DARPA Taurus	391 kg	860 lb
Taurus Standard	448 kg	985 lb
Taurus XL	518 kg	1,140 lb
Taurus XLS	689 kg	1,515 lb

Propulsion

Taurus Standard		
Stage 0	(1)	Castor 120 solid rocket engine, 1,615 kN (363,087 lb) average vacuum thrust
Stage 1	(1)	Orion 50S-G solid rocket engine, 471.5 kN (106,000 lb) average vacuum thrust
Stage 2	(1)	Orion 50 solid rocket engine, 115.2 kN (25,910 lb) average vacuum thrust
Upper stage	(1)	Orion 38 solid rocket engine, 31.8 kN (7,155 lb) average vacuum thrust
Upper stage (optional)	(1)	Star 37FM solid rocket engine, 47.1 kN (10,600 lb) average vacuum thrust
Taurus XL		
Stage 0	(1)	Castor 120 solid rocket engine, 1,615 kN (363,087 lb) average vacuum thrust
Stage 1	(1)	Orion 50S-XL solid rocket engine, 593.8 kN (133,500 lb) average vacuum thrust
Stage 2	(1)	Orion 50-XL solid rocket engine, 171.4 kN (36,300 lb) average vacuum thrust
Upper stage	(1)	Orion 38 solid rocket engine, 31.8 kN (7,155 lb) average vacuum thrust
Upper stage (optional)	(1)	Star 37FM solid rocket engine, 47.1 kN (10,600 lb) average vacuum thrust
Taurus XLS		
SSRMs	(2)	Castor IVB solid rocket engines, 401.7 kN (90,309 lb) average vacuum thrust each
Stage 0	(1)	Castor 120 solid rocket engine, 1,615 kN (363,087 lb) average vacuum thrust
Stage 1	(1)	Orion 50S-XL solid rocket engine, 593.8 kN (133,500 lb) average vacuum thrust
Stage 2	(1)	Orion 50-XL solid rocket engine, 171.4 kN (36,300 lb) average vacuum thrust
Upper stage	(1)	Orion 38 solid rocket engine, 31.8 kN (7,155 lb) average vacuum thrust
Upper stage (optional)	(1)	Star 37FM solid rocket engine, 47.1 kN (10,600 lb) average vacuum thrust

Variants/Upgrades

DARPA Taurus. First Taurus model; developed for the Defense Advanced Research Projects Agency.

Taurus Standard. The original four-stage Taurus variant.

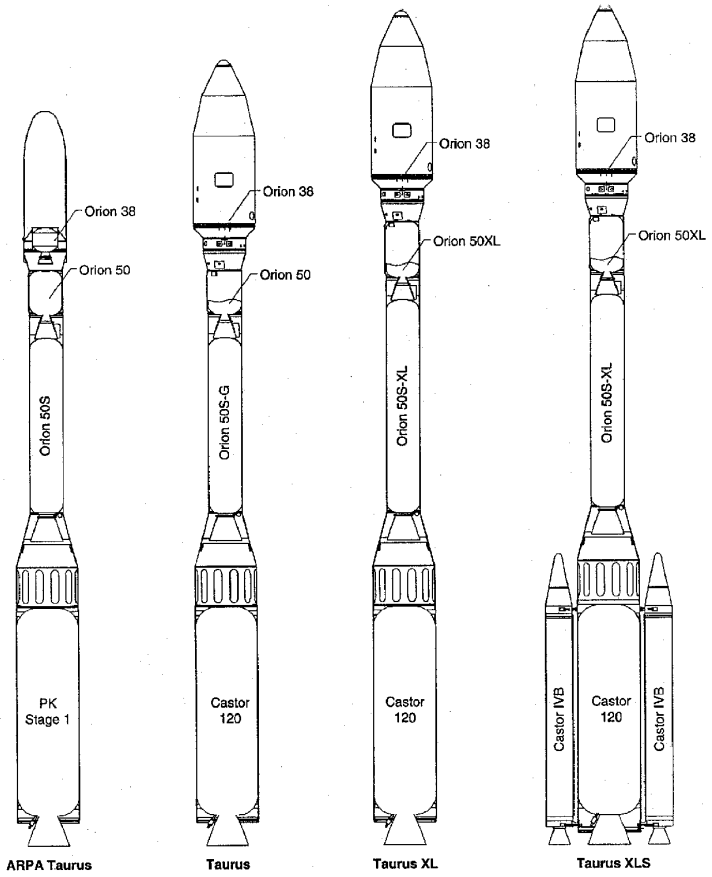
Taurus XL. Taurus rocket with longer Orion 50S-XL Stage 1 motor.

