# ARCHIVED REPORT

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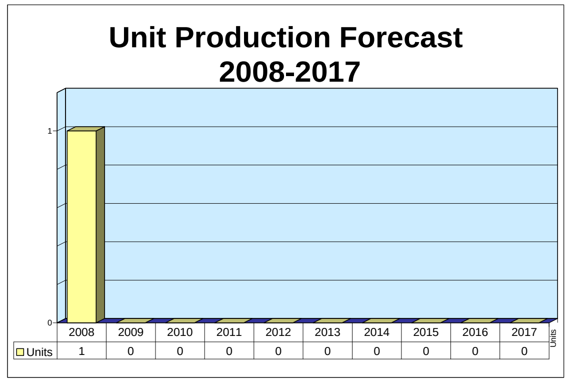
# Boeing-601 – Archived 1/2009

## Outlook

- Tight market, past malfunctions taking its toll on sales
- No commercial Boeing-601s have launched since Superbird-6 in early 2004; no commercial 601s in production
- Boeing may retire this model to focus solely on the company's 702 platform (see the "Boeing-702" report in this tab)




## Orientation

**Description.** The Boeing-601 (formerly HS-601) is a communications satellite designed for operation in geo-synchronous and medium-altitude orbits.

**Sponsor.** Sponsorship for the Boeing-601 varies, depending on the application. Sponsors include Motient Corporation/TMI Communications (MSAT), Societe Europeenne des Satellites (Astra), Mexican government (Solidaridad), Satmex (Satmex 5), PT Satelit Palapa Indonesia (Satelindo), APT Satellite (ApStar), and New ICO.

Additional sponsors include Japan Satellite Systems (JCSAT), Japan's Space Communications Corp (Superbird C), NASA (TDRS H/I/J), PanAmSat (Galaxy and PAS), Asia Satellite Telecommunications Co Ltd (AsiaSat), Cable & Wireless Optus (Optus), and Loral Space & Communications (Orion).

The Naval Space and Warfare Systems Command, Dahlgren, Virginia, has overall responsibility for the UHF Follow-On (UFO) military communications satellite. The Geostationary Operational Environmental Satellite (GOES) program is funded and operated by the National Oceanic and Atmospheric Administration (NOAA).

**Status.** In production.

**Total Produced.** Approximately 73 Boeing-601 and Boeing-601HP satellites have been produced to date.

**Application.** The Boeing-601 satellite model is intended for use in many applications, including direct broadcast, mobile satellite communications, and very small aperture terminal (VSAT) networks. The satellite bus is also used for military communications and high-volume data transfer for NASA spacecraft, and as a platform for meteorological instruments.

**Price Range.** $90 million to $200 million, depending on the application.

## Contractors

### Prime

| | |
|---|---|
| **Boeing Satellite Development Center** | http://www.boeing.com/defense-space/space/bss/flash.html, 2260 E Imperial Hwy, El Segundo, CA 90245 United States, Tel: + 1 (310) 662-9000, Prime |

## Subcontractor

| | |
|---|---|
| **Alliant Techsystems - Launch Systems Group** | http://www.atk.com, PO Box 98, Magna, UT 84044-0098 United States, Tel: + 1 (801) 251-5911, Fax: + 1 (801) 251-4464, Email: businessdevelopment@atk.com (Composite Reflectors; Antennae) |
| **Alliant Techsystems - Mission Systems Group, Space Division** | http://www.psi-pci.com, 6033 E Bandini Blvd, Commerce, CA 90040 United States, Tel: + 1 (213) 722-0222, Fax: + 1 (213) 721-6002 (Titanium Propellant Tank) |
| **EADS CASA, Military Transport Aircraft Division** | http://www.eads.net, Avenida de Aragon, 404, Madrid, 28022 Spain, Tel: + 34 91 585 7000, Fax: + 34 91 585 7666 (Spacecraft Structural Panel) |
| **General Dynamics Ordnance and Tactical Systems** | http://www.gd-ots.com, 11399 16th Court North, Suite 200, St. Petersburg, FL 33716 United States, Tel: + 1 (727) 578-8100, Fax: + 1 (727) 578-8119 (Apogee Liquid Kick Motor) |
| **Spectrolab Inc** | http://www.spectrolab.com, 12500 Gladstone Ave, Sylmar, CA 91342-5373 United States, Tel: + 1 (818) 365-4611, Fax: + 1 (818) 361-5102 (Dual-Junction Gallium Arsenide Solar Cell) |



## Technical Data

**Design Features.** Hughes developed the three-axis-stabilized Boeing-601 in the 1980s in response to customer demands for higher power. The spin-stabilized Boeing-376 typically produces 800 to 1,000 watts and carries 24 transponders. Increasing the Boeing-376's power would have meant making the spacecraft wider, which would have exceeded the 4-meter-diameter payload capacity for most of the large, expendable launch vehicles in service at that time. The Boeing-601, however, uses solar panels that fold accordion style, which adds only a few inches to the satellite's stowed dimensions.

The Boeing-601 body comprises two modules. The primary structure holds all launch vehicle loads and the propulsion subsystem. The second module contains honeycomb shelves that hold the communications equipment, electronics, battery packs, and isothermal heat pipes. Reflectors, antenna feeds, and solar arrays mount directly to the primary module, and antenna configurations can be placed on three faces of the bus.

The modular approach allows work to move in parallel, which shortens the production time. Hughes can build a Boeing-601 in about 12 months, depending on the payload's complexity.

Some Boeing-601 models employ an optional electronic propulsion system, called Xenon Ion Propulsion System (XIPS), for station keeping. Compared with traditional chemical propulsion systems, this xenon-based system is more efficient. With an XIPS on board, propellant mass on a satellite designed for 12 to 15 years of operations can be reduced by up to 90 percent. Customers using XIPS can either extend satellite life or increase payload capabilities while holding satellite weight constant.