Taurus XLS. Same as Taurus XL, but equipped with two Castor IVB strap-on rocket motors.

Taurus II/Antares. Orbital Sciences was selected to build a launch vehicle and cargo transfer vehicle for

Taurus

NASA under the Commercial Orbital Transport System (COTS) program in 2008. The company responded with a variant of the Taurus, known as the Taurus II. However, by late 2011, Orbital Sciences decided that it had made enough changes to the launch vehicle to justify a name change. On December 12, 2011, Orbital Sciences announced that it had rebranded its Taurus II rocket as the Antares. Forecast International now includes that launch vehicle in a separate report in this service.



Source: Orbital Sciences Corporation

Program Review

Background. In 1989, Space Data Corp, later part of Orbital Sciences Corp, was awarded a DARPA contract worth $10.9 million to develop, demonstrate, and launch the Standard Small Launch Vehicle (SSLV), which is now called Taurus. The award contained options for four additional vehicles that could boost the total value of the contract to $69.4 million.

DARPA's Taurus arrangement with OSC was similar to the one worked out for development of the OSC Pegasus air-launched winged launch vehicle. Under this arrangement, the contractor foots the bill for most of the development costs – in this case, $25 million. In turn, the contractor has the opportunity to position itself in the commercial launch vehicle market while simultaneously giving the government a cost-effective means of demonstrating new launch technologies.

NASA and OSC signed an agreement in 1990 in support of the firm's Pegasus and Taurus commercial launch vehicle programs. Terms of the five-year agreement allowed OSC to enter specific sub-agreements with NASA installations in which NASA would provide, on a cost-reimbursable basis, access to agency launch support property and services.

OSC Switches to Castor 120 Motor. In 1992, OSC agreed to use the Castor 120 solid rocket motor for the Taurus' first stage. The commercially available Castor 120 motor is based on the flight-proven

Peacekeeper first stage, which was originally picked for Taurus.

Taurus Takes a STEP on Maiden Voyage

The first Taurus mission took place in 1994; it carried a 204-kilogram DARPA payload and the 500-kilogram TAOS spacecraft for the USAF's Space Test Experiment Program (STEP). After approximately 10 minutes of ascent, Taurus deployed the two spacecraft into a 290 x 300-nautical-mile orbit, inclined at 105°.

Additional Missions. Ball Corporation selected the Taurus rocket in 1995 to launch the U.S. Navy's Geosat Follow-On (GFO) satellite. For the mission launched in 1998 from Vandenberg Air Force Base, California, Taurus used a larger, Orbital-developed payload fairing, providing a 120 percent increase in payload volume.

Taurus was used again in 1998 to place the National Reconnaissance Office's Space Technology Experiment spacecraft into an orbit 665 kilometers above Earth, inclined at 85° to the equator. Built by Lockheed Martin, STEX is a 690-kilogram spacecraft slated to demonstrate 29 new technologies over two years.

Korean Firm Selects Taurus. OSC signed a contract with Korea Aerospace Research Institute in 1997 to launch the Korea Multi-Purpose Satellite (KOMPSAT) on a Taurus rocket. The launch from Vandenberg AFB took place in December 1999.

OSC Lands Major Order

In 1998, NASA's Kennedy Space Center awarded a contract to OSC to provide up to 16 Pegasus and Taurus rocket launches over a five-year period. The contract for launch vehicles and related services, under the space agency's Small Expendable Launch Vehicle Services (SELVS) program, was worth up to $400 million over the five-year term. NASA has used most of its options for launches aboard the Pegasus; only one launch was assigned to the Taurus.

The SELVS program is designed to supply launch vehicles for future missions conducted by NASA's Earth Science and Space Science initiatives. These scientific missions are typically carried out by small-class satellites that are best launched into orbit aboard small, cost-effective launch vehicles, such as the Pegasus and Taurus rockets.

Taurus Picked for QuikTOMS. NASA selected OSC in August 1999 to build, launch, and operate the QuikTOMS atmospheric ozone monitoring satellite, as well as to integrate the Total Ozone Mapping Spectrometer (TOMS) instrument that the company had built for the space agency.

OSC Wins ROCSAT-2 Contract. Orbital Sciences Corporation was selected by the Republic of China's National Space Program Office (NSPO) to provide Taurus launch services for the ROCSAT-2 remote sensing satellite. The primary objective of the ROCSAT-2 satellite mission is to observe and monitor via satellite the terrestrial and marine environment and natural resources throughout Taiwan, its remote islands, and surrounding ocean for civil applications.