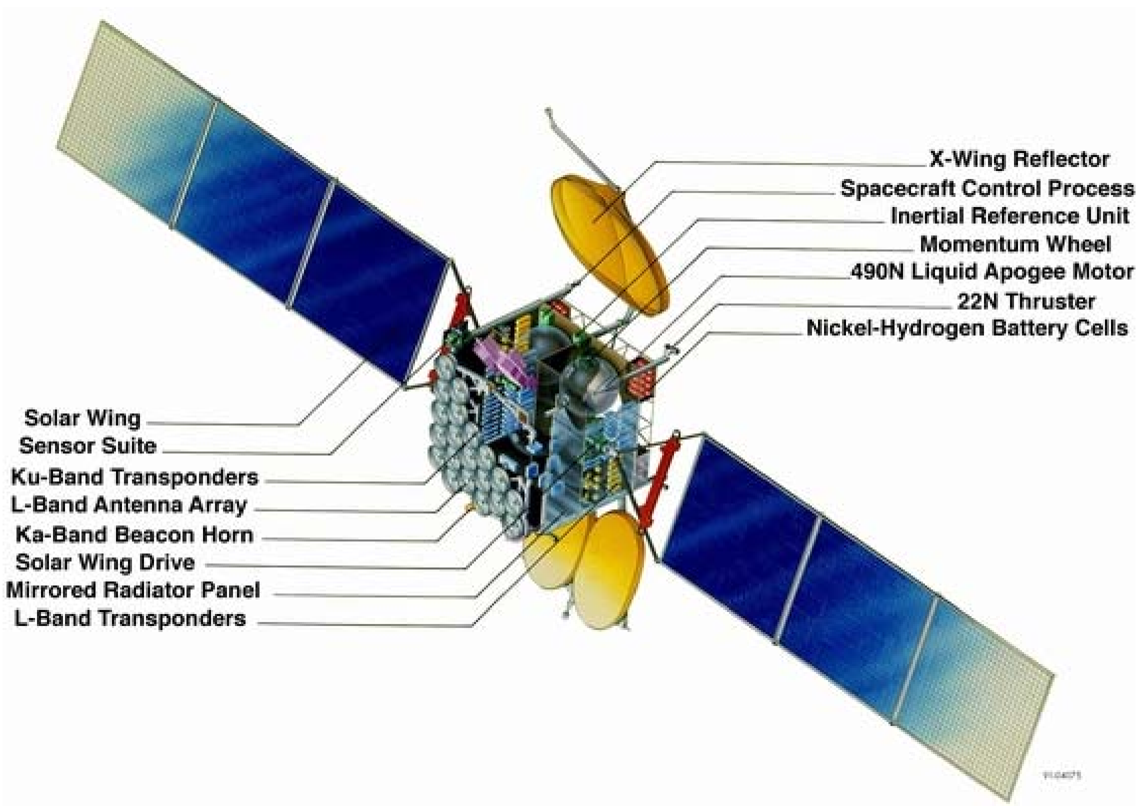
Newer versions of the Boeing-601 use an onboard liquid apogee engine supplied by Kaiser Marquardt (acquired by Primex Technologies, which in turn was acquired by General Dynamics in 2001). The 76-centimeter-long engine features an iridium-lined rhenium combustion chamber capable of operating at temperatures 370°C higher than conventional apogee engines. The engine was first used on the Galaxy X-R and later on the PAS-9 satellite. Called the High Performance Thruster, the engine produces 445 newtons (100 lb) of thrust, using the standard satellite bipropellants monomethyl hydrazine and nitrogen tetroxide.

Boeing-601 satellites weigh 2,500 to 3,000 kilograms, with a payload capacity of up to 680 kilograms. Launch vehicles with the capacity to carry the Boeing-601 include the Atlas 5, Ariane 5, Delta II, Delta IV, Long March 2E and Long March 3B (although launches on Chinese ELVs are *extremely* unlikely), H-2A, Proton, and Sea Launch.

Design Flaws. After the failure of four spacecraft in 1998, Hughes investigated and reviewed the design of its -601 model. The company found that the spacecraft control processor (SCP) on some 25 Boeing-601 spacecraft built before 1998 contained tin-plated relay switches that were susceptible to a buildup of crystals (known as “tin whiskers”), which caused processor-disabling short circuits. After both processors failed, the spacecraft was unable to maintain its orientation. In 1998, Hughes began using nickel relay switches, eliminating the potential for crystal growth. However, the affected spacecraft that have been launched are suffering SCP failures, one by one.

An antenna failure on TDRS-H in 2001 was traced to defective material used in the manufacture of the antenna. Boeing corrected the problem for its TDRS-I and -J models.

| | Metric | U.S. |
|---|---|---|
| **Dimensions (Astra 1E)** | | |
| (Excluding solar panels) | 2.7 x 3.2 x 4.3 m | 8.8 x 10.5 x 14.1 ft |
| **Weight** | | |
| Launch mass | 3,000 kg | 6,614 lb |
| Mass in orbit | 1,800 kg | 3,968 lb |
| **Performance** | | |
| Power supply | 4,150 W | |
| Design life | 15 years | |
| Ku-band transponders | 18 (plus 6 spares) | |
| TWTA power | 85 W | |
| Frequency bands | Downlink: 11.70-12.10 GHz; Uplink: 17.30-18.10 GHz | |
| Channel capacity | 16 @ 10.70-10.95 GHz | |
| | 16 @ 10.95-11.20 GHz | |
| | 16 @ 11.45-11.70 GHz | |
| | 16 @ 11.70-12.07 GHz | |
| Channel bandwidth | 26 MHz in FSS, 33 MHz in BSS | |




Configuration of a Boeing-601

Source: Boeing Satellite Systems

# Variants/Upgrades

**Boeing-601HP.** A high-power version of the standard model Boeing-601 featuring up to 10 kilowatts of power, the Boeing-601HP made its debut in 1995. As many as 60 transponders can be accommodated on the Boeing-601HP platform.

**Boeing-601$^+$.** Hughes announced in 1999 that it had expanded the Boeing-601 and Boeing-702 line to include higher power versions, called the Boeing-601$^+$ and Boeing-702$^+$. The Boeing-702$^+$ is capable of producing up to 25 kilowatts.

**GOES.** Civilian weather satellite (see "GOES-Next" report in Tab C).

**UHF Follow-On.** U.S. Navy communications satellite (see "UHF Follow-On/MUOS" report in Tab B).

# Program Review

**Background.** The Boeing-601 model was Hughes' first major attempt to develop a communications satellite with three-axis, or body, stabilization. All previous Hughes satellite models have been cylindrical spacecraft that were spin-stabilized at 50 revolutions per minute. Boeing continues to market the Boeing-376 spinner, but the trend toward larger, more powerful satellites pushed the company toward the three-axis stabilized design.

Design of the Boeing-601 began in 1985, with full-scale development following two years later. The new satellite's first official public presentation took place at the Telecom 87 conference in Geneva, Switzerland.

Optus. Aussat, the Australian domestic satellite service, selected Hughes in 1988 to supply two Aussat B communications satellites in a deal worth some $500 million. New management later changed the satellite's name to Optus. The contract marked the first sale of the Boeing-601.

Optus B1 was launched on a Chinese Long March 2E booster in 1992. Optus B2 was also launched that year on the same rocket model but was lost in an explosion 48 seconds after liftoff. A replacement satellite, Optus 3, was launched on a CZ-2E rocket in 1994.

## *Boeing-601 Tapped for UFO*

The Space and Naval Warfare Systems Command awarded Hughes a $1.9 million contract in 1988 for delivery of 11 UHF Follow-On satellites, plus launch and support. The UFO satellites replenished the Navy's UHF satellite communications system, which included aging Fleet Satellite Communications and Leasat satellites.

The first Boeing-601-based UFO satellite, launched on an Atlas I in 1993, was left stranded in a useless orbit. Later that year the UFO F2 was placed in the proper orbit. Through 2000, Hughes successfully launched an additional eight UFO satellites (F3-F10). UFO F11 was ordered in 1999 and was launched in December 2003.

In 2002, in response to a dire need for critical UHF military communications capacity for U.S. forces in Operation Enduring Freedom, Boeing brought the 601-based UFO F2 spare satellite into operation. UFO-F2 brought in nine additional channels for a 15-percent increase in vital voice and data communications capacity available to U.S. forces in Afghanistan.

No more UFO orders are expected. The narrowband secure communications satellites will be replaced by the Mobile User Objective System starting in 2009/10. A team led by Lockheed Martin was named MUOS prime contractor in September 2004.

Galaxy Application. The Boeing-601 satellite model plays a major role in the Hughes Communications Galaxy constellation, which merged with PanAmSat's system of telecommunications satellites in 1997. Galaxy IV, a Westar IV replacement, and Galaxy VII are dual-frequency types, each equipped with 24 16-watt C-band transponders and 24 50-watt Ku-band transponders. Galaxy IV and VII were launched to 99° W and 91° W, respectively. Both satellites were launched on Ariane 42P boosters, Galaxy VII in 1992, and Galaxy IV in 1993. Hughes also built a ground spare.

In 1998, the Galaxy IV's spacecraft control processor failed, rendering it useless for communications services. Galaxy IV was moved into a higher orbit, and PanAmSat relocated the C-band Galaxy VI into its 99° W position.

Other Boeing-601s operating within the Galaxy constellation include Galaxy III-R, launched in 1995 on an Atlas IIA. A follow-on to this spacecraft, Galaxy VIII-i, provides DirecTV service to the Latin American region and was launched on an Atlas IIAS in 1997. The primary spacecraft control processor failed on Galaxy IIIR in April 2001; it is operating on its backup.

Galaxy X, a Boeing-601HP model with 24 C-band and 24 Ku-band transponders, was lost in 1998 when the

Delta III rocket it was riding on exploded shortly after lift-off from Cape Canaveral, Florida. PanAmSat ordered a replacement unit, Galaxy X-R, in 1998, which was launched on an Ariane 42L in January 2000. The company also ordered the Galaxy IV-R to replace the dysfunctional Galaxy IV satellite. Galaxy IV-R was launched on an Ariane 42L in April 2000 and positioned at 99° W.

In September 2000, the Galaxy VIII-i satellite experienced difficulties with its primary propulsion system, XIPS. Without the use of XIPS, the spacecraft reached the end of its service life in 2003.

In November 2000, the backup spacecraft control processor powering Galaxy VII failed, leaving the satellite useless. Its primary SCP had failed in June 1998, prompting PanAmSat to develop a restoration plan that included the launch of four new Galaxy spacecraft. Galaxy XI was launched in December 1999 as a replacement for the ailing Galaxy VII spacecraft.

In April 2001, the primary SCP on Galaxy VIII-i failed, causing a partial temporary outage of C- and Ku-band capacity to sole user Galaxy Latin America (GLA). PanAmSat ordered the Boeing-601-based Galaxy IIIC to replace it in the second quarter of 2001 for GLA. Galaxy VIII-iR was ordered on the same platform as a backup in case the IIIC was lost during launch. Meanwhile, Galaxy VIII-i operated on its backup unit while it waited for the Galaxy IIIC, which arrived in June 2002 to join PanAmSat's fleet as its 22nd satellite.