Taurus Launch Failure. The September 2001 Taurus launch carrying Orbimage's OrbView-4 and NASA's QuikTOMS spacecraft ended in failure. An in-flight anomaly occurred during the rocket's second-stage burn, releasing the satellites at an unstable orbit.

XL Model Debuts with ROC Spacecraft

In May 2004, a Taurus XL successfully boosted the Republic of China's ROCSAT-2 remote sensing satellite into low-Earth orbit. The mission originated from Vandenberg AFB. The mission was the seventh in the Taurus program's history and was the inaugural flight of the enhanced-performance XL version.

NASA's Orbiting Carbon Observatory (OCO) satellite, built to study atmospheric carbon dioxide, was launched aboard a Taurus XL rocket from VAFB on February 24, 2009, but failed to reach orbit. A NASA panel that investigated the unsuccessful launch completed its report and verified that the Taurus launch vehicle fairing failed to separate upon command. The fairing is a clamshell structure that encapsulates the satellite as it travels through the atmosphere. The failure to shed the fairing mass prevented the satellite from reaching its planned orbit and resulted in its destruction. NASA selected Orbital Sciences to deliver the OCO replacement, known as the OCO-2, in June 2010.

On March 4, 2011, a Taurus XL experienced a failure similar to that of the February 2009 launch. This launch vehicle was carrying NASA's Glory spacecraft into orbit. However, the fairing failed to separate, adding weight to the launch vehicle and preventing it from placing the spacecraft into the appropriate orbit.

Orbital Sciences and NASA have been unable to pinpoint exactly why these failures occurred, even though a similar system is used on the company's Minotaur IV and has operated successfully in that application. For that reason, NASA has pulled its OCO-2 from a Taurus XL launch manifest, although it remains on the NASA Launch Services 2 list of launch vehicles. NASA has said that Orbital Sciences Corp will need to create a return-to-flight plan before the agency will use the launch vehicle; however, OSC has decided to stop marketing the Taurus.

Taurus

Timetable

Month	Year	Major Development
Mar	1994	Taurus demo launch (T-1) from Vandenberg AFB with DARPA payload and STEP satellite
Feb	1998	Launch of GFO, two ORBCOMM satellites, and Celestis-2 from VAFB on Taurus (T-2)
Oct	1998	Launch of STEX spacecraft and ATE from VAFB on Taurus (T-3)
Dec	1999	Launch of KOMPSAT and ACRIMSAT from VAFB on Taurus (T-4)
Mar	2000	Launch of Multispectral Thermal Imager (MTI) from VAFB on Taurus (T-5)
Nov	2001	Failed launch of OrbView-4 and QuikTOMS from VAFB on Taurus (T-6)
May	2004	Launch of ROCSAT-2 aboard Taurus XL
Feb	2009	Failed launch of NASA OCO aboard Taurus XL
Mar	2011	Failed launch of Glory on board Taurus XL

Forecast Rationale

On February 24, 2009, and again on March 4, 2011, Taurus XL launch vehicles failed to place NASA payloads into orbit. Despite a redesign of the upper-stage fairing between the 2009 and the 2011 launches, the launch failures were both blamed on the fairings. Still, Orbital and NASA could not identify the exact cause of these failures. Even in NASA's final report on the investigation, the agency could not pinpoint the root cause of the failure, although it did issue some recommendations to Orbital Sciences for future launches.

Because of these setbacks, NASA has decided not to use the Taurus XL for its launch needs until Orbital Sciences creates an acceptable return-to-flight plan. NASA is one of the primary customers of the Taurus XL, so no usage by the space agency will hurt the launch vehicle's sales prospects. In addition, the lack of approval by NASA will make any other potential customer question the launch vehicle's safety.

Taurus' failures have come at a bad time, as several new launch vehicles are currently being introduced to the market. Space Exploration Technologies' Falcon 9 is gaining new contracts rapidly, and even Orbital Sciences' own Antares and Minotaur series are taking market share away from the Taurus.

Ultimately, Orbital Sciences decided to stop marketing the Taurus. The company will instead focus on its Antares and Minotaur families of launch vehicles. In fact, the Minotaur C will utilize components from the Taurus. The rocket motors will come from the Taurus, while the fairing will come from the Minotaur. With that decision, no more Taurus launch vehicles will be produced or delivered. This report will be archived next year.

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