In November 2002, PanAmSat canceled the construction of the Galaxy VIII-iR when GLA exercised its pre-launch right to terminate its lease agreement.

Galaxy IIIC is now part of the Power of Five antenna program, which includes the Galaxy XI at 91° W, Galaxy XR at 123° W, Galaxy V at 125° W, and Galaxy IX at 91° W. The system allows cable operators simultaneous access to five Galaxy neighborhood satellites, ensuring continuous delivery to cable head ends. Galaxy IIIC is the culmination of PanAmSat's 30-month, $2 billion fleet-modernization program, which placed an additional seven satellites and 404 transponders in space.

In August 2001, PanAmSat signed the Horizons/Galaxy XIII joint venture agreement with Japan's JSAT Corporation. PanAmSat ordered the Boeing-601HP Horizons satellite to meet specific market demand for satellite-based broadcast and telecommunications services. As part of the agreement, both companies will develop and operate expanded Ku-band services at 127° W.

JSAT licensed the joint Ku-band payload as Horizons through Japan's Ministry of Public Management, Home Affairs, Posts and Telecommunications in October 2002. PanAmSat, however, wholly owns the C-band payload, which it will license through the FCC as Galaxy XIII for U.S. cable network services.

### *DirecTV Emerges with Opportunity for Boeing-601*

DirecTV, a unit of Hughes Electronics Corporation, was formed in 1991. Under the plan, Stanley Hubbard's United States Satellite Broadcasting (USSB) leased five transponders on one of three 16-transponder Boeing-601 satellites, which Hughes located at 101º W. Each satellite features 120-watt Ku-band transponders. DirecTV acquired the business and assets of USSB in 1998 in a deal worth about $1.3 billion.

DirecTV offers a variety of television programming, particularly to rural viewers. The system uses video compression techniques to provide nearly 400 television channels. DirecTV began operations using the first satellite (launched in 1993) in 1994; the second spacecraft was launched that year, followed by DBS-3 in 1995. All three satellites were collocated at 101° W. DBS-1 failed in 1998 when both SCPs failed.

In 1999, Hughes Electronics acquired the 2.3-million-subscriber Primestar DBS medium-power business and its related Tempo high-power satellite assets in two transactions worth about $1.8 billion. Primestar operated a 160-channel service using leased satellite capacity at 85° W. Hughes acquired Tempo 1 and Tempo 2 (renamed DirecTV-5 and -6) and 11 frequencies at the 119° W orbital slot in 1999.

DirecTV ordered a fourth satellite, DirecTV-1-R, a Boeing-601HP model carrying 16 Ku-band transponders and producing 7.5 kilowatts. DirecTV-1-R was launched in 1999 as the first commercial satellite carried by Sea Launch.

DirecTV-4S was ordered in late 1999. It was the fifth Boeing satellite built for DirecTV, and was launched to the 101° W position on an Ariane 4 in November 2001. This spacecraft is the first DirecTV model to use highly focused spot beam technology aimed at providing local channel offerings in metropolitan markets throughout the United States. In May 2002, DirecTV-3 lost the use of its SCP. Hughes Electronics was able to transfer its services to other DirecTV satellites without interruption of service. In November, the company removed DTV-3 from service altogether.

## Boeing-601

DirecTV ordered three new satellites in 2004, but these will be based on the larger Boeing-702 (see the "Boeing-702" report in this tab.)

Astra. Societe Europeenne des Satellites (SES) ordered a pair of Boeing-601s in 1991 for its direct broadcasting system. Each is equipped with eighteen 63-watt Ku-band transponders with six spares. The two spacecraft share the same 19.2° E orbital slot. Astra 1C was launched on an Ariane 42L in 1993, and Astra 1D's launch took place in 1994.

In late 1992, Astra picked the Boeing-601 for the Astra 1E. This satellite was launched in 1995.

Hughes received a contract from SES in 1993 to build Astra 1F, also based on the Boeing-601. This satellite features twenty-two 82-watt Ku-band transponders (plus six spares). Launched in 1996, this satellite shares the same 19.2° orbital slot as the earlier Astra spacecraft.

SES awarded Hughes a contract in 1995 to build the Astra 1G broadcast satellite, the seventh in the Astra constellation, and took an option for an additional unit, the Astra 1H. The new satellites have gallium arsenide solar panels that generate 7 kilowatts of power, allowing SES to extend the Astra system's television and radio coverage to more of Europe. The contract calls for 15 years of operation.

Aside from the new solar panels, Astra 1G and 1H use other enhancements to the Boeing-601 series. The satellites use an advanced antenna design, with two large lightweight reflectors featuring Hughes' contoured-surface technology. Each features a xenon ion propulsion system, which results in a lighter launch weight. Astra 1G and Astra 1H were launched on Proton rockets in 1997 and 1999, respectively.

SES ordered the Astra 2A satellite from Hughes in 1996. Astra 2A is a Boeing-601HP model, similar to the Astra 1G and 1H. The satellite carries 28 active Ku-band transponders (32 for the first five years) operating in the BSS frequency band (11.7 to 12.5 GHz), powered by 100-watt traveling-wave-tube amplifiers. Astra 2A was built in just 13 months and launched on a Proton rocket in 1998; it has a design life of 15 years.

In addition to the new order, SES requested Hughes to modify the Astra 1H satellite to include a Ka-band payload for interactive applications across Europe. The two transponders operate at 18.8 to 19.3 GHz (downlink) and 29.5 to 30 GHz (uplink). The Ka-band payload allows SES to launch services for point-to-point or point-to-multipoint interactive applications across Europe.

SES ordered two additional satellites – Astra 2C and Astra 2D – in 1999. Astra 2D is a Boeing-376HP model, and Astra 2C is based on the Boeing-601HP bus. Astra 2D was launched in December 2000 aboard an Ariane booster, and Astra 2C was launched in June 2001 on a Proton rocket.

Astra 2C carries 28 Ku-band transponders (32 for the first five years) and is expected to be in service for more than 15 years.

AMSC/MSAT. Hughes Aircraft and Spar Aerospace Ltd of Canada were selected in 1990 to build two satellites for mobile communications services (called MSAT) throughout North America. The team's selection was jointly announced by American Mobile Satellite Corp (now Motient Corp), Washington, D.C., and Telesat Mobile Inc (TMI), now TMI Communications, Montreal, Canada.

Two contracts valued at approximately $100 million called for AMSC and TMI to purchase two Boeing-601s jointly. Under the terms of the contract, Hughes supplied the satellite bus, and Spar was responsible for the communications payload.

AMSC and TMI Communications each own and operate one spacecraft, the AMSC-1 (aka MSAT-2) and the MSAT-1, respectively. Each satellite has sufficient capacity to support 400,000 mobile telephone subscribers. The satellites cover the entire continental United States and Canada, as well as Alaska, Hawaii, Puerto Rico, the Virgin Islands, and 200 miles of U.S. and Canadian coastal waters. They can also cover Mexico.

The AMSC-1 marks the first use of Hughes' innovative springback antennas, which are two lightweight 16-foot by 22-foot graphite ovals. Spar built the high-power electronic payload and conducted the integration and test program in the Canadian Space Agency's David Florida Laboratory in Ottawa. The satellite was launched on an Atlas IIA in 1995, followed by the MSAT-1 on an Ariane 42P in 1996.

In January 2002, Motient and TMI formed a joint venture company to consolidate their satellite businesses. The new company, Motient Satellite Ventures (MSV), assumed operations of AMSC-1 and MSAT-1 satellites. MSV is funded by an investment group that includes Motient, Columbia Capital, and Spectrum Equity Investors.

Satmex 3, 4/Solidaridad. The Mexican government selected the Boeing-601 in 1991 for its second-generation Solidaridad satellites, also known as Satmex 3 and 4. The two spacecraft feature 18 C-band

and 16 Ku-band transponders for voice, data, and facsimile transmission and television broadcasting. Each has an L-band capability for mobile telecommunications and rural telephone service. Design life is 12 to 14 years.

Solidaridad 1 was launched on an Ariane 44LP in 1993 to assume the services of the aging Morelos satellites. Solidaridad 2 followed in 1994 aboard an Ariane 44L. In 1999, Solidaridad 1 lost the use of its primary space control processor. Its backup failed in August 2000.

Satmex 5. Telecomunicaciones de Mexico (now Satmex) ordered a Boeing-601HP in 1996 for the Satmex 5 (formerly called Morelos III) communications satellite. Featuring 24 C-band and 24 Ku-band transponders, the new satellite reaches all of Mexico and North and South America from its orbital position of 116.8° W. The satellite's launch on an Ariane 42L took place in 1998.

Space Systems/Loral built the Satmex 6 on its 1300 bus for a launch that was planned for 2003 but finally took place in 2006. Two more Satmex satellites are expected, possibly for a first launch around 2009 or 2010, presenting a slim future for the BSS-601 bus. However, with the Satmex 6 contract already in hand, Space Systems/Loral's 1300 bus may beat it to the punch.

PanAmSat. PanAmSat announced in 1991 that it would purchase three Boeing-601s to augment the sole PAS-1 satellite then in operation. PAS-2, -3, and -4 would be C/Ku-band hybrids with cross-strapping to allow news organizations to uplink in one frequency band and downlink in another. Signal strength is sufficient to allow C-band reception on dishes of 1.8 to 2 meters in diameter, and Ku-band on antennas 1 meter or smaller.

PAS-2 was launched on an Ariane 42P booster in 1994. PAS-3, which was to provide expanded services in the Atlantic Ocean region, was lost in an Ariane 4 accident in 1994; its replacement, PAS-3R, was launched in 1996.

PAS-4 was launched on an Ariane 4 in 1995. The year before, demand for PAS-4 Ku-band services over the Indian Ocean region had already exceeded capacity, prompting PanAmSat to add eight more high-powered Ku-band transponders. The new configuration for the satellite allows for 16- to 54-MHz C-band, 16- to 27-MHz Ku-band and 8- to 54-MHz Ku-band transponders. The primary SCP failed in late 1998; it is currently operating on its backup.

PanAmSat again tapped Hughes for a satellite in 1995, this time for PAS-5, a Boeing-601HP providing digital direct-to-home (DTH) program channels in Latin America. The satellite, the first application for the HP model, was launched on a Proton rocket in 1997. PAS-5 has since been removed from service due to XIPS failure and the subsequent loss of onboard fuel.

PanAmSat ordered PAS-6B in 1998, a Boeing-601HP spacecraft model to provide DTH television transmissions in South America. It was launched on an Ariane 44L in late 1998, carrying a 7-kilowatt payload with 32 Ku-band transponders powered by a combination of 105-watt and 140-watt TWT amplifiers. Its service life was at least 15 years, but failures of the XIPS in 2003 have cut its life by several years.

PAS-6B and Galaxy IV-R have experienced failures to their xenon ion propulsion systems and will likely lose several years of life. Both satellites have backup chemical propellant, but only enough for approximately three years. PanAmSat's VIII-i, which also used the BSS-601HP bus, was taken from service after similar XIPS malfunctions. In July 2003, Boeing recorded a second quarter $265 million loss at its satellite manufacturing division. Boeing's BSS-702 also uses a XIP system, but it is different from the one used on the 601 and has not experienced any in-orbit problems.

PanAmSat also arranged with Hughes for up to three ground spares. One of them, PAS-9, was launched on a Sea Launch Zenit-3SL in July 2000, followed by PAS-10 on a Proton in May 2001.

JCSAT. In 1995, Japan Satellite Systems Inc (JSAT) launched its next-generation satellite, JCSAT-3 (based on the Boeing-601), on a Lockheed Martin Atlas IIAS. The satellite relays voice, data, and television signals, and carries 28-GHz Ku-band transponders with a footprint covering Australia, Hawaii, and Russia, and 12 4-GHz C-band transponders covering most of Asia.

In 1996, JCSAT ordered two more Boeing-601s, JCSATs -4 and -5, which were launched on an Atlas IIAS and an Ariane 44P, respectively, in 1997. JCSAT-5 features 32 active Ku-band transponders, half of which operate at 60 watts in the 27-MHz bandwidth and the other half at 60 or 90 watts in the 36-MHz bandwidth. It carries voice, data, and television signals to Japan, the Asia-Pacific region, and Hawaii.

JSAT ordered the JCSAT-6 from Hughes in 1997. Launched on an Atlas IIAS vehicle in 1999, the satellite carries 32 Ku-band transponders, each with 70 watts.

JCSAT-8 was ordered in 2000 and was delivered to PanAmSat and Japan's JSAT Corporation in early 2003, and launched on an Ariane 4 in March of that year. With a hybrid C-band and Ku-band payload, the satellite provides coverage to North America, Central

America, Alaska, and Hawaii. From its orbital position at 127° W, JCSAT-8 uses PanAmSat's relay station in Napa, California, and JSAT's Hawaii-based station to link U.S. and Asia. It carries 48 active transponders (24 in Ku-band and 24 in C-band), and has a design life of 15 years. JCSAT-8 was launched side by side with Astra 3C, a Boeing-376 satellite, marking the first dual launch of Boeing satellites in five years.

Future JCSAT production seems to be trending toward the Lockheed Martin A2100, with three of the last satellites ordered going to the Boeing competitor.

Palapa. PT Satelit Palapa Indonesia (Satelindo), ordered two Boeing-601s for the Palapa C series in 1993. An Atlas IIAS carried Palapa C1 into orbit in 1996, followed by Palapa C2, which was launched on an Ariane 44L rocket that same year. C-1 was later sold to Turk Telecom.

Each satellite carries 30 C-band and four Ku-band transponders and provides coverage for Indonesia, Southeast Asia, and portions of China, Australia, and New Zealand. Design life of the satellites is 12 years.

ApStar II. Hughes signed a contract with APT Satellite Co Ltd of Hong Kong in 1993 to provide a Boeing-601 satellite. Called ApStar 2 (ApStar 1 used the Boeing-376 bus), the new satellite was to be used primarily for television broadcasting. It had 26 active 52-watt C-band transponders, plus six 50-watt Ku-band transponders and two 120-watt Ku-band transponders. ApStar 2 was lost in an explosion during launch of a Long March 2E in 1995.

TDRS. In 1995, Hughes Space and Communications Company beat one of its chief rivals and the incumbent TDRS satellite provider, TRW Defense & Space Systems Group (now Northrop Grumman), in a contest to build the next generation of NASA communications satellites. NASA awarded Hughes a $482 million contract to build three Tracking and Data Relay Satellites, TDRS-H, -I and -J, the first of which was launched on an Atlas IIA in June 2000.

The TDRSs provide primary, continuous, high-data-rate communications with the Space Shuttle, the International Space Station, and dozens of unmanned scientific satellites in low-Earth orbit, including the Hubble Space Telescope. The new TDRSs operate in the Ku-and S-band frequencies but also feature Ka-band capability. The Ka-band operations double the available bandwidth, boost transmission data rates by some 500 Mbps, reduce interference, and allow for compatibility with European and Japanese satellite systems under development.

TDRS-H, I, and J, are medium-powered versions of the Boeing-601 spacecraft design. Each features two 4.5-meter-diameter single-access antennas, which can simultaneously transmit and receive, allowing for two independent two-way communications functions. In addition, an S-band phased array antenna can receive signals from five spacecraft simultaneously, and another S-band antenna will provide transmission. The necessary 2,040 watts of power will be provided by two wings covered with silicon solar cells.

TDRS-H was launched in June 2000, but a performance shortfall on its multiple-access phased array antenna prevented NASA from accepting the satellite into its fleet until August 2001. The problem impaired the functions of five of the 18 communications services on board, but did not affect the high-data-rate services using the 15-foot-diameter single-access antennas. Boeing isolated a specific material used in the assembly of the antenna as the culprit and implemented corrective measures for TDRS -I and -J. No other -601s carry this antenna.

TDRS-I was launched in March 2002 aboard an Atlas IIA rocket. One of the spacecraft's two propellant fuel tanks did not properly pressurize after launch, leaving TDRS-I in an improper orbit. From the ground, Boeing controllers uplinked commands to reroute fuel tank pressurant around a blocked valve. They then conducted a series of burns to raise the satellite's orbit to 22,300 miles. Six months later, in late September, it reached geosynchronous orbit.

Meanwhile, TDRS-J was launched into space in December 2002 from Kennedy Space Center. Considering the difficulties with TDRS-H and -I, not to mention the PanAmSat and DirecTV satellites, successful operation of TDRS-J is imperative for NASA to consider using the Boeing-601 platform for future applications.

Superbird. Hughes Space and Communications sold a Boeing-601 satellite to Space Communications Corp (SCC) of Tokyo in 1995. Dubbed Superbird C, it was launched in 1997 and will operate for 13 years.

The satellite features 24 active transponders to carry television signals and business communications services throughout Japan, Southern and Eastern Asia, and Hawaii. The transponders power 90-watt traveling wave tubes. Electrical power is provided by two solar panels producing 4,000 watts.

SCC ordered a Boeing-601HP hybrid satellite, Superbird 4, in 1998. It was launched on an Ariane 44LP into the 162° E position in February 2000. The satellite carries 23 Ku-band transponders, plus six

Ka-band transponders, which provide broadband and high-speed data services to the Asia-Pacific region.

In September 2001, SCC contracted with Boeing for another HS-601 satellite, Superbird-6, to assume the services of Superbird-A. Superbird-6 will offer business telecommunications services via its 23 active Ku-band and four Ka-band transponders. In April 2004, ILS launched the satellite into the 158° E orbital position aboard an Atlas IIAS booster.

Superbird-6 was inserted into the precise orbit specified by SCC and Boeing, but the planned release point did not factor in the relative gravitational pull of the Earth and Moon. The resulting altitude required the Superbird-6 to raise its own orbit by about 100 kilometers, thereby consuming too much fuel. Additionally, the satellite suffered a power shortage due to difficulty deploying one of its solar panels.

AsiaSat. Asia Satellite Telecommunications Co Ltd (AsiaSat) selected Hughes in 1996 to build a Boeing-601HP, provide a launch vehicle, and perform ground station upgrades. The satellite, AsiaSat 3, was to serve Asia and neighboring regions.

AsiaSat 3 was stranded in useless orbit shortly after liftoff aboard a Proton rocket from the Baikonur Cosmodrome in 1997.

Insurers declared AsiaSat 3 a total loss for its original purposes. Hughes later acquired the satellite under the agreement that it would try to find a lucrative use for the spacecraft and share the profits with the insurers. Hughes renamed it HGS-1 and sent it around the Moon twice to reposition it into a useful orbit. It was the first commercial communications satellite to travel to the Moon and back. HGS-1's slightly inclined new orbit is unsuitable for normal broadcast and telecommunications services, but may be used for maritime communications, satellite newsgathering, or Internet traffic.

In 1998, AsiaSat ordered an exact replica replacement satellite from Hughes. Designated AsiaSat 3S, the new satellite was launched on a Proton in 1999. It provides television distribution and telecommunications services throughout Asia, the Middle East, Australasia, and the Commonwealth of Independent States, with multiple spot beams for selected areas. It carries 28 active C-band transponders and 16 active Ku-band transponders.

AsiaSat placed an order for AsiaSat 4 in 2000. Launch had been delayed repeatedly but finally took place in April 2003 aboard an Atlas vehicle. From its orbital position of 122° E, the satellite provides broadcast, telecommunications, and broadband multimedia services to the Asia Pacific region, and direct-to-home broadcast services to Hong Kong. AsiaSat 4 is designed to operate for 15 years, carrying 58 transponders: 28 active and 6 spare in C-band, and 20 active and 4 spare in Ku-band.

GOES-N/O/P/Q. NASA's Goddard Space Flight Center awarded Hughes (now Boeing) a $423 million contract in 1998 for the production, integration, and launch of two Geostationary Operational Environmental Satellites, known as GOES. The GOES program is funded and operated by the National Oceanic and Atmospheric Administration (NOAA).

Under terms of the contract, Boeing will deliver two spacecraft into geostationary orbit. Designated GOES-N and GOES-O, the satellites will ensure continuity of the GOES East and GOES West spacecraft. The contract includes fixed-price options for two additional spacecraft, GOES-P and GOES-Q, priced at $190.9 million and $185 million, respectively.

### *Malaysia Chooses the 601*

Binariang Satellite Systems Sdn Bhd and Boeing Satellite Systems signed a contract for the procurement of a Boeing-601HP satellite, designated MEASAT-3. It will join the existing Boeing-built MEASAT-1 and MEASAT-2 spacecraft in the Malaysia-East Asia Satellite (MEASAT) system at 91.5° E and will provide expansion and backup capacity for Binariang to meet the increasing market demand for satellite services within the region. MEASAT-3 will be equipped with 24 C-band and 24 Ku-band transponders, each providing 36 MHz of bandwidth over a 15-year minimum service life. Launch took place in December 2006 on an ILS Proton M.

Satellite Development Center. In 2005, Boeing restructured its satellite manufacturing unit by eliminating the Boeing Satellite Systems division and folding this capacity into a new Satellite Development Center. The SDC falls under Boeing's Space and Intelligence Systems.

The move was made in order to separate Boeing's struggling commercial satellite business from the company's strong government-satellite work. Boeing was quick to reassure customers that the name change would not impact client relations nor would it signal a retreat from the commercial satellite sector.

Boeing-601

# Timetable

| Month | Year | Major Development |
|---|---|---|
| | 1985 | Design phase of Boeing-601 begins |
| Jun | 1987 | Full-scale development begins |
| Aug | 1992 | Launch of first Boeing-601 (Optus B1) on Long March 2E |
| Oct | 1992 | Galaxy VII launches on Ariane 42P |
| Dec | 1992 | Optus B2 lost in Long March 2E accident |
| May | 1993 | Astra 1C launches on Ariane 42L |
| Jun | 1993 | Galaxy IV launches on Ariane 42P |
| Nov | 1993 | Solidaridad-1 launches on Ariane 44L |
| Dec | 1993 | DBS-1 launches on Ariane 44L |
| Jul | 1994 | PAS-2 launches on Ariane 42P |
| Aug | 1994 | Optus B3 launches on CZ-2E |
| Aug | 1994 | DBS-2 launches on Atlas IIA |
| Oct | 1994 | Solidaridad-2 launches on Ariane 44L |
| Nov | 1994 | Astra 1D launches on Ariane 42P |
| Dec | 1994 | PAS-3 lost in Ariane 4 accident |
| Jan | 1995 | ApStar 2 lost in Long March 2E accident |
| Apr | 1995 | AMSC-1 (MSAT-2) launches on Atlas IIA |
| Jun | 1995 | DBS-3 launches on Ariane 42P |
| Aug | 1995 | PAS-4 launches on Ariane 42L |
| Aug | 1995 | JSCAT-3 launches on Atlas IIAS |
| Oct | 1995 | Astra 1E launches on Ariane 42L |
| Dec | 1995 | Galaxy III-R launches on Atlas IIA |
| Jan | 1996 | PAS-3R launches on Ariane 44P |
| Jan | 1996 | Palapa C1 launches on Atlas IIAS |
| Mar | 1996 | MSAT-1 launches on Ariane 42P |
| Apr | 1996 | Astra 1F launches on Proton |
| May | 1996 | Palapa C2 launches on Ariane 44L |
| Feb | 1997 | JCSAT-4 launches on Atlas IIAS |
| Jul | 1997 | Superbird C launches on Atlas IIAS |
| Aug | 1997 | PAS-5 launches on Proton |
| Aug | 1997 | PAS-5 launches on Proton |
| Dec | 1997 | JCSAT-5 launches on Ariane 44P |
| Dec | 1997 | Astra 1G launches on Proton |
| Dec | 1997 | Galaxy VIII-i launches on Atlas IIAS |
| Dec | 1997 | AsiaSat 3 launches on Proton; booster failure places satellite in useless orbit |
| Mar | 1998 | UFO F8 launches on Atlas II |
| Aug | 1998 | Galaxy X lost in Delta III explosion |
| Aug | 1998 | Astra 2A launches on Proton |
| Oct | 1998 | UFO F9 launches on Atlas II |
| Dec | 1998 | Satmex 5 launches on Ariane 42L |
| Dec | 1998 | PAS-6B launches on Ariane 42L |
| Feb | 1999 | JCSAT-6 launches on Atlas IIAS |
| Mar | 1999 | AsiaSat 3S launches on Proton |
| May | 1999 | Orion 3 launches on Delta III; booster failure leaves satellite in useless orbit |
| Jun | 1999 | Astra 1H launches on Proton |
| Oct | 1999 | DirecTV 1-R launches on Sea Launch on booster's first commercial mission |
| Nov | 1999 | UFO F10 launches on Atlas IIA |
| Jan | 2000 | Galaxy X-R launches on Ariane 42L |
| Feb | 2000 | Superbird 4 launches on Ariane 44LP |
| Mar | 2000 | ICO F1 launches on Sea Launch Zenit-3SL (failure) |
| Apr | 2000 | Galaxy IV-R launches on Ariane 42L |
| Jun | 2000 | TDRS-H launches on Atlas IIA |
| Jul | 2000 | PAS-9 launches on Seal Launch Zenit-3SL |
| May | 2001 | PAS-10 launches on Proton |
| Jun | 2001 | Astra 2C launches on Proton |
| Jun | 2001 | ICO-F2 launches on Atlas |

| Month | Year | Major Development |
|---|---|---|
| Nov | 2001 | DirecTV-4S launches on Ariane-44LP H10-3 |
| Mar | 2002 | JCSAT-8 launches on Ariane Ariane-44L H10-3 |
| Mar | 2002 | TDRS-I launches on Atlas IIA |
| Dec | 2002 | TDRS-J launches on Atlas IIAS |
| Apr | 2003 | AsiaSat 4 launches on Atlas IIIB |
| Sep | 2003 | Galaxy XIII/Horizons launches on Zenit from Sea Launch |
| Dec | 2003 | UHF-F11 launches on Atlas III |
| Apr | 2004 | Superbird-6 launches on Atlas IIAS |
| May | 2006 | GOES-N launches on Delta IV |
| Dec | 2006 | Measat-3 launches on Proton |

## Forecast Rationale

At least seven Boeing-601 models have suffered SCP failures to date. Some estimates put the number of affected systems as high as 25, meaning many more failures can be expected. A red flag has gone up among insurance underwriters, which – as we've seen in the past with the Space Systems/Loral 1300 bus – are actively scaling back their coverage for designs that suffer from chronic failures.

Boeing understands this and was reportedly developing a new satellite bus based on the Boeing-601 with the propulsion and payload systems of the larger Boeing-702. The Boeing-702 has not suffered the XIPS failures of the Boeing-601, and this should attract some customers. This model, as yet unnamed or confirmed, would probably cost about half the price of the Boeing-702 (which costs about $200 million). However, there has been no formal release or timeline concerning the debut of this model. This new hybrid bus, if successful, would go a long way in restoring faith in Boeing medium/large satellite buses.

That said, our production forecast remains very low. Cumulative, long-lasting successes and improved insurance coverage on the Boeing-601 would help to repair owner and operator faith in the system. Until that happens, we just don't see many contracts going their way. If a few more years go by without a 601 order, Boeing may wisely decide to offer the 702 model as its only commercial platform.

## Ten-Year Outlook

| ESTIMATED CALENDAR YEAR UNIT PRODUCTION | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Designation or Program | | High Confidence | | | | Good Confidence | | | Speculative | | | |
| | Thru 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
| Boeing Satellite Development Center | | | | | | | | | | | | |
| GOES-P <> BOEING-601 | | | | | | | | | | | | |
| | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |