Space Almanac

On the following pages appears a variety of information and statistical material about space—particularly military activity in space. This almanac was compiled by the staff of *Air Force* Magazine, with assistance and information from Dr. R.W. Sturdevant, Air Force Space Command History Office; Tina Thompson, editor of *TRW Space Log;* Phillip S. Clark, Molniya Space Consultancy, Whitton, UK; Joseph J. Burger, Space Analysis and Research, Inc.; and Air Force Space Command Public Affairs Office.

Figures that appear in this section will not always agree because of different cutoff dates, rounding, or different methods of reporting. The information is intended to illustrate trends in space activity.

Illustration by Leo Cronin

Compiled by Tamar A. Mehuron, Associate Editor

A Boeing Delta IV Heavy lifts a satellite into Geosynchronous Transfer Orbit. The Delta IV Heavy is capable of lifting 33,000 pounds into GTO. Boeing is developing the Delta IV family of rockets in response to the US Air Force Evolved Expendable Launch Vehicle program.

The Year in Space

July 1–17, 1997 Shuttle *Columbia* (STS-94), with crew of seven astronauts, completes record 33-project science mission—fire, plant, crystal, and metal studies—cut short in April because of fuel cell problems.
July 4 Mars Pathfinder lands on surface of Red Planet and, next day, the lander is officially renamed *Carl Sagan* Memorial Station in honor of renowned astronomer who died in December 1996.
July 5 Sojourner rover rolls down stationary lander's ramp onto Martian soil, becoming first mobile, semiautonomous, robotic vehicle to traverse another planet's surface.
July 23 After failed attempt in January 1997, USAF successfully launches first Navstar GPS Block IIR satellite on Delta II booster from Cape Canaveral AS, Fla.
Aug. 5 Air Force Research Lab in its Warfighter-1 hyperspectral sensor demonstration departs from decades of tradition with dedicated intelligence satellites using agency-specific hardware and awards first satellite-imaging contract based on commercial technology to Orbital Sciences.
Aug. 7–19 Shuttle *Discovery* (STS-85) performs environmental study using Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere–Shuttle Pallet Satellite-2 to measure trace gases that deplete ozone layer.
Aug. 22 Mir crew—two Russians and an American—repairs damage caused by collision of cargo ship with Spektr module June 25 and restores much of station's power-generating capacity.
Aug. 22 First successful launch of two-stage Lockheed Martin Launch Vehicle, subsequently renamed Athena I, places NASA's Lewis communications satellite in orbit.
Aug. 25 USAF launches NASA Advanced Composition Explorer to provide real-time data on solar disturbances to National Oceanic and Atmospheric Administration (NOAA) Space Environment Center in Boulder, Colo.
Aug. 27 Proton K rocket from Baikonur, Kazakhstan, launches PanAmSat Corp.'s PAS-5 communications satellite, first commercial spacecraft to use xenon ion propulsion, toward geosynchronous orbit.
Sept. 1 Air Force Reserve Command acknowledges increasing importance of military space operations by activating its first space group and a space operations squadron—the 310th and 8th, respectively.
Sept. 1 Although too late for John Blaha, who missed the 1996 presidential election because he was aboard Mir, democracy enters the Space Age with Texas law permitting registered voters flying in space to cast ballots via electronic mail.
Sept. 3 Boeing, working under USAF contract, unveils prototype of reusable space vehicle designed for military reconnaissance and quick deployment of small satellites.
Sept. 9 James W. Benson announces plan for his Colorado-based SpaceDev, Inc., to become first private organization to land spacecraft—Near Earth Asteroid Prospector—on asteroid to collect and sell data, as well as stake commercial mining claim.
Sept. 11 Global Surveyor arrives at Mars and swings into initial orbit to map planet's atmosphere and surface from physical, chemical, meteorological, and, perhaps, biological perspectives.
Sept. 25–Oct. 6 Amidst congressional questions about whether US presence should continue aboard accident-prone, 11-year-old Russian space station, shuttle *Atlantis* (STS-86) carries astronaut David A. Wolf to Mir and picks up his colleague C. Michael Foale.
Oct. 4 In celebration of 40th anniversary of Sputnik 1 launch, Progress-M 36 cargo freighter carries Sputnik 40/RS-17 from Baikonur to Mir, where cosmonauts will hand-deploy the scale-model satellite Nov. 3.
Oct. 15 USAF Titan IVB Centaur launches plutonium-powered Cassini, with European Space Agency (ESA) Huygens probe and Italian Space Agency high-gain antenna, toward rendezvous with Saturn in July 2004.
Oct. 17 Mid-Infrared Advanced Chemical Laser sends beam 260 miles into space from White Sands Missile Range, N.M., and hits USAF's aging Miniature Sensor Technology Integration III satellite, marking first time US has fired a high-powered laser at an orbiting spacecraft.
Oct. 22 Space Test Experiment Platform (STEP) 4, launched via Pegasus XL booster, fails to deploy successfully, signaling end—with only one successful mission in five attempts (STEP 0–STEP 4)—of USAF Space Test Program experiments designed to evaluate standardized, flexible systems for future spacecraft using new generation of TRW–built, low-cost, lightweight satellites.
Oct. 30 First successful launch to orbit of Ariane 5 rocket from Kourou, French Guiana, carries two instrument platforms to measure launcher performance, as well as several experiments by young graduate trainees.
Nov. 2 Brazil's first space booster, 15 years in development by that nation's Air Force Space Research Institute, is destroyed 65 seconds after liftoff from Alcantara Launch Center.
Nov. 4 NASA's Solar and Heliospheric Observatory spacecraft detects first major flare—X flare—of new 11-year solar cycle.
Nov. 5 First outdoor test of laser-boosted "lightcraft" at White Sands Missile Range uses 10-kilowatt pulse-beam laser to boost vehicle to altitude of 50 feet.
Nov. 6 Astronomers using NASA's Rossi X-Ray Timing Explorer (RXTE) spacecraft report observing space-time distortion by a black hole, the first evidence to support prediction made in 1918 using Einstein's theory of relativity.
Nov. 12 Launch of Orbital Sciences' Cakrawarta-1, or Indostar-1, satellite marks first time outside vendor—Princeton Satellite Systems—supplied whole set of attitude control algorithms and their software implementation to spacecraft manufacturer for geosynchronous satellite.
Nov. 14 Representatives from NASA, USAF, and industry break ground for X-33 RLV launch facility at Edwards AFB, Calif.
Nov. 19–Dec. 5 Shuttle *Columbia* (STS-87) tests sodium–sulfur batteries weighing one-third less than current nickel–hydrogen cells and promising to reduce launch costs by as much as $4 million per flight, as well as a free-flying robotic camera intended for use during assembly of International Space Station.
December Virginia Commercial Spaceflight Authority receives license to operate commercial spaceport in US at NASA's Wallops Flight Facility, Va.
Dec. 16 Galileo Europa Mission begins with first of eight consecutive flybys of Jupiter's moon Europa and captures amazingly detailed images of its surface, which appears to be relatively young ice as thick as 1 kilometer in places.
Dec. 23 Orbcomm passes major milestone in its "Countdown to Global Service" with launch of eight LEO satellites via Pegasus XL from Wallops Flight Facility.
Dec. 24 Colorado-based EarthWatch's EarlyBird 1, first commercial satellite capable of intelligence-quality—3-meter resolution—imaging is successfully launched from Svobodny via Russian Start-1 booster, but ground controllers lose contact with spacecraft Dec. 28.
Dec. 25 Russia's Proton booster grounded after premature cutoff of fourth-stage engine leaves AsiaSat 3 spacecraft short of planned geostationary orbit. The booster will not return to service until April 1998 with the launch of seven Iridium satellites.
Jan. 6, 1998 First launch from Spaceport Florida Authority's Commercial Launch Complex 46 at Cape Canaveral AS and first operational use of Lockheed Martin's three-stage Athena II sends NASA's Lunar Prospector spacecraft toward moon.
Jan. 15 According to Ballistic Missile Defense Organization, a small piece of unidentified orbital debris destroys expended third stage of modified Minuteman II during test flight that involves Raytheon-built warhead tracking sensor—Exoatmospheric Kill Vehicle sensor—over Kwajalein Atoll in the Pacific.
Jan. 16 NASA Administrator Daniel S. Goldin announces that Sen. John Glenn (D–Ohio), at age 77, will return to space in October 1998 as payload specialist on STS-95 to assist with research on the aging process.
Jan. 22–31 Shuttle *Endeavour* (STS-89) carries Andrew S.W. Thomas to Mir to replace Wolf, making Thomas the seventh and last American to inhabit the Russian space station.
Jan. 29 Senior officials from US, Russia, and 13 other nations sign new agreement to cooperate in building International Space Station.
Feb. 10 Upgraded Taurus vehicle, making first use of USAF–designed payload isolator system—a ring of shock absorbers that

replace bolts traditionally used to fasten satellite to launch vehicle—launches US Navy's GeoSat Follow-On oceanographic satellite and two Orbcomm telecommunications satellites.
Feb. 14 Deployment of Globalstar's $2.6 billion, 48-satellite constellation for telecommunications begins with launch of first four spacecraft on Boeing's new Delta II/7420 booster.
Feb. 17 Voyager 1, launched from Kennedy Space Center, Fla., Sept. 5, 1977, becomes most distant human-made object in space at 6.5 billion miles from Earth.
Feb. 24 USAF awards Boeing a four-year contract to design and build experimental Solar Orbit Transfer Vehicle to demonstrate radically cheaper means of boosting payloads into high orbits.
Feb. 25 Pegasus XL launches two small satellites: Student Nitric Oxide Explorer (SNOE), developed by University of Colorado at Boulder, to study how nitric oxide layer at approximately 70 miles altitude causes drag on satellites and the space shuttle; and Teledesic Corp.'s experimental T1 satellite—designed, built, and launched in less than one year—enters orbit to conduct tests for fielding a $9 billion, 288-satellite fleet offering "Internet in the sky" services as early as 2002.
March 5 NASA announces that a neutron spectrometer aboard its Lunar Prospector, launched Jan. 6, has found "significant quantities of water–ice at both lunar poles."
March 5 First Lady Hillary Rodham Clinton announces that USAF Lt. Col. Eileen Collins, already first female shuttle pilot, will become first woman to command a US spaceflight—*Columbia* (STS-93).
March 12 NASA's X-38 lifting body, the crew-return "lifeboat" for International Space Station, completes first unpiloted flight test after being released from beneath wing of B-52 approximately 23,000 feet over the Mojave Desert in Calif.
March 16 Navy's eighth Ultrahigh frequency Follow-on (UFO) Satellite, first DoD communications spacecraft to carry three distinct payloads in three spectra—including package for new Global Broadcast Service (GBS)—enters orbit atop Atlas II launched from Cape Canaveral AS.
April 1 Pegasus XL from Vandenberg AFB, Calif., launches NASA's Transition Region and Coronal Explorer (TRACE) spacecraft to collect data on shape and behavior of upper solar atmosphere, which affects satellite communications and Earth's climate.
April 3 Spin-2 satellite, sponsored jointly by Aerial Images, Inc., of Raleigh, N.C., and Sovinformsputnik, a branch of Russian Space Agency, lands at Baikonur after 45-day mission to obtain 2-meter-resolution images of southeastern US.
April 7 ESA announces that its Infrared Space Observatory (ISO), after orbiting Earth for over two years, has detected water vapor in the atmosphere of Titan, Saturn's largest moon, and elsewhere in universe.
April 17 Ulysses, joint NASA–ESA solar probe launched in 1990, completes first orbit of sun having delivered reams of data about solar wind and sun's magnetic field.
April 17–May 3 Shuttle *Columbia* (STS-90) Neurolab mission, seeking to unlock mysteries of brain and nervous system, uses more than 2,000 animals—rodents, fish, snails, and crickets—to perform several space firsts: direct nerve recordings, joint recording of sleep and breathing, embalming of animals, and surgery on animals meant to survive.
April 28 Ariane 4 from Guiana Space Center, Kourou, launches first Egyptian satellite, NileSat 101, for Egyptian Radio and Television Union.
April 30 Pentagon awards Boeing a three-year, $1.6 billion contract to design, develop, and test variety of components for National Missile Defense system.
May 13 NOAA-K meteorological satellite, launched via Titan II from Vandenberg AFB, includes first flight of Advanced Microwave Sounding Unit to peer through cloud cover for better monitoring of hurricanes and other severe storms.
May 14 NASA announces Hubble Space Telescope has provided unprecedented multiple views of "galactic cannibalism"—massive black hole at center of nearby giant galaxy that is feeding on smaller galaxy.
May 19 Due to failure of its attitude control processors, PanAmSat's Galaxy IV spacecraft begins tumbling and leaves approximately 90 percent of America's 35 million pager customers without service.
May 20 NASA announces that combination of data gathered from Rossi X-Ray Timing Explorer and Advanced Satellite for Cosmology and Astrophysics confirms existence of "magnetars," a special class of neutron stars with magnetic fields one thousand trillion times stronger than Earth's.
May 28 NASA announces Hubble Space Telescope has provided first image of possible planet orbiting another star.
May 29 In first ever transfer of an operational military space system to a civilian agency, Air Force hands control of Defense Meteorological Satellite Program (DMSP) spacecraft to NOAA per 1994 White House directive to merge US military and civilian weather satellite programs.
June 1 Pentagon merges high-level management of classified and unclassified satellite systems under newly established Deputy Assistant Secretary of Defense for Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance (C^3ISR) and Space Systems.
June 2–12 Shuttle *Discovery* (STS-91), using super-lightweight external tank for first time, completes ninth docking mission with Mir and retrieves astronaut Thomas, thereby ending 812 days of continuous US presence in space.
June 17 Hughes, completing first commercial mission to the moon, uses dual lunar flybys to maneuver AsiaSat 3 (now designated HGS-1), left in unusable, highly elliptical orbit after Dec. 25, 1997, launch anomaly, into usable, geosynchronous orbit.
June 17 National Reconnaissance Office lifts veil of secrecy surrounding first US signals intelligence satellite, Galactic Radiation and Background Experiment (GRAB), launched June 22, 1960.

Recent Space Issues and Developments

■ **Advanced technology launchers**
The nation continues its efforts to develop new, lower cost launch vehicles. The Air Force announced in November 1997 that it would award two development contracts for its Evolved Expendable Launch Vehicle (EELV) rather than select a single contractor. In September 1998, USAF expects to award contracts for development and initial launch services to both Boeing and Lockheed Martin. Each contractor has been working the 17-month pre–engineering and manufacturing development phase of the program. EELV is aimed at evolving current launcher systems into a common core family of medium- and heavy-lift boosters with launch costs 25 to 50 percent lower than today's rockets. The first medium launch is scheduled for Fiscal 2002, and the first heavy launch is scheduled for Fiscal 2003. In addition, several US companies, with some USAF support, are planning reusable or inexpensive disposable boosters for smaller satellites. Some of these private boosters are scheduled for launch later this year.

■ **Commercial remote sensing**
This year, two commercial companies operating high-resolution, remote-sensing satellite systems are expected to begin selling data to DoD, as well as many commercial and international customers. EarthWatch, Inc., orbited its first satellite, capable of providing imagery with 3-meter resolution, Dec. 24, 1997. It failed four days later. Space Imaging, Inc., their leading competitor, plans to launch Ikonos 1, capable of 1-meter imagery, this year. EarthWatch will orbit QuickBird 1, an 82-centimeter system in 1998. Ikonos 2 and QuickBird 2 will be launched within the next eight months. Other companies will follow suit in the next few years. The images will be useful for a variety of tactical defense missions and for mapping. The companies also expect to sell imagery to commercial and civil users to help agricultural production, urban planning, transportation planning, and many other endeavors.

■ **Communications**
The LEO multisatellite communications system presents a need for DoD access. One of the methods is to use individual access devices. But a more efficient method is working through a gateway facility. The companies, with the support

of DoD, are looking into a mobile gateway that can be transported to any crisis area. This has the additional capability for high level security in the communicators using the constellation. In another area, USAF last year awarded a $59.2 million contract to develop and produce an engineering prototype for DoD's next generation satellite communications system. This advanced extremely high frequency system will include onboard processing capabilities 10 times that of the current Milstar system. Procurement is expected in 2001, with deployment in 2006.

■ **Space Based Laser (SBL)**

With the spread of weapons of mass destruction and missile technology, the US and its allies are increasingly in danger of ballistic missile attack from many countries. The Patriot missile system is of some help in a theater role, as will be USAF's Airborne Laser system. To supplement them, the Ballistic Missile Defense Organization, USAF, TRW, and Boeing are working on the SBL Readiness Demonstrator program. The SBL could add a third tier to theater defense, and it would be available to defend a theater commander in minutes, rather than the days or weeks required by conventional missile defense batteries. Using the Alpha Laser, the plan is to intercept the boosters when they clear the Earth's atmosphere, as the laser cannot penetrate to the ground.

■ **Space Debris**

The number of objects cataloged by US Space Command in the last two years was in excess of 1,500. The potential for major explosions of payloads or rocket bodies, like the explosion of the Pegasus fourth stage launched in May 1994 that resulted in over 680 new pieces in space, is increasing with all the new payloads being launched. Sometimes there are as many as 12 payloads per launch. Because of this, NASA and DoD have established an Orbital Debris Working Group. The first meeting was held in January 1998. Co-chairmen of the working group are Col. James Brechwald of Air Force Space Command and Nicholas Johnson of NASA. The focus will be on collection and interpretation of orbital debris space surveillance data to better define the current near-Earth environment. They also discussed plans and techniques for evaluating the threat of the 1998 Leonid Meteor Stream/Storm.

■ **Unified Command Plan (UCP) for US Space Command**

The UCP, which was signed into law in January 1998, states that unless otherwise directed by the Secretary of Defense, USCINCSPACE will serve as the single point of contact for military space operational matters, to include communications. USCINCSPACE must coordinate with other appropriate CINCs when undertaking any military activities with other nations or unilaterally in the area of responsibility of another CINC. USSPACECOM will also work with other US government, commercial, and international agencies on military space operations issues, as well as provide space expertise to other CINCs to plan, implement, and assess security assistance. The command will develop space campaign planning as part of the joint planning process for the National Military Strategy. It will also be the focal point for countering the proliferation of weapons of mass destruction in space.

■ **Vision for 2020**

The two principal themes of the US Space Command Vision are dominating the space medium and integrating space-power throughout military operations. To transform the vision into capabilities, the command has adopted four operational concepts: Control of Space, Global Engagement, Full Force Integration, and Global Partnerships. US Space Command's end-to-end planning system uses Joint Vision 2010, the National Security Space Master Plan, and the US Space Command Vision as overarching guidance. Annually the command assesses current and future space requirements, capabilities, and shortfalls in its support of warfighters. With its vision, USSPACECOM expects to extend the time horizons from the Future Years Defense Plan to 2020.

US Space Funding

(Millions of current dollars)

FY	NASA	DoD	Other	Total
1959	$ 261	$ 490	$ 34	$ 785
1960	462	561	43	1,066
1961	926	814	69	1,809
1962	1,797	1,298	200	3,295
1963	3,626	1,550	259	5,435
1964	5,016	1,599	216	6,831
1965	5,138	1,574	244	6,956
1966	5,065	1,689	217	6,971
1967	4,830	1,664	216	6,710
1968	4,430	1,922	177	6,529
1969	3,822	2,013	141	5,976
1970	3,547	1,678	115	5,340
1971	3,101	1,512	127	4,740
1972	3,071	1,407	97	4,575
1973	3,093	1,623	109	4,825
1974	2,759	1,766	116	4,641
1975	2,915	1,892	106	4,913
1976	4,074	2,443	143	6,660
1977	3,440	2,412	131	5,983
1978	3,623	2,738	157	6,518
1979	4,030	3,036	177	7,243
1980	4,680	3,848	233	8,761
1981	4,992	4,828	233	10,053
1982	5,528	6,679	311	12,518
1983	6,328	9,019	325	15,672
1984	6,858	10,195	392	17,445
1985	6,925	12,768	580	20,273
1986	7,165	14,126	473	21,764
1987	9,809	16,287	462	26,558
1988	8,322	17,679	737	26,738
1989	10,097	17,906	560	28,563
1990	11,460	15,616	512	27,588
1991	13,046	14,181	697	27,924
1992	13,199	15,023	769	28,991
1993	13,064	14,106	698	27,868
1994	13,022	13,166	601	26,789
1995	12,543	10,644	629	23,816
1996	12,569	11,514	750	24,833
1997	12,457	11,727	727	24,911
Total	**241,090**	**254,993**	**12,783**	**508,866**

Figures are expressed in current dollars and are rounded. NASA totals represent space activities only. "Other" category includes the Departments of Energy, Commerce, Agriculture, Interior, and Transportation; the National Science Foundation; the Environmental Protection Agency; and other agencies. (Note: NSF recalculated its space expeditures since 1980, making them significantly higher than reported in previous years.) Fiscal 1997 figures are preliminary.

Proposals and Prospects

Launcher Concepts

■ **Astroliner**
The Astroliner from Kelly Space & Technology is a manned Single-Stage-To-Orbit (SSTO) vehicle that will deliver satellites into LEO. It will be towed by a 747 aircraft to 20,000 feet and released. (The towing concept was tested successfully six times between Dec. 20, 1997, and Feb. 6, 1998, using a QF-106 and C-141.) The Astroliner's internal motors will then be fired. When in space, the cargo doors will be opened and the satellite and its booster will be released. The Astroliner will coast up to about 95 nautical miles before it starts its reentry and comes in for a normal airplane-like landing. It can be launched from any airfield of 10,000 feet in length. From Kennedy Space Center, Fla., it can place an 8,800-pound package into a 28.5°, 100–nautical mile orbit. Suborbital test flights are planned for mid-2001, with orbital flights later that year or early 2002. The number to be built will depend on the need for launch services.

■ **Atlas III**
The Atlas IIIA and IIIB are the new names for Lockheed Martin's Atlas IIAR and IIARC. The Atlas III reduces the number of engines and staging events and requires 15,000 fewer parts. Using the Centaur upper stage, the Atlas IIIA can lift 8,940 pounds to GTO. The first flight is expected in December 1998. The Atlas IIIB will use a stretched dual-engine Centaur upper stage and be capable of lifting 9,920 pounds to GTO.

■ **BA-1**
Beal Aerospace Technologies announced June 16 that it would move directly to development of its commercially financed BA-2 Ariane 5–class ELV, bypassing the smaller BA-1 it had intended to build first. The BA-1 was projected to lift about 5,800 pounds to GTO, while the BA-2 will transport payloads weighing more than 11,000 pounds to GTO. The Texas corporation plans to launch the three-stage BA-2 from the UK dependency of Anguilla in the Leeward Islands. The actual launch site will be on Sombrero island (18.5° north), on which Beal has a 98-year lease. The first launches are planned for late 1999.

■ **Delta IV**
The Boeing EELV program is a multiyear US Air Force effort to reduce launch costs by up to 50 percent. The three variants that will be available in the next century are the Small (4,800 pounds to GTO), Medium (10,000 pounds to GTO), and the Heavy (33,000 pounds to GTO).

■ **Intrepid I and II**
Universal Space Lines plans to build two Intrepid ELVs that will be launched from Kodiak Island in the Gulf of Alaska. The simplicity of the design makes them very cost-effective. It is estimated that as few as 10 people will be needed for a launch. Intrepid I will probably be capable of launching 1,000 pounds to LEO polar orbit. Intrepid II will probably be capable of lofting 5,000 pounds to a similar orbit. Current plans call for operations beginning 1999–2000.

■ **K-1**
Kistler Aerospace's K-1 two-stage RLV is scheduled for its first launch in late 1998. Because the US government has not approved launch from Nevada, where Kistler is working to establish a test facility, the first launch will be out of Woomera, Australia. Kistler plans to build five launchers using Russian NK-33 and NK-43 rocket motors. Each will be used 100 times, as both stages will be returned to Earth using parachutes and air bags. Launching due east from the Nevada site, the K-1 can place 3,400 pounds into a 650-mile orbit. A nine-day turnaround is planned.

■ **MLV-D, MLV-A, HLV-L, and HLV-G**
The Lockheed Martin concept for the EELV calls for a family of four vehicles featuring a number of common elements. Those elements include the company's 12.5-diameter, structurally stable Common Core Booster, a common propulsion system featuring the RD-180 engine, and standard commercial payload adapters and avionics. The four vehicles are the MLV-D (8,575 pounds to LEO; 4,060 pounds to GTO), MLV-A (16,100 pounds to LEO; 8,500 pounds to GTO), HLV-L (41,000 pounds to LEO), and HLV-G (13,500 pounds to GEO).

■ **Roton**
Rotary Rocket Co.'s Roton is an inexpensive, piloted, fully reusable SSTO space vehicle. It is unique in that it is designed to return to Earth with a fully loaded cargo bay. Although initially intended for the LEO telecommunications markets, the piloted return capability will appeal to the space manufacturing industry. Rotary Rocket says it can deliver 7,000 pounds to a 200-mile circular orbit from their Mojave, Calif., launch site. The first flight tests are planned for the spring–summer of 1999 and will be suborbital. The first flights to orbit will be in late 1999 or early 2000 and probably carry either developmental or microgravity payloads that will be brought back to Mojave after a one or two orbit flight. Three to five Rotons are to be built initially and production is expected to continue as the market builds. Each Roton is designed to make at least 100 flights. A one- to two-day turnaround is expected.

■ **Sea Launch**
Sea Launch Co. is a partnership among Boeing, Kvaerner Maritime a.s. of Norway, RSC Energia of Moscow, and KB Yuzhnoye/PO Yuzhmash in Ukraine. The assembly and command ship and the launch platform have both passed their sea trials. From their home port of Long Beach, Calif., the first launch of the Galaxy XI satellite is scheduled for October 1998. Launching on the equator at 154° west longitude near Christmas Island, the Zenit launcher can place an 11,000-pound payload into GTO. Sea Launch has 17 additional launches purchased.

■ **VentureStar**
If Lockheed Martin's X-33 (see below) technology proves to be promising, a full-scale RLV will be built. Technology development will continue through 1999 when, if the concept seems viable, vehicle development will take place. The planned VentureStar will be capable of lifting 24,250 pounds to the International Space Station. The cost per pound to orbit is expected to be a small fraction of the current costs of more than $10,000 per pound. The first flight is planned for the beginning of 2004.

■ **X-33**
The Lockheed Martin X-33 is a 53 percent–scale working model of the VentureStar RLV. The X-33 will take off vertically from Edwards AFB, Calif., and land horizontally on 15 planned missions. The short missions (14 minutes) will climb to 31 miles and land at Michael Army Air Field, Utah. The long missions (24 minutes) will climb to 47 miles and land at Malmstrom AFB, Mont. Flights are scheduled to begin mid-1999. If the X-33 technology works, it will be transferred to the VentureStar vehicle that is planned to go into space.

■ **X-34**
The X-34 is Orbital Sciences' RLV technology demonstrator built under contract to NASA. The X-34 will be carried to altitude by an L-1011. When released it will reach speeds of Mach 8 and an altitude of 41 nautical miles. It will then return to its launch base. The technology learned will be used in the VentureStar program or to build a usable follow-on. A 24-hour turnaround on a surge basis is planned.

Satellite Concepts

■ **Combined weather satellites**
Civil and military weather LEO polar satellites are being merged into a single system. The number of satellites will be reduced from four to three, with savings now estimated at $560 million through 1999. DoD and NOAA are coordinating the purchase of the remaining satellites. NOAA, DoD, and NASA are maintaining a tri-agency office for the National Polar-Orbiting Operational Environmental Satellite System, which took responsibility for DMSP in May. Operational control at the primary site in Suitland, Md., began May 29, 1998, with the backup site at Schriever AFB, Colo. The first NPOESS satellite is now scheduled for launch in 2007.

■ **Milstar II**
The last four Milstar satellites will have a higher data-rate capability added to respond to a shift in emphasis since the end of the Cold War from mostly strategic users to a more tactical use. The medium-data-rate payload takes advantage of current technology and includes two Nulling Spot Beam Antennas that give the satellite an antijam capability. The launch dates for the satellites are January and December 1999, November 2000, and October 2001.

■ **Space Based Infrared System (SBIRS)**
Advanced infrared sensing satellites to replace the Defense Satellite Program satellites and perform the four space surveillance missions of missile warning, theater and National Missile Defense, battlespace characterization, and technical intelligence. The SBIRS architecture will deploy a combination of GEO, highly elliptical orbit, and LEO satellite constellations to detect and track advanced missile threats that will not be detected by currently fielded DSP surveillance satellites. SBIRS high constellation will include four GEO satellites and two sensor payloads hosted on highly elliptical orbit satellites. The SBIRS high component, now in the Engineering and Manufacturing Development phase, provides a near-term capability in all four infrared mission areas (first launch in 2001). The SBIRS low constellation of 20 or more LEO satellites further enhances the SBIRS high and provides the unique capability to track ballistic missiles after booster burnout, significantly enhancing our nation's ability to target enemy warheads in midflight for intercept and destruction. The SBIRS low component is currently in program definition and risk reduction phase, with two contractor teams scheduled to launch demonstration satellites in 1999. An SBIRS low EMD milestone decision is planned in Fiscal 2000 with first operational satellite launch projected for Fiscal 2004. SBIRS low was formerly known as the Space and Missile Tracking System and, prior to that, as Brilliant Eyes.

■ **Small satellites**
The National Reconnaissance Office decided in 1996 to move to a smaller class of satellites than the very large spacecraft that had supported its intelligence-gathering mission in the past, after pressure from Congress and an independent advisory panel. Details of the new satellites and design changes to current satellites to downsize them remain classified, but one indication of a drop in satellite size was a decision to switch some NRO payloads from the large Titan IV to Atlas-class launchers in the next decade. The NRO study, completed in 1997, provided intelligence leaders and the Secretary of Defense with options on how to proceed with NRO's adoption of small satellites.
The Air Force Research Lab's Space Vehicles Directorate at Kirtland AFB, N.M., is a leader in the development of advanced technology for small satellites. It is involved in the Space Test Experiment Platform series of satellites, having successfully launched the STEP/Technology for Autonomous Operational Survivability satellite, which has passed its fourth anniversary. Additionally, the directorate is developing the Clementine 2 microsatellite's mother ship, which will be launched later this year. There is also a new, inexpensive series of spacecraft known as MightySat, the first of which is to be launched in September 1998. The Kirtland operation also has a program called the Integrated Space Technology Demonstration, which supports the integration and demonstration of technologies critical to the warfighter. It is also involved in NASA's Lewis (failed) and Clark (canceled) and New Millennium small-satellite projects.

Major Military Space Commands

	Personnel	Budget, FY 1999	Activities
Unified Command US Space Command Peterson AFB, Colo.	851	$18.0 million	Responsible for placing DoD satellites into orbit and operating them; supports unified commands with space-based communications, weather, intelligence information, navigation, and ballistic missile attack warning; enforces space superiority through protection, prevention, negation, and surveillance; ensures freedom of access to and operations in space and denies same to adversaries; applies force from or through space; plans for and executes strategic ballistic missile defense operations; supports NORAD by providing missile warning and space surveillance information; advocates the space and missile warning requirements of the other unified commands.
Service Command Air Force Space Command Peterson AFB, Colo.	37,797	$1.7 billion	Operates military space systems, ground-based missile-warning radars and sensors, missile-warning satellites, national launch centers, and ranges; tracks space debris; operates and maintains the USAF ICBM force (a component of US Strategic Command). Budget includes funding for 11,326 contractor personnel and operations and maintenance for seven bases and 50 worldwide sites.
Naval Space Command Dahlgren, Va.	521	$79.7 million	Operates assigned space systems for surveillance and warning; provides spacecraft telemetry and on-orbit engineering; develops space plans, programs, concepts, and doctrine; advocates naval warfighting requirements in the joint arena. Budget includes funding for nearly 100 contractor personnel and operations and maintenance of headquarters, component commands, and field sites.
Army Space Command Colorado Springs, Colo.	625	$51 million	Manages joint tactical use of DSCS through the 1st Satellite Control Battalion; operates the Army Space Support Teams and Army Space Support Cell; operates the Joint Tactical Ground Stations; operates the Army National Missile Defense Element; manages the Army Astronaut Program.

Major Military Satellite Systems

Global Positioning System (GPS)
Constellation of 24 satellites used by military and civilians to determine a precise location anywhere on Earth. A small receiver takes signals from four GPS satellites and calculates a position. The satellites transmit a highly precise signal to authorized users, permitting accurate navigation to within 16 meters. DoD has deployed more than 110,000 GPS receivers to US government and allied users, with terminals becoming much more widely available since the 1991 Persian Gulf War. Civilians use a commercial version of the terminals, with a degraded signal with an accuracy to 100 meters. Receivers are priced as low as $200. The less accurate signal prevents adversaries from using GPS for precision weapons targeting. Civilian users are working to obtain a much better signal through auxiliary equipment, known as differential GPS, that corrects the degradation. DoD has become increasingly concerned about enemy use of GPS during a conflict and has begun an effort called NAVWAR (navigation warfare) to protect its advantage while preventing adversary use of GPS. GPS III is an overarching requirements process to develop a document that encompasses civil, military, scientific, and commercial use of GPS. It is also referred to as positioning, navigation, and timing. The current constellation is 25 operational Block II/IIA series and one test-and-checkout satellite. The GPS office has procured 21 Block IIR replenishment satellites. GPS IIR-2 was destroyed in the January 1997 Delta rocket explosion. GPS IIR-3 was launched July 23, 1997. No IIR satellites are scheduled for launch in 1998. One is scheduled for February 1999 and a second in September 1999.

Defense Satellite Communications System (DSCS)
Constellation of five primary spacecraft in geostationary orbit provides voice, data, digital, and television transmissions between major military terminals and National Command Authorities. Secure voice and high-data-rate communications, operating in superhigh frequency, primarily for high-capacity fixed users. Four DSCS satellites remain to be launched in 1999–2003. Launches are scheduled for July 1999, July 2000, May 2002, and May 2003. The Air Force has funded a program that will allow more tactical users access on DSCS. The Pentagon is developing the architecture to replace the capacity in the next decade.

Milstar
The first two Milstars of an intended constellation of four that would provide coverage between 65° north and 65° south latitude are in orbit. The first $1 billion Milstar was launched Feb. 7, 1994, and the second Nov. 5, 1995. Originally conceived as a communications system that could survive a nuclear conflict and connect National Command Authorities to commanders of ships, aircraft, and missiles during a war, the system's design and application have been altered in the aftermath of the Cold War. Milstar currently serves tactical forces as well as strategic, and the last four Milstars (Milstar IIs) will include medium-data-rate payloads able to transmit larger volumes of data up to 1.45 mbps. The four are scheduled for launch between January 1999 and October 2001. All satellites have low-data-rate payloads providing communications at five bps to 2.4 kbps. The system can handle a data stream equal to 50,000 fax pages an hour and 1,000 simultaneous users. The satellites are designed to be jam-proof and use sophisticated techniques to provide secure communications.

Defense Support Program (DSP)
Infrared detectors aboard these satellites have provided early warning of ballistic missile attack to NORAD since the 1970s. During Operation Desert Storm, operators at Space Command used DSP data to provide warnings of Scud attacks to theater commanders, though DSP was not designed to spot and track smaller missiles. Information on procurement situation, number of satellites launched, and number to be launched is classified. DoD intends to replace the system with a new spacecraft, the Space Based Infrared System (SBIRS), designed to spot and track the smaller, faster-burning theater missiles that have proliferated in recent years. It will be fielded in three increments: Increment 1, Fiscal 1999; Increment 2, Fiscal 2002; and Increment 3, Fiscal 2006.

Defense Meteorological Satellite Program (DMSP)
Weather satellites, whose flight operations were transferred from the military to NOAA in May 1998, operate in LEO to collect and disseminate global weather information directly to the warfighter and government agencies. Operating in a two-satellite constellation, each spacecraft collects high-resolution cloud imagery (visible and infrared) from a 1,800-mile-wide area beneath it. Satellites collect other specialized data, such as atmospheric temperature and moisture, snow cover, precipitation intensity and area, and oceanographic and solar–geophysical information for DoD air, sea, land, and space operations. Five satellites remain to be launched (USAF launched its last April 4, 1997). Joint satellites will be procured with NOAA for the follow-on system, with the first to be launched in the 2007–10 time frame. It will be called the National Polar-Orbiting Operational Environmental Satellite System (NPOESS).

Fleet Satellite Communications (FLTSATCOM)
Constellation of four satellites operated by USN, USAF, and the presidential command network. A secure link among the three, providing ultrahigh frequency (UHF) communications. Satellites carry 23 channels for communications with naval forces, nuclear forces, and National Command Authorities. The last two FLTSATCOM satellites (Flights 7 and 8) carry extremely high frequency (EHF) payloads. In operation since 1978 in geostationary orbit, with a minimum of four satellites needed for worldwide coverage.

UHF Follow-On (UFO) Satellites
New generation of satellites providing UHF communications to replace FLTSATCOM satellites. UFO satellites have 39 channels—compared to the FLTSATCOM's 23—are bigger, and have higher power. Compatible with the same terminals used by the earlier systems. UFO-4 was first in the series to include an EHF communications payload with enhanced antijam telemetry, command, broadcast, and fleet interconnectivity. EHF channels provide an additional 11 channels. Ten UFO satellites were ordered; eight have been launched and are operational.

Global Broadcast System (GBS)
GBS is projected to be a high-speed, one-way broadcast communications system that provides high-volume information worldwide directly to theater warfighters. GBS will provide data to large populations of dispersed users with small, mobile receiver terminals. These terminals will allow data to be disseminated directly to lower-echelon forces, providing current weather, intelligence, news, imagery, and other mission- essential information. GBS will be implemented in three phases. Phase 1 will consist of leased commercial transponders. Phase 2 will consist of GBS packages aboard three UFO satellites. Phase 3 will be an objective system consisting of military assets, a commercial leased system, or a combination of the two.

Dark and Spooky
An undisclosed number and type of intelligence satellites are operated by intelligence agencies in cooperation with the military. The missions and, especially, the capabilities are closely guarded secrets. Using a page from the Soviet book on naming satellites, the US government started in the 1980s calling all government satellites "USA" with a sequential number. This allowed them to keep secret the names of satellites which monitor the Earth with radar, optical sensors, and electronic intercept capability. Most of the names of satellites, like White Cloud (ocean reconnaissance), Aquacade (electronic ferret), and Trumpet (Sigint) are secret and cannot be confirmed by the Intelligence Community. However, the move to declassify space systems has begun, leading to the release of selected information on some systems. Pictures of the Lacrosse radar imaging satellite have been released without details on the system. Details of the Keyhole optical imaging systems in the Corona program have been released.

Major US Civilian Satellites in Military Use

Advanced Communications Technology Satellite (ACTS)
NASA's ACTS was launched in 1993 on the space shuttle to demonstrate Ka-band communications and onboard switching equipment. Military use of the technology demonstration satellite included communications service to US Army troops deployed to Haiti in 1994.

Geostationary Operational Environmental Satellite (GOES)
NOAA operates GOES-8 and GOES-9. GOES-7 provides backup. Satellites hover at 22,300 miles altitude over the equator, monitoring storms and tracking their movements for short-term forecasting. Satellites are a new design that has improved spatial resolution and full-time operational soundings of the atmosphere.

Globalstar
Globalstar L.P. filed an FCC application in June 1991 for the $2 billion Globalstar mobile communications system of 48 satellites plus eight satellites as backups. Two Delta II ELVs have launched eight satellites through May 1998. The system has been used for communications links already and will continue to be expanded with three launches of SL-16 Zenit launchers out of Tyuratam, Kazakhstan, with 12 satellites each in 1998. The three final launches will also be from Tyuratam on SL-04 Soyuz launchers with four satellites each, during the first half of 1999. Globalstar has looked into a deployable mobile gateway that would permit more terminals in a given area and allow DoD to add security controls.

International Telecommunications Satellite Organization (Intelsat)
Established in 1964 to own and operate a global constellation of communications satellites. Has 143 members and 21 operational satellites. Intelsat is in the process of restructuring into an intergovernmental treaty organization, which will continue to provide basic global satellite connectivity, and a commercial spin-off called New Skies, which has been given seven satellites for competitive services like broadcasting and data networking. The restructuring was approved in May 1998. US signatory to Intelsat is Comsat Corp. The US military uses the system for routine communications and to distribute the Armed Forces Radio and TV Services network and used it to set up a Very Small Aperture Terminal data network for field commanders in Bosnia in 1996.

International Mobile Satellite Organization (IMSO)
Formerly called International Maritime Satellite (Inmarsat) Organization. They have retained the Inmarsat name for their satellites. Established in 1979 to own and operate satellites for mobile communications. Has 79 member–countries. IMSO is 10.5 percent owner of ICO Global Communications, which was spun off as a separate company in 1995 to develop a satellite system for global mobile telephone services. IMSO operates seven satellites, including the first three of the third-generation Inmarsat 3 series and one Inmarsat 2 satellite. Another three satellites serve as orbital spares. The spacecraft are sometimes used by military forces for peacetime mobile communications services. Inmarsat is prohibited by convention from being used for military purposes. Briefcase- and laptop-sized satellite telephone terminals are used to communicate through the satellites. Inmarsat use in Somalia and Bosnia included the transmission of medical data and supply orders.

Iridium
Motorola announced its Iridium mobile communications system plan in June 1990. Iridium, Inc., was incorporated in June 1991 to own and operate the 66-satellite (plus spaceborne spares) system. The system applications are for voice, fax, and data transmission worldwide using satellite-to-satellite or satellite-to-ground interfaces. The system was started with the launch of five satellites on a Delta II out of Vandenberg AFB on May 5, 1997. During the past year 21 satellites were launched from Tyuratam on three Russian SL-12 Proton launchers; six (plus two test loads) were launched from Taiyuan, China, on four Long March-2C boosters; 45 have been launched on nine Delta IIs from Vandenberg AFB. The system is being checked out and will be operational in September 1998. DoD will have 2,000 people using the system, with a potential for as many as 120,000 users.

Landsat
US government's civilian remote sensing satellite system. Used in polar orbit since 1972. Carries a multispectral scanner able to operate at a resolution of 30 meters and provide imagery that can be computer enhanced to show deforestation, expanding deserts, crop blight, and other phenomena. Space Imaging EOSAT operates the aging Landsat 5. The government plans to launch a Landsat 7 satellite in 1998. Military use of Landsat imagery has included mapping and planning for tactical operations.

NOAA-12, NOAA-14, and NOAA-15
Three polar orbit satellites for long-term forecasting of weather, operated by NOAA. The satellites fly in a 450–nautical mile orbit, carrying visible and infrared radiometry imaging sensors and ultraviolet sensors to map ozone levels in the atmosphere. Provide weather updates for all areas of the world every six hours to civil and military users. NOAA-15 (formerly NOAA-K) was launched May 13, 1998, and will replace NOAA-12. Launch of NOAA-L is planned for 1999.

Orbcomm
Orbcomm Global L.P.'s first two satellites were launched in April 1995, and commercial service in the US and Canada began in February 1996. Orbcomm is a joint venture between Orbital Sciences and Teleglobe of Canada. Orbcomm's satellite constellation will comprise 28 satellites, with an additional eight satellites to serve as ground

Worldwide Launches by Site, 1957–97

Launch Site	Nation	Launches
Plesetsk	Russia	1,445
White Sands Missile Range, N.M.	US	1,105
Tyuratam/Baikonur	Kazakhstan	1,019
Vandenberg AFB, Calif.	US	527
Cape Canaveral AS, Fla.	US	524
Poker Flat Research Range, Alaska	US	274
JFK Space Center, Fla.	US	107
Kapustin Yar	Russia	83
Kourou	French Guiana	102
Tanegashima	Japan	29
Shuang Cheng-tzu/Jiuquan	China	23
Wallops Flight Facility, Va.	US	24
Uchinoura	Japan	22
Xichang	China	23
Indian Ocean Platform	Kenya	9
Sriharikota	India	8
Edwards AFB, Calif.	US	5
Hammaguir	Algeria	4
Taiyuan	China	4
Yavne	Israel	3
Woomera	Australia	2
Svobodny	Russia	2
Gando AFB, Canary Islands	Spain	1
Total		**5,345**

spares or to be launched at a later date. Twelve were launched by early May 1998, with two more Pegasus XL launches of eight satellites each this year that will complete the constellation. Orbcomm worked with DoD in 1995 and 1996 to demonstrate the potential military use of the commercial system under the Joint Interoperability Warfighter Program. Today, DoD still possesses more than 100 Orbcomm units.

Orion Network Systems
Orion provides commercial satellite-based, rooftop-to-rooftop communications in support of the US Army Trojan program via its own satellite as part of the GE American Communications team. In addition, Orion provides communications through wholesalers to other DoD agency locations in the US and Europe. Rooftop-to-rooftop support is also provided to selected State Department overseas locations. Orion continues its support for the troops deployed to Bosnia via leased capacity to the Defense Information Systems Agency. Future plans include the launch and operation of two additional satellites covering the Asia–Pacific region, Latin America, the Middle East, and parts of Russia and Africa.

***Satellite Pour l'Observation de la Terre* (SPOT)**
Remote sensing satellite system developed by the French space agency, CNES. Owned and operated by a commercial firm, SPOT Image S.A. of Toulouse. Two satellites produce images with resolution as fine as 10 meters and can be used for stereoscopic viewing for three-dimensional terrain modeling. SPOT 3 failed Nov. 17, 1996, and SPOT 1 was reactivated to augment SPOT 2. SPOT 4 was launched March 24, 1998. SPOT 5 is scheduled for launch in 2002. DoD is a large customer, purchasing the images for mission-planning systems, terrain analysis, mapping, and humanitarian missions.

Tracking and Data Relay Satellite System (TDRSS)
NASA operates six TDRSS satellites to form a global network that allows low Earth orbiting spacecraft, such as the space shuttle, to communicate with a control center without an elaborate network of ground stations. The geostationary TDRSS, with its ground station at White Sands, N.M., allows mission control in Houston to maintain nearly constant contact with the shuttle. Other satellites using TDRSS include the Hubble Space Telescope, Compton Gamma Ray Observatory, Earth Radiation Budget Satellite, and military satellites. TDRSS satellites have been used since 1983. Three next generation satellites are being built for use with the shuttle, the space station, and other satellites. Hughes is the contractor for TDRS H, I, and J. The first will be launched in July 1999.

Current US Launchers

Delta II

Space Shuttle

Titan II

Athena I and II
Lockheed Martin's Athena I and II launch vehicles (formerly LMLV-1 and LMLV-2) provide access to space for small to medium class spacecraft. The Athena II launched the Lunar Prospector Jan. 6, 1998. The Athena I is capable of lifting 1,750 pounds to LEO. The Athena II increases that lift to 4,350 pounds to LEO. Both Athenas can be launched from Cape Canaveral AS and Vandenberg AFB.

Atlas I
The Atlas I, built by Lockheed Martin, is a two-stage commercial launcher using the Centaur booster as the upper stage. It is now also used to launch GOES satellites for NASA, the X-ray Astronomy Satellite for the Italian Space Agency, and three UHF satellites for the US Navy. The four versions can lift from 5,000 to 8,000 pounds into LEO of 100 nautical miles out of Cape Canaveral AS. The Atlas I can additionally lift 5,235 pounds to GTO.

Atlas II
A modified version of Lockheed Martin's Atlas I, the Atlas II carries DSCS satellites and NASA and commercial payloads. No failures have occurred with Atlas II since first launch Dec. 7, 1991. The range of payloads Atlas II through IIAS can lift into GTO from Cape Canaveral AS is 6,193 to 8,197 pounds and 12,144 to 15,895 pounds to a polar LEO from Vandenberg AFB. The Atlas IIAR and Atlas IIARC have been renamed Atlas IIIA and IIIB, respectively. They are listed in the "Proposals and Prospects" section.

Delta II
Boeing's medium launcher, in operation since 1989. Payloads include Global Positioning System and other DoD, scientific, and commercial communications satellites. Launches from both Cape Canaveral AS and Vandenberg AFB. Available in two- and three-stage configurations. It can lift

Pegasus, mounted under an L-1011

Titan IV

4,120 pounds to GTO or 7,000 pounds into a 448–nautical mile sun synchronous orbit. Has successfully launched 27 GPS satellites for USAF. Delta IIs have launched most of the Iridium satellites and all of the GlobalStar units to date. Before the end of 1998 they will also have launched Deep Space 1 and the Landsat 7 Earth Resource satellite.

Delta III
Boeing's Delta III carries twice the payload of the Delta II. It can loft 8,400 pounds to GTO and 18,280 pounds to LEO. The first launch this summer is with the Galaxy X communications satellite. There are six more confirmed launches before the end of the century.

Titan II
Modified ICBM. Lockheed Martin has modified 14 missiles; seven have been launched successfully, with the latest transporting the NOAA-15. Puts 4,200 pounds into polar LEO. The Air Force used it for DMSP launches. Titan II is launched from Vandenberg AFB. It launched the Clementine 1 mission to the moon and places NOAA satellites into orbit. In the 1960s, NASA used Titan II for the manned Gemini flights.

Titan IV
Lockheed Martin's heavy-lift launcher, adapted from an ICBM as an expendable launch system. First launch in 1989. Due to be phased out in 2003. Carried DSP, Milstar, and DoD classified satellites and NASA's Cassini to Saturn. With Centaur G-prime upper stages, lifts 10,200 pounds to GEO, 39,000 pounds to LEO, and 32,000 pounds into polar LEO. Titan IVB, with upgraded solid rocket motors that provide 25 percent better performance, had its first launch Feb. 23, 1997. The Air Force has contracted for 40 Titan IVs; 24 (with one failure) have been launched as of May 1998. Lockheed Martin will complete production of all Titan IVs by 1999 but will continue to launch them until all have been expended.

Pegasus
Orbital Sciences' three- or four-stage winged small launcher, dropped from an L-1011, the Pegasus and Pegasus XL can carry payloads of 440 to 615 pounds to a 250–nautical mile polar orbit. The Pegasus launchers have flown 21 missions with two failures. The fourth stage, a Star 27 booster, can give a satellite an Earth escape capability. Three launches are scheduled for the remainder of 1998.

Space Shuttle
Manned space transportation system operated by United Space Alliance, a venture between Lockheed Martin and Boeing, under contract to NASA. Launched from Kennedy Space Center, lifts 46,000 pounds to 160–nautical mile, 28.5°-inclined orbit. The delta-winged orbiters have flown 91 missions since its first use April 12, 1981. There was one failure. The shuttle carries scientific and military payloads and experiments and will be used to assemble the International Space Station starting in 1999.

Taurus
Orbital Sciences' ground-launched, four-stage rocket with some Pegasus commonality. The Taurus family can launch from Cape Canaveral AS into a 216–nautical mile orbit from 2,684 to 3,850 pounds to LEO; or from 1,125 to 1,472 pounds to GTO. From Vandenberg AFB, they can launch 2,024 to 2,904 pounds into a sun synchronous LEO. Two launches have taken place to date. A classified payload and the STEX satellite are scheduled for mid- to late 1998.

Russian Space Activity

Russian Launches, 1997

	Launches	Spacecraft
Communications	4	9
Photoreconnaissance	3	3
Unmanned space station resupply	4	4
Navigation	2	2
Military ocean surveillance	1	1
Manned flight	2	2
Science	1	1
Commercial	7	20
Remote Sensing	1	1
Early Warning	3	3
Total	**28**	**46**

Russian Launch Site Activity, 1997

Spacecraft	Number of launches
Baikonur Cosmodrome, Tyuratam, Kazakhstan	
Proton-K	9
Soyuz-U	7
Tsyklon-M	1
Total	**17**
Plesetsk Cosmodrome, Plesetsk, Russia	
Tsyklon-3	1
Kosmos-3M	2
Soyuz-U	3
Molniya-M	3
Total	**9**
Svobodny Cosmodrome, Siberia, Russia	
Start-1	2
Total	**2**

(Maiden launch from Svobodny was March 4, 1997.)

Russian Operational Spacecraft, 1997

Mission	Type	Number
Communications	Kosmos (Strela-3)	20
	Gonets-D	6
	Raduga/Raduga-1	7
	Gorizont	9
	Molniya-1	4
	Molniya-3	4
	Kosmos (Geizer)	2
	Luch/Luch-1	2
	Ekran-M	1
	Ekspress	2
	Gals	2
	Radio Rosto	1
	Kupon	1
Navigation	Kosmos GLONASS	20
	Kosmos (military)	6
	Kosmos (civil)	4
Meteorology	Meteor-2	1
	Meteor-3	2
	Elektro (GOMS)	1
Early warning	Kosmos (Oko)	6
	Kosmos (Prognoz)	2
Electronic intelligence	Kosmos (Tselina-2)	3
	Kosmos (EORSAT)	2
Photoreconnaissance	Kosmos (Orlets-1)	1*
	Kosmos (Yantar-4K class)	1
	Kosmos (Arkon-1)	1
Remote sensing	Okean-O	2
	Resurs-01	1
	Sich	1
	Resurs-F1M	1*
Geodesy	Kosmos (Etalon)	2
	Kosmos (GEO-IK)	1
Radar calibration	Kosmos (Romb)	1
Space station activity	Mir	1
	Kvant-1	1
	Kvant-2	1
	Kristall	1
	Spektr	1
	Priroda	1
	Soyuz TM	1
	Progress M	1
Scientific activity	Foton	1*
	Coronas-I	1
	Granat	1
	Interball	2
	MAGION 4 (Czech satellite)	2

Older spacecraft sometimes are placed in orbital standby mode.

*Number of spacecraft launched during 1997 but not in orbit at the end of the year.

Comparison of US and Russian Space Activity

Military vs. Civilian Launches

Military

Year	US	Russia	Year	US	Russia
1978	8	60	1957	0	0
1979	4	60	1958	0	0
1980	5	64	1959	6	0
1981	5	59	1960	10	0
1982	6	68	1961	19	0
1983	7	58	1962	31	5
1984	12	63	1963	26	7
1985	6	64	1964	32	15
1986	3	63	1965	28	25
1987	6	62	1966	32	27
1988	6	53	1967	24	46
1989	13	42	1968	20	49
1990	13	45	1969	16	51
1991	9	30	1970	15	55
1992	12	32	1971	10	60
1993	13	26	1972	11	53
1994	12	26	1973	8	58
1995	9	15	1974	6	52
1996	11	8	1975	7	60
1997	9	10	1976	7	74
Total	**486**	**1,614**	1977	9	69

Civilian

Year	US	Russia	Year	US	Russia
1978	24	28	1957	0	2
1979	12	27	1958	7	1
1980	8	25	1959	5	3
1981	13	39	1960	6	3
1982	12	33	1961	10	6
1983	15	40	1962	21	15
1984	10	34	1963	12	10
1985	11	34	1964	25	15
1986	3	28	1965	35	23
1987	2	33	1966	41	17
1988	6	37	1967	34	20
1989	5	32	1968	25	25
1990	14	30	1969	24	19
1991	9	29	1970	14	26
1992	16	22	1971	22	23
1993	10	21	1972	20	21
1994	14	22	1973	15	28
1995	18	17	1974	18	29
1996	22	17	1975	21	29
1997	28	18	1976	19	25
Total	**641**	**935**	1977	15	29

Manned Spaceflights

	US		Russia	
Year	Flights	Persons	Flights	Persons
1961	2	2	2	2
1962	3	3	2	2
1963	1	1	2	2
1964	0	0	1	3
1965	5	10	1	2
1966	5	10	0	0
1967	0	0	1	1
1968	2	6	1	1
1969	4	12	5	11
1970	1	3	1	2
1971	2	6	2	6
1972	2	6	0	0
1973	3	9	2	4
1974	0	0	3	6
1975	1	3	4	8
1976	0	0	3	6
1977	0	0	3	6
1978	0	0	5	10
1979	0	0	2	4
1980	0	0	6	13
1981	2	4	3	6
1982	3	8	3	8
1983	4	20	2	5
1984	5	28	3	9
1985	9	58	2	5
1986	1	7	1	2
1987	0	0	3	8
1988	2	10	3	9
1989	5	25	1	2
1990	6	32	3	7
1991	6	35	2	6
1992	8	53	2	6
1993	7	42	2	5
1994	7	42	3	8
1995	7	42	2	6
1996	7	43	2	5
1997	8	53	2	5
Total	**118**	**573**	**85**	**191**

Payloads by Mission, 1957–97

Category	US	Russia
Platforms	**0**	**492**
Earth orbital science	**226**	**211**
Automated lunar, planetary	**59**	**86**
Moon	25	34
Mercury	1	0
Venus	8	33
Mars	11	19
Outer planets	5	0
Interplanetary space	9	0
Applications	**490**	**509**
Communications	355	294
Weather	101	74
Geodesy	20	34
Earth resources	12	97
Materials processing	2	10
Piloted activities	**157**	**243**
Earth orbital	107	90
Earth orbital (related)	13	145
Lunar	20	0
Lunar (related)	17	8
Launch vehicle tests	**11**	**22**
General engineering tests	**57**	**4**
Reconnaissance	**430**	**1,088**
Photographic	249	798
Electronic intelligence	94	131
Ocean electronic intelligence	39	83
Early warning	48	76
Minor military operations	**44**	**161**
Navigation	**84**	**213**
Theater communication	**0**	**535**
Weapons-related activities	**2**	**56**
Fractional orbital bombardment	0	18
Antisatellite targets	2	18
Antisatellite interceptors	0	20
Other military	**18**	**1**
Other civilian	**3**	**2**
Total	**1,581**	**3,623**

Military Functions in Space

Communications
Provide communications from National Command Authorities to Joint Force Commander. Provide communications from JFC to squadron-level commanders. Permit transfer of imagery and situational awareness to tactical operations. Permit rapid transmission of JFC intent, ground force observations, and adaptive planning.

Environmental/Remote Sensing
Use space systems to create topographical, hydrographic, and geological maps and charts and to develop systems of topographic measurement.

Space Environment/Meteorological Support
NOAA took over flight operations of DMSP weather satellites from the Air Force in May 1998. The Air Force operates ground-based systems and directs NOAA on the operations of space-based systems to provide solar/geophysical support to the warfighter. The weather systems provide data on worldwide and local weather systems affecting combat operations.

Missile Defense
Employ space assets to identify, acquire, track, and destroy ballistic and cruise missiles launched against forward deployed US forces, allied forces, or US territory.

Navigation
Operate GPS network and certain smaller Navy systems. Enable commanders to determine precise locations of friendly and enemy forces and targets. Permit accurate, timely rendezvous of combat forces. Map minefields and other obstacles.

On-Orbit Support
Track and control satellites, operate their payloads, and disseminate data from them.

Reconnaissance and Surveillance
Identify possible global threats and surveillance of specific activity that might be threatening to US or allied military forces or US territory. Reduce effectiveness of camouflage and decoys. Identify "centers of gravity" in enemy forces. Accurately characterize electronic emissions.

Space Control
Control and exploit space using offensive and defensive measures to ensure that friendly forces can use space capabilities, while denying their use to the enemy. This mission is assigned to USCINCSPACE in the Unified Command Plan.

Spacelift
Prepare satellite and booster, joining the two. Conduct checkout prior to launch, carry out launch, and conduct on-orbit checkout.

Strategic Early Warning
Operate satellites to give national leaders early warning of all possible strategic events, including launch of ICBMs. Identify launch locations and impact areas. Cue area and point defense systems.

Tactical Warning/Attack Assessment
Discharge the NORAD mission calling for use of all sensors to detect and characterize an attack on US or Canadian territory. US Space Command carries out similar tactical warning in other theaters.

Force Application
US Space Command is identifying potential future roles, missions, and systems which, if authorized by civilian leadership for development and deployment, could attack terrestrial targets from space in support of national defense.

Gen. James V. Hartinger, here with Gen. Jerome F. O'Malley (left) and Edward C. Aldridge Jr., became the first commander of Air Force Space Command, upon its establishment Sept. 1, 1982, at Peterson AFB, Colo.

Air Force Space Command Headquarters, Peterson AFB, Colo.

Commander
Gen. Richard B. Myers*

- **Space Warfare Center** • Schriever AFB, Colo.
  Commander **Brig. Gen. William R. Looney III**

- **14th Air Force** • Hq., Vandenberg AFB, Calif.
  Commander **Maj. Gen. Gerald F. Perryman Jr.**
  - **21st Space Wing,** Peterson AFB, Colo.
  - **30th Space Wing,** Vandenberg AFB, Calif.
  - **45th Space Wing,** Patrick AFB, Fla.
  - **50th Space Wing,** Schriever AFB, Colo.

- **20th Air Force** • Hq., F.E. Warren AFB, Wyo.
  Commander **Maj. Gen. Donald G. Cook**
  - **90th Missile Wing,** F.E. Warren AFB, Wyo.
  - **91st Missile Wing,** Minot AFB, N.D.
  - **341st Missile Wing,** Malmstrom AFB, Mont.

*Confirmed by Senate June 25, 1998; assumes position upon retirement of Gen. Howell M. Estes III.

Air Force Space Acquisition Organizations

Air Force Materiel Command • Wright–Patterson AFB, Ohio
Commander **Gen. George T. Babbitt Jr.**

- **Space and Missile Systems Center** • Los Angeles AFB, Calif.
  Commander **Lt. Gen. Roger G. DeKok***
  - **Defense Meteorological Satellite SPO**[1]
  - **Launch Programs SPO**
  - **Advanced Systems SPO**
  - **Satellite and Launch Control SPO**
  - **Navstar Global Positioning System JPO**[2]
  - **Space & Missile Test & Evaluation Directorate,** Kirtland AFB, N.M.

*DeKok nominated June 18, 1998, to be DCS, Plans & Programs, USAF, Pentagon.

Air Force Program Executive Office • Pentagon
Air Force Acquisition Executive (Vacant)

Program Executive Officer for Space Programs
Brent R. Collins

- **MILSATCOM**
- **Launch Systems**
- **Space Based Infrared System**
- **Evolved Expendable Launch Vehicle**
- **ICBM/National Missile Defense**

[1]System Program Office [2]Joint Program Office

Major US Agencies in Space

National Imagery and Mapping Agency (NIMA)
Headquarters: Bethesda, Md.
Established: Oct. 1, 1996
Director (acting): Army Maj. Gen. James C. King

Mission, Purpose, Operations
Provide timely, relevant, and accurate imagery intelligence and geospatial information to support national security objectives. This DoD–chartered combat support agency is also a member of the Intelligence Community and has been assigned, by statute, important national-level support responsibilities.

Structure
Three principal directorates: Operations, Systems and Technology, and Corporate Affairs.
Major facilities in Virginia, Maryland, Washington, D.C., and Missouri, with the NIMA College located at Ft. Belvoir, Va. Also, customer support teams and technical representatives stationed around the world at major customer locations.
Personnel: Classified

Central Intelligence Agency (CIA)
Office of Development and Engineering
Headquarters: Washington, D.C.
Established: 1973
Director: Dennis Fitzgerald

Mission, Purpose, Operations
Develop systems from requirements definition through design, testing, and evaluation to operations. Works with systems not available commercially. Disciplines include laser communications, digital imagery processing, real-time data collection and processing, electro-optics, advanced signal collection, artificial intelligence, advanced antenna design, mass data storage and retrieval, and large systems modeling and simulations. Work includes new concepts and systems upgrades.
Structure: Classified
Personnel: Classified

National Aeronautics and Space Administration (NASA)
Headquarters: Washington, D.C.
Established: 1958
Administrator: Daniel S. Goldin

Mission, Purpose, Operations
Explore and develop space for human enterprise, increase knowledge about Earth and space, and conduct research in space and aeronautics. Operate the space shuttle and lead an international program to build a permanently occupied space station, which will be launched starting in 1998. Launch satellites for space science, Earth observations, and a broad range of technology Research and Development. Conduct aeronautical R&D.

Structure
Ten centers around the US: Johnson Space Center, Houston; Marshall Space Flight Center, Huntsville, Ala.; Kennedy Space Center, Fla.; Lewis Research Center, Cleveland; Langley Research Center, Hampton, Va.; Ames Research Center, Mountain View, Calif.; Dryden Flight Research Center, Edwards AFB, Calif.; Stennis Space Center, Bay St. Louis, Miss.; Jet Propulsion Laboratory, Pasadena, Calif.; and Goddard Space Flight Center, Greenbelt, Md.

Personnel
Civilians 18,500
Contractors 166,000

National Oceanic and Atmospheric Administration (NOAA)
Headquarters: Washington, D.C.
Established: Oct. 3, 1970
Administrator and Undersecretary for Oceans and Atmosphere: Dr. D. James Baker

Mission, Purpose, Operations
Provide satellite observations of the global environment by operating a national system of satellites. Explore, map, and chart the global ocean and its resources and describe, monitor, and predict conditions in the atmosphere, ocean, and space environment. Its National Environmental Satellite, Data, and Information Service processes vast quantities of satellite images and data. Its prime customer is NOAA's National Weather Service, which uses satellite information in creating forecasts.

Structure
National Environmental Satellite, Data, and Information Service
National Weather Service
National Ocean Service
National Marine Fisheries Service
Office of Oceanic and Atmospheric Research
NOAA Corps
Office of Sustainable Development and Intergovernmental Affairs
Coastal Ocean Program

Personnel
National Environmental Satellite, Data, and Information Service 839
Other NOAA employees 11,055
Total 11,894

National Reconnaissance Office (NRO)
Headquarters: Chantilly, Va.
Established: September 1961
Director: Keith R. Hall

Mission, Purpose, Operations
Design, build, and operate reconnaissance satellites to support global information superiority for the US. It has operated hundreds of satellites during its nearly 37-year history. Responsible for innovative technology; systems engineering; development, acquisition, and operation of space reconnaissance systems; and related intelligence activities. Supports monitoring of arms control agreements, military operations and exercises, natural disasters, environmental issues, and worldwide events of interest to the US.

Structure
NRO is a DoD agency, funded through part of the National Foreign Intelligence Program, known as the National Reconnaissance Program. Both the Secretary of Defense and Director of Central Intelligence have approval of the program. Four offices and four directorates report up to the level of the director. Offices are management services and operations, plans and analysis, space launch, and operational support. Directorates are signals intelligence systems acquisition and operations, communications systems acquisition and operations, imagery systems acquisition and operations, and advanced systems and technology.

Personnel
Staffed by CIA (37 percent), USAF (51 percent), Navy (7 percent), Army (1 percent), and National Security Agency (4 percent), both military and civilian employees. Exact personnel numbers are classified.

National Security Agency (NSA)
Headquarters: Ft. Meade, Md.
Established: 1952
Director: Lt. Gen. Kenneth A. Minihan, USAF

Mission, Purpose, Operations
Protect US communications and produce foreign intelligence information. Supply leadership, products, and services to protect classified and unclassified information from interception, unauthorized access, and technical intelligence threats. In the foreign signals intelligence area, the central point for collecting and processing activities conducted by the US government, with authority to produce signals intelligence in accord with objectives, requirements, and priorities established by the CIA director with the advice of the National Foreign Intelligence Board.

Structure
Established by a presidential directive in 1952 as a separate agency within DoD under the direction, authority, and control of the Secretary of Defense, who serves as the executive agent of the US government for the production of communications intelligence information. The Central Security Service was established in 1972 by a presidential memorandum to provide a more unified cryptological organization within DoD. The NSA director also serves as chief of the CSS and controls the signals intelligence activities of the military services.
Personnel: Classified

Other Agencies
The White House Office of Science and Technology Policy; Defense Advanced Research Projects Agency; Ballistic Missile Defense Organization; US Space Command and the component commands of the Air Force, Navy, and Army; NORAD; and the FAA's Office of Commercial Space Transportation.

Other Spacefaring Nations

For eight years after Sputnik went into orbit in October 1957, the two superpowers alone were able to launch spacecraft. France broke the monopoly in 1965, establishing an independent capability. China, India, Japan, and Israel also have hurled satellites into space using indigenously built rockets. European capabilities are embodied in the European Space Agency (ESA), cur-rently a group of 14 nations.

China launched its first satellite in 1970 and has had at least 50 satellites on orbit. China also launches science and military reconnaissance satellites and has made commercial launches for other nations. Its primary launch site is near Jiuquan, in northern China; a newer site is near Xichang, in southeastern China, and a third is at Taiyuan. The launch program relies on the Long March series of rockets, one version of which has a cryogenic upper stage. Chinese astronauts were in training in the 1970s, but the country has indefinitely deferred manned spaceflight.

ESA was formed in 1975 for civilian activities only. It has 14 members: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the UK. A major activity is development of the Ariane rocket. France led development of the booster, which is launched from Kourou, French Guiana. Arianespace, a private company, markets Ariane and manages launches. France, Italy, and Germany all have strong programs.

India launched its first satellite, Rohini 1, into orbit in July 1980. The Indian Space Research Organization operates an offshore Sriharikota Island launch site in the Bay of Bengal. India's booster program includes the Satellite Launch Vehicle, Augmented Satellite Launch Vehicle, and Polar Satellite Launch Vehicle. The latter is capable of placing spacecraft into polar orbit. India is particularly interested in remote sensing for resource, weather, and reconnaissance purposes. An Indian cosmonaut flew on a Soviet Soyuz mission in 1984.

Israel launched its first test satellite, Ofeq 1, into orbit September 1988 and has had two more successful flights since then. Launched from the Palmachim missile range in the Negev Desert, satellites in the Ofeq series are thought to be dedicated to military purposes. Ofeq is seen as a step toward creation of a military satellite reconnaissance system. The prime booster is Shavit, possibly based on the Jericho 2 missile.

Japan put its first satellite into orbit in 1970 and has made at least 51 successful satellite launches. Communications, remote sensing, weather, and scientific satellites are on orbit. Japan's satellite program is run by the National Space Development Agency and the Institute of Space and Astronautical Science. Main launch sites are Kagoshima, on Kyushu, southwest of Tokyo, and Tanegashima, an island south of Kyushu. The Mu series of launch vehicles is used to orbit scientific satellites and toss spacecraft into deep space. N-1 and N-2 rockets were based on the US Delta. The H-series is replacing the N-1 and N-2 boosters. The H-2 booster was first launched in 1994.

Launches

Year	France	China	Japan	Europe	India	Israel
1965	1					
1966	1					
1967	2					
1968						
1969						
1970	2	1	1			
1971	1	1	2			
1972			1			
1973						
1974			1			
1975	3	3	2			
1976		2	1			
1977			2			
1978		1	3			
1979			2	1		
1980			2		1	
1981		1	3	2	1	
1982		1	1			
1983		1	3	2	1	
1984		3	3	4		
1985		1	2	3		
1986		2	2	2		
1987		2	3	2		
1988		4	2	7		1
1989			2	7		
1990		5	3	5		1
1991		1	2	8		
1992		4	1	7	1	
1993		1	1	7		
1994		5	2	6	2	
1995		2	1	11		1
1996		3	1	10	1	
1997		6	2	12	1	
Total	**10**	**50**	**51**	**96**	**8**	**3**

Italy	3
Japan	5

Spacefarers

(As of end of 1997)

Nation	Persons
Afghanistan	1
Austria	1
Belgium	1
Bulgaria	2
Canada	6
Cuba	1
Czechoslovakia	1
France	7
Germany	8
Hungary	1
India	1
Mexico	1
Mongolia	1
Netherlands	1
Poland	1
Romania	1
Russia	86
Saudi Arabia	1
Switzerland	1
Syria	1
Ukraine	1
United Kingdom	1
United States	233
Vietnam	1
Total	**368**

Payloads in Orbit

(As of end of 1997)

Launcher/operator	Objects
Argentina	3
Australia	6
Brazil	6
Canada	17
China	24
Czechoslovakia	3
ESA	35
France	30
France/Germany	2
Germany	15
India	17
Indonesia	9
Israel	2
Italy	7
ITSO[1]	54
Japan	63
Luxembourg	7
Malaysia	2
Mexico	5
NATO	8
Norway	2
Philippines	1
Portugal	1
Russia	1,364
Saudi Arabia	6
South Korea	4
Spain	5
Sweden	6
Thailand	3
Turkey	2
United Kingdom	24
United States	778
Total	**2,511**

[1]International Telecommunications Satellite Organization

Selected NASA Projects Fiscal 1999 Proposal Current Dollars

■ **AXAF, $92.2 million.** Space science. The Advanced X-Ray Astrophysics Facility spacecraft to study the composition and nature of galaxies, stellar objects, and interstellar phenomena. Scheduled for launch aboard the space shuttle in 1998 but schedule under review.

■ **Cassini, $8.8 million.** Space science. Spacecraft mission to Saturn. Seeks data on formation of solar system and on how the building blocks needed for the chemical evolution of life are formed elsewhere in the universe. Launched in October 1997. Scheduled to arrive in Saturnian system in 2004.

■ **Discovery, $126.5 million.** Space science. Lunar Prospector launched in January 1998. In March, its instruments detected significant amounts of water–ice in the shaded polar regions. The Stardust mission, scheduled for launch in February 1999, is designed to gather dust samples from the comet Wild-2 and return the samples to Earth for analysis. Discovery is intended as NASA's low-cost planetary exploration program. NASA's next two Discovery missions are: Genesis, which will collect samples of charged particles in the solar wind and return to Earth laboratories for study; and the Comet Nucleus Tour (Contour), which will intercept and collect data on three comets. Launch for Genesis is January 2001, and launch for Contour is June 2002.

■ **Earth Observing System, $659.1 million.** Earth Science Enterprise (formerly Mission to Planet Earth) environmental project. Series of satellites to document global climatic change and observe environmental processes. Scheduled launches start in 1998.

■ **Explorer, $114.3 million.** Space science. Four missions and spacecraft development. Study of X-ray sources, solar corona, and organic compounds in interstellar clouds. Scheduled launches each year from 1997 to 2000.

■ **Galileo, $30.0 million.** Space science, planetary exploration. Funds to support operations of mission to explore Jupiter and its moons.

■ **Mars Surveyor, $164.0 million.** Space science. Launch of the Mars Global Surveyor orbiter occurred in November 1996. It arrived in September 1997. Development of spacecraft for new Mars exploration strategy. Mapping, in situ climate and soil measurements, and eventual goal to return rock samples from Mars. Follow-on orbiter launch is planned for December 1998, and the first lander launch is scheduled for January 1999.

■ **New Millennium Spacecraft, $90.0 million.** Space science. Flight-technology demonstration to produce new microspacecraft with reduced weight and life-cycle costs. Funding increase to spur deep-space mission technology and development. Deep Space 1 mission will test several new technologies during its flight. Launch is scheduled for October 1998.

■ **Relativity (Gravity Probe B), $37.6 million.** Space science. Major test of Einstein's general theory of relativity. Development of a gravity probe. Launch is scheduled for March 2000.

■ **Space shuttle, $3.1 billion.** Spaceflight. Program emphasizes continuing improvement of safety margins, fulfillment of the flight manifest, reduction of costs, and launch of nine flights for Fiscal 1999 and nine in Fiscal 2000.

The Golden Age of NASA

Name	**Project Mercury**
Duration	**Nov. 3, 1958–May 16, 1963**
Cost	$392.1 million (cost figures are in then-year dollars)
Distinction	First US manned spaceflight program
Highlight	Astronauts are launched into space and returned safely to Earth
Number of flights	Six
Key events	**May 5, 1961** Lt. Cmdr. Alan B. Shepard Jr. makes first US manned flight, a 15-minute suborbital trip. **Feb. 20, 1962** Lt. Col. John H. Glenn Jr. becomes first American to orbit Earth. **May 15, 1963** Maj. L. Gordon Cooper Jr. begins flight of 22 orbits in 34 hours.
Name	**Project Gemini**
Duration	**Jan. 15, 1962–Nov. 15, 1966**
Cost	$1.3 billion
Distinction	First program to explore docking, long-duration flight, rendezvous, space walks, and guided reentry
Highlight	Dockings and rendezvous techniques practiced in preparation for Project Apollo
Number of flights	10
Key events	**June 3–7, 1965** Flight in which Maj. Edward H. White II makes first space walk. **Aug. 21–29, 1965** Cooper and Lt. Cmdr. Charles "Pete" Conrad Jr. withstand weightlessness. **March 16, 1966** Neil A. Armstrong and Maj. David R. Scott execute the first space docking. **Sept. 15, 1966** Conrad and Richard F. Gordon Jr. make first successful automatic, computer-steered reentry.
Name	**Project Apollo**
Duration	**July 25, 1960–Dec. 19, 1972**
Cost	$24 billion
Distinction	Space program that put humans on the moon
Highlights	Neil Armstrong steps onto lunar surface. Twelve astronauts spend 160 hours on the moon.
Number of flights	11
Key events	**May 28, 1964** First Apollo command module is launched into orbit aboard a Saturn 1 rocket. **Jan. 27, 1967** Lt. Col. Virgil I. "Gus" Grissom, Lt. Cmdr. Roger B. Chaffee, and White die in a command module fire in ground test. **Oct. 11–22, 1968** First manned Apollo flight proves "moonworthiness" of spacecraft. **Dec. 21–27, 1968** First manned flight to moon and first lunar orbit. **July 16–24, 1969** Apollo 11 takes Armstrong, Col. Edwin E. "Buzz" Aldrin Jr., and Lt. Col. Michael Collins to the moon and back. Armstrong and Aldrin make first and second moon walks. **Dec. 7–19, 1972** Final Apollo lunar flight produces sixth manned moon landing.

NASA Spending on Major Space Missions

FY 1999 Proposal, Current Dollars

Project Office	Millions
Human spaceflight	$5,511.0
Space science	2,058.4
Earth science	1,372.0
Aeronautics	1,305.0
Mission communication services	380.0
Life and microgravity sciences	242.0
Safety and mission assurance	35.6
Total	**$10,904.0**

Upcoming Shuttle Flights

FY 1999 Proposal

Month/Year	Mission	Name
10/1998	**STS-95**	*Discovery*
12/1998	**STS-88**	*Endeavour*
1/1999	**STS-93**	*Columbia*
5/1999	**STS-96**	*Atlantis*
6/1999	**STS-92**	*Discovery*
8/1999	**STS-97**	*Endeavour*
9/1999	**STS-99**	*Atlantis*

■ **International Space Station, $2.3 billion.** Spaceflight. International manned space facility. Ultimate capacity for seven persons. Crew capability for three persons to be available with delivery of Soyuz crew transfer vehicle in Fiscal 1999. Efficiencies gained through design changes and participation of the Russians in an international partnership.

■ **US/Russian Cooperative Program.** (Funding ended in Fiscal 1997, but activities still ongoing.) Spaceflight. Program provides for contract with Russian Space Agency for services and hardware and joint activities with Russia on the Mir. The ninth and final joint shuttle–Mir mission took place in June 1998.

■ **Other space operations, $526.6 million.** Space science. Operation of Hubble Space Telescope, the AXAF program, the Compton Gamma Ray Observatory, and the International Solar Terrestrial Physics program. Support of planetary missions includes Galileo, NEAR, Mars Surveyor, Cassini, Lunar Prospector, and Stardust.

US Space Launch Sites

Orbital Sites

Cape Canaveral AS, Fla.
Located 28.5° N, 80° W. One of two primary US space launch sites. Handles piloted, lunar, and planetary launches and launches of satellites into geostationary orbit. First US satellite in space, first manned spaceflight, and first flight of a reusable spacecraft all originated here. Scene of more than 3,000 launches since 1950. Tract covers more than 15,000 acres. Cape Canaveral also provides range operations for NASA's shuttle, military, civil, and commercial space launches, and military ballistic missile tests.

John F. Kennedy Space Center, Fla.
Located 28° N, 80° W. NASA's primary launch base for the space shuttle. Occupies 140,000 acres of land and water on Merritt Island, adjacent coastal strand, and the Indian and Banana Rivers and Mosquito Lagoon surrounding the center. NASA holdings include 84,031 acres. The Merritt Island location was better suited than nearby Cape Canaveral to serve as a launch site for the Apollo program's 363-foot-tall Saturn V, the largest rocket ever built. With the 1972 completion of the Apollo lunar landing program, KSC's Complex 39 was used to launch four Skylab missions and for the Apollo spacecraft for the Apollo–Soyuz Test Project. In the mid- to late 1970s, the Kennedy facilities were modified to accommodate the space shuttle program.

Vandenberg AFB, Calif.
Located 35° N, 121° W. Second of two primary US launch sites. Used for satellites (mostly weather, remote sensing, navigation, communications, and reconnaissance) that must go into polar orbits. Provides basic support for R&D tests for DoD, USAF, and NASA space, ballistic missile, and aeronautical systems. Furnishes facilities and essential services to more than 60 aerospace contractors on base. Base covers 98,400 acres. Originally Army's Camp Cooke, taken over by the Air Force June 7, 1957.

Wallops Flight Facility, Va.
Located 38° N, 76° W. Founded in 1945 on Wallops Island, Va. One of the oldest launch sites in the world. First research rocket launched July 4, 1945. Resumed orbital launches in 1995 with the EER Systems Conestoga rocket. From 1961 to 1985, 21 satellites were placed in orbit from Wallops using the Scout vehicle. Wallops currently serves as the East Coast launch site for Orbital Sciences' Pegasus missions. Additional small launch vehicles are expected to be launched from Wallops with the establishment of the Virginia Space Flight Center. Site for launches of NASA's suborbital sounding rockets and the like. Conducts about 15 suborbital launches per year. Covers 6,166 acres on Virginia's eastern shore.

Spaceport Florida Facility
Located 28.5° N, 80° W. New commercial launch site at Cape Canaveral AS. Designed to meet growing demand for private-sector access to space and to tap underutilized military launch sites. Operated by the Spaceport Florida Authority, a state agency. Launch Complex 46 launchpad has been converted to handle small to medium commercial launch vehicles, boosting satellites into equatorial orbit. The Navy originally used LC-46 to support land-based testing of the Trident II fleet ballistic missile program. The Naval Ordnance Test Unit will maintain launch capability for future programs. Lockheed Martin launched NASA's Lunar Prospector Jan. 6, 1998, aboard their Athena II. Expected to handle up to 12 launches per year.

California Spaceport
Located 34.33° N, 120.37° W. Designed to handle polar and near-polar LEO launches, the California Spaceport is a commercial launch facility at Vandenberg AFB. Spaceport Systems International, a limited partnership formed by ITT Federal Services Corp. and California Commercial Spaceport, Inc., is to build and operate the facility. The spaceport will provide both commercial launch and payload processing capability. Payload processing is operational. Construction of the launch duct was completed in early 1997, with design plans ongoing for launchpad completion. The launchpad will have an initial rate of 15 launches per year.

Alaska Spaceport
Located 57.5° N, 153° W. Designed for polar and near-polar launches, the dual-use commercial launch facility is sited on 3,100 acres at Kodiak Island, Alaska. With funding secured by the Alaska Aerospace Development Corp., Alaska's spaceport authority, construction for the Kodiak Launch Complex is scheduled for completion by June 1999. KLC's initial operational capability is September 1998 for AADC's first scheduled launch by the Air Force. There will be an eventual capacity for nine launches per year. KLC will launch payloads up to 8,000 pounds into polar LEO, primarily communications, remote sensing, and scientific satellites. The site has the capacity for a total of three launchpads. With its large launch corridor, the spaceport would provide an additional backup launch capability for both polar satellites and for DoD's ICBM launches at Vandenberg AFB.

Virginia Space Flight Center
Located 38° N, 76° W. NASA and the Commonwealth of Virginia reached an agreement in March 1997 for the establishment of a Virginia Spaceport on the south end of Wallops Island. Construction of the commercial launch facility began in 1998. The flight center can currently accommodate some small ELVs using up to a Castor 120 power plant at the EER Systems launch tower located on the island, in addition to payload processing. When fully operational, the flight center is expected to be able to handle launch vehicles up to the Athena III.

Suborbital Sites

Poker Flat Research Range, Alaska
Located 65° N, 147° W. Owned by the University of Alaska. Established 1968. Operated by the Geophysical Institute under contract to NASA's Goddard Space Flight Center, Wallops Flight Facility. Only US launch facility currently in polar region. World's largest land-based range. Payload recovery and observatories in flight zone extending north 600 kilometers to coast and over Arctic Ocean. Conducts launches primarily to investigate aurora borealis and other middle- to upper-atmosphere phenomena. Site of more than 274 military and civilian launches.

White Sands Missile Range, N.M.
Located 32° N, 106° W. Established July 9, 1945, as White Sands Proving Ground. Site of July 16, 1945, Trinity shot, world's first test of atomic bomb, and of postwar test and experimental flights with captured German V-2 rockets. Scene of Feb. 24, 1949, launch of Bumper rocket, whose second stage achieved altitude of 244 miles—becoming the first man-made object in space. Now used for launches of suborbital sounding rockets. New Mexico is in the process of establishing a spaceport adjacent to White Sands for commercial orbital launches.

Space Firsts

Feb. 24, 1949 Project Bumper, the first fully successful two-stage rocket-launch into space, reaches a record altitude of 244 miles.

July 24, 1950 Bumper–WAC becomes first missile launched from Cape Canaveral, Fla.

Sept. 20, 1956 US Jupiter C rocket achieves record first flight, reaching an altitude of 682 miles and landing 3,400 miles from Cape Canaveral.

Aug. 21, 1957 First successful launch of Soviet R7 rocket, which six weeks later will loft Sputnik into orbit.

Oct. 4 USSR launches Sputnik 1, the first man-made satellite, into Earth orbit.

Nov. 3 First animal in orbit, a dog, is carried aloft by Soviet Sputnik 2.

Dec. 6 First US attempt to orbit satellite fails when Vanguard rocket loses thrust and explodes.

Dec. 17 First successful Atlas booster launch.

Jan. 31, 1958 Explorer 1, first US satellite, launched.

May 15 USSR launches first automatic scientific lab aboard Sputnik 3, proving satellites can have important military uses.

Dec. 18 Project Score spacecraft conducts first US active communication from space.

Feb. 28, 1959 Discoverer 1 becomes first satellite launched from Vandenberg AFB, Calif.

June 9 First engineer group arrives at Cape Canaveral to prepare Atlas booster carrying first Mercury capsule.

Aug. 7 Explorer 6 spacecraft transmits first television pictures from space.

Sept. 12 Soviet Union launches Luna 2, which two days later becomes first man-made object to strike the moon.

April 1, 1960 TIROS 1 becomes first US weather satellite to go aloft.

April 13 Transit 1B becomes first US navigation satellite in space.

May 24 Atlas D/Agena A booster places MIDAS II, first early warning satellite, in orbit.

June 22 US performs first successful launch of multiple independently instrumented satellites by a single rocket.

Aug. 11 Capsule ejected from Discoverer 13 parachutes into Pacific Ocean and becomes first orbital payload ever recovered.

Aug. 12 First passive communications carried via Echo 1 satellite.

Aug. 19 Capsule containing first satellite photographs of Soviet Union ejected from Discoverer 14 becomes first orbital payload recovered in midair by C-119 Flying Boxcar.

Jan. 31, 1961 Preparing for manned spaceflight, US launches a Mercury capsule carrying the chimpanzee Ham on a suborbital trajectory.

Feb. 16 Explorer 9 becomes first satellite launched from Wallops Island, Va.

April 12 Soviet cosmonaut Yuri Gagarin pilots Vostok 1 through nearly one orbit to become first human in space.

May 5 Lt. Cmdr. Alan B. Shepard Jr., aboard Freedom 7 Mercury capsule, becomes first American in space, climbing to 116.5 miles during suborbital flight lasting 15 minutes, 28 seconds.

Oct. 27 First flight of Saturn rocket marks beginning of more than 11 years of Apollo launches.

Feb. 20, 1962 Project Mercury astronaut Lt. Col. John H. Glenn Jr., aboard the Friendship 7 capsule, completes the first US manned orbital flight.

July 17 Air Force Capt. Robert M. White earns astronaut wings when he reaches altitude of nearly 60 miles in rocket-powered X-15, the first aircraft to be flown to the lower edge of space, considered to be 50 miles.

Dec. 14 Mariner 2 passes Venus at a distance of 21,600 miles, becoming the first space probe to encounter another planet.

June 16, 1963 Valentina Tereshkova of USSR pilots Vostok 6 to become first woman in space.

July 26 Hughes Corp.'s Syncom 2 (prototype of EarlyBird communications satellite) orbits and "parks" over the Atlantic to become world's first geosynchronous satellite.

Oct. 17 Vela Hotel satellite performs first space-based detection of a nuclear explosion.

July 28, 1964 First close-up lunar pictures provided by Ranger 7 spacecraft.

Aug. 14 First Atlas/Agena D standard launch vehicle successfully fired from Vandenberg AFB.

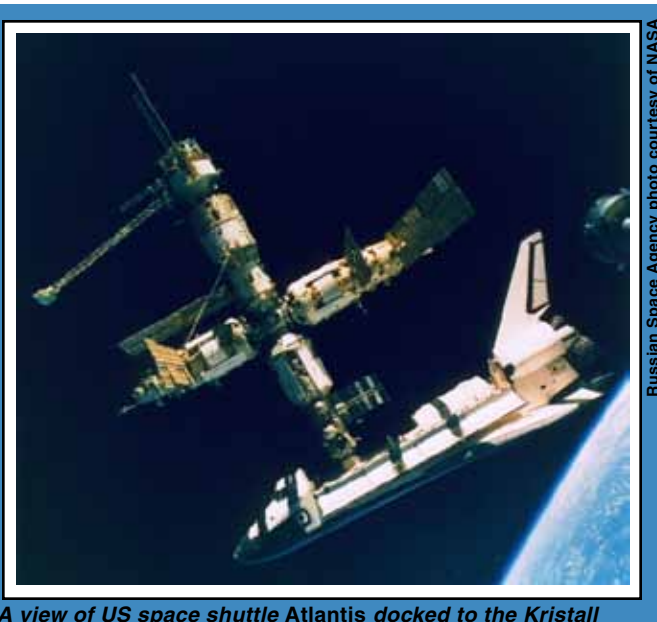
March 18, 1965 First space walk conducted by Alexei Leonov of Soviet Voskhod 2.

March 23 Gemini 3 astronauts Maj. Virgil I. "Gus" Grissom and Lt. Cmdr. John W. Young complete world's first piloted orbital maneuver.

June 4 Gemini 4 astronaut Maj. Edward H. White performs first American space walk.

July 14 Mariner provides the first close-up pictures of Mars.

Aug. 21 Gemini 5 launched as first manned spacecraft using fuel cells for electrical power rather than batteries.



Russian Space Agency photo courtesy of NASA

A view of US space shuttle* Atlantis *docked to the Kristall module of the Russian space station Mir. This photo was taken from a Soyuz spacecraft by Mir-19 cosmonaut Nikolai M. Budarin July 4, 1995, shortly before completion of the historic first docking mission between a US shuttle and the Russian space station.

March 16, 1966 Gemini 8 astronauts Neil A. Armstrong and Maj. David R. Scott perform first manual docking in space with Agena rocket stage.

June 2 Surveyor 1 is first US spacecraft to land softly on the moon. It analyzes soil content and transmits surface images to Earth.

Jan. 25, 1967 Soviet Cosmos 139 antisatellite weapon carries out first fractional orbit bombardment.

Jan. 27 First deaths of US space program occur in flash fire in Apollo 1 command module, killing astronauts Grissom, White, and Lt. Cmdr. Roger B. Chaffee.

Sept. 8 Surveyor 5 conducts first chemical analysis of lunar soil.

Oct. 20, 1968 Soviet Cosmos 248 and Cosmos 249 spacecraft carry out first co-orbital antisatellite test.

Dec. 21–27 Apollo 8 becomes first manned spacecraft to escape Earth's gravity and enter lunar orbit. First live lunar television broadcast.

March 3–13, 1969 Apollo 9 crew members Col. James A. McDivitt, Col. David R. Scott, and Russell L. Schweickart conduct first test of lunar module in Earth orbit.

July 20 Apollo 11 puts first human, Neil A. Armstrong, on the moon.

Nov. 14–24 US Apollo 12 mission deploys first major scientific experiments on the moon and completes first acquisition of samples from an earlier spacecraft—Surveyor 3.

Feb. 11, 1970 Japan launches first satellite, Osumi, from Kagoshima Space Center using Lambda 4S solid-fuel rocket.

Jan. 31, 1971 Apollo 14 launched; its astronauts will complete first manned landing on lunar highlands.

April 19 First space station, Salyut 1, goes aloft.

June 6 USSR's Soyuz 11 performs first successful docking with Salyut space station.

Oct. 28 First British satellite, Prospero, launched into orbit on Black Arrow rocket.

Nov. 2 Titan IIIC launches first Defense Satellite Communications System (DSCS) Phase II satellites into GEO.

April 16–27, 1972 Apollo 16 astronauts Capt. John Young, Lt. Cmdr. Thomas K. Mattingly II, and Lt. Col. Charles M. Duke Jr. are first to use the moon as an astronomical laboratory.

July 23 US launches first Earth Resources Technology Satellite (ERTS A), later renamed Landsat 1.

Dec. 3, 1973 Pioneer 10 becomes first space probe to come within reach of Jupiter.

July 15, 1975 US Apollo and Soviet Soyuz 19 perform first international docking of spacecraft in space.

July 20, 1976 NASA's Viking 1 performs first soft landing on Mars and begins capturing images of Red Planet's surface, with Viking 2 doing the same on Sept. 3.

Aug. 12, 1977 Space shuttle *Enterprise* performs first free flight after release from a Boeing 747 at 22,800 feet.

Feb. 22, 1978 Atlas booster carries first Global Positioning System (GPS) Block I satellite into orbit.

Dec. 13 Successful launch of two DSCS II satellites puts a full four-satellite constellation at users' disposal for first time.

July 18, 1980 India places its first satellite, Rohini 1, into orbit using its own SLV-3 launcher.

April 12–14, 1981 First orbital flight of shuttle *Columbia* (STS-1) and first landing from orbit of reusable spacecraft.

Dec. 20, 1982 First Defense Meteorological Satellite Program (DMSP) Block 5D-2 satellite launched.

June 13, 1983 Pioneer 10 becomes first spacecraft to leave solar system.

June 18 Space shuttle *Challenger* crew member Sally K. Ride becomes first American woman in space.

Sept. 11, 1985 International Cometary Explorer becomes first man-made object to encounter a comet (Giacobini–Zinner).

Sept. 13 First US antisatellite intercept test destroys Solwind scientific satellite by air-launched weapon.

Oct. 3, 1985 First launch of *Atlantis* (STS-51J) results in first launch of pair of DSCS III satellites from space shuttle using Inertial Upper Stage.

Jan. 28, 1986 In the first shuttle mishap, *Challenger* explodes after liftoff, killing seven astronauts.

Feb. 22 France launches first *Satellite Pour l'Observation de la Terre* (SPOT) for remote sensing.

Aug. 12 First launch of Japanese H-I rocket puts Experimental Geodetic Satellite into circular orbit.

May 15, 1987 USSR stages first flight of its Energia heavy launcher, designed to lift 100 tons into Low Earth Orbit.

Nov. 15, 1988 USSR makes first launch of 30-ton shuttle *Buran* using Energia rocket.

Feb. 14, 1989 Launch of first Block II GPS satellite begins an operational constellation.

Jan. 17, 1991 What the Air Force calls "the first space war," Operation Desert Storm, opens with air attacks.

Oct. 29 Galileo swings within 10,000 miles of Gaspra, snapping first close-up images of an asteroid.

May 13, 1992 The first trio of space-walking astronauts, working from the shuttle *Endeavour,* rescues Intelsat 6 from useless low orbit.

Jan. 13, 1993 USAF Maj. Susan Helms, flying aboard *Endeavour,* becomes first US military woman in space.

July 19 Launch of a DSCS Phase III satellite into GEO provides the first full five-satellite DSCS III constellation.

Dec. 2–13 USAF Col. Richard O. Covey pilots shuttle *Endeavour* on successful $674 million mission to repair $2 billion Hubble Space Telescope, a mission for which the crew wins the 1993 Collier Trophy.

Jan. 25, 1994 Launch of the 500-pound unpiloted Clementine spacecraft marks the first post-Apollo US lunar mission.

Feb. 7 First Titan IV–Centaur booster launches first Milstar Block I satellite into orbit.

March 13 First launch of Taurus booster (from Vandenberg AFB) places two military satellites in orbit.

June 29 First visit of a US space shuttle to a space station, the Russian Mir.

Nov. 5 Ulysses, first probe to explore the sun's environment at high latitudes, completes a pass over the sun's southern pole and reveals that solar wind's velocity at high latitudes (i.e., about two million mph) is nearly twice its velocity at lower latitudes.

Feb. 6, 1995 Shuttle *Discovery* (STS-63) and space station Mir perform first US–Russian space rendezvous in 20 years, with Air Force Lt. Col. Eileen M. Collins coincidentally becoming first woman to pilot a US spaceship.

March 14 US astronaut Norman E. Thagard becomes first American to accompany Russian cosmonauts aboard Soyuz TM-21 spacecraft and, two days later, becomes first American to inhabit space station Mir.

June 29 *Atlantis* (STS-71) docks with Mir, the first docking of a US spacecraft and a Russian space station.

March 8, 1996 First successful launch of Pegasus XL rocket from beneath modified L-1011 aircraft sends Air Force Radiation Experiment–II satellite into polar orbit.

June 27 Galileo captures first close-up images of Jupiter's moon Ganymede.

April 21 Celestis, Inc., of Houston performs first space "burial" when Pegasus rocket launched from L-1011 off coast of northwest Africa carries cremated remains of "Star Trek" creator Gene Roddenberry, LSD guru Timothy Leary, and 22 other space enthusiasts into orbit 300 miles above Earth.

April 29 US astronaut Jerry Linenger and Russian cosmonaut Vasily Tsibliev complete five-hour space walk outside Mir, the first such joint excursion in space history.

June 27 In first flyby of "dark, primitive main-belt" type asteroid, NASA's Near-Earth Asteroid Rendezvous spacecraft passes 253 Mathilde.

Space Leaders

(As of July 1, 1998)

Commanders in Chief, US Space Command

Gen. Robert T. Herres ..... Sept. 23, 1985–Feb. 6, 1987
Gen. John L. Piotrowski ..... Feb. 6, 1987–March 29, 1990
Gen. Donald J. Kutyna ..... March 29–June 30, 1992

Commanders, Air Force Space Command

Gen. James V. Hartinger ..... Sept. 1, 1982–July 30, 1984
Gen. Robert T. Herres ..... July 30, 1984–Oct. 1, 1986
Maj. Gen. Maurice C. Padden ..... Oct. 1, 1986–Oct. 29, 1987
Lt. Gen. Donald J. Kutyna..... Oct. 29, 1987–March 29, 1990
Lt. Gen. Thomas S. Moorman Jr..... March 29, 1990–March 23, 1992

Commanders in Chief, US Space Command, and Commanders, Air Force Space Command

Gen. Donald J. Kutyna ..... March 23, 1992–June 30, 1992
Gen. Charles A. Horner..... June 30, 1992–Sept. 13, 1994
Gen. Joseph W. Ashy.....Sept. 13, 1994–Aug. 26, 1996
Gen. Howell M. Estes III..... Aug. 26, 1996–(Oct. 1, 1998)*
Gen. Richard B. Myers ..... (Oct. 1, 1998)–

*Announced retirement date.

Directors, NASA

T. Keith Glennan..... Aug. 19, 1958–Jan. 20, 1961
James E. Webb ..... Feb. 14, 1961–Oct. 7, 1968
Thomas O. Paine ..... March 21, 1969–Sept. 15, 1970
James C. Fletcher ..... April 27, 1971–May 1, 1977
Robert A. Frosch..... June 21, 1977–Jan. 20, 1981
James M. Beggs ..... July 10, 1981–Dec. 4, 1985
James C. Fletcher ..... May 12, 1986–April 8, 1989
Richard H. Truly..... May 14, 1989–March 31, 1992
Daniel S. Goldin ..... April 1, 1992–

Directors, National Reconnaissance Office

Joseph V. Charyk ..... Sept. 6, 1961–March 1, 1963
Brockway McMillan ..... March 1, 1963–Oct. 1, 1965
Alexander H. Flax..... Oct. 1, 1965–March 11, 1969
John L. McLucas..... March 17, 1969–Dec. 20, 1973
James W. Plummer ..... Dec. 21, 1973–June 28, 1976
Thomas C. Reed..... Aug. 9, 1976–April 7, 1977
Hans Mark ..... Aug. 3, 1977–Oct. 8, 1979
Robert J. Hermann..... Oct. 8, 1979–Aug. 2, 1981
Edward C. Aldridge Jr..... Aug. 3, 1981–Dec. 16, 1988
Martin C. Faga ..... Sept. 26, 1989–March 5, 1993
Jeffrey K. Harris..... May 19, 1994–Feb. 26, 1996
Keith R. Hall (acting) ..... Feb. 27, 1996–March 27, 1997
Keith R. Hall ..... March 28, 1997–

Space and Missile Badges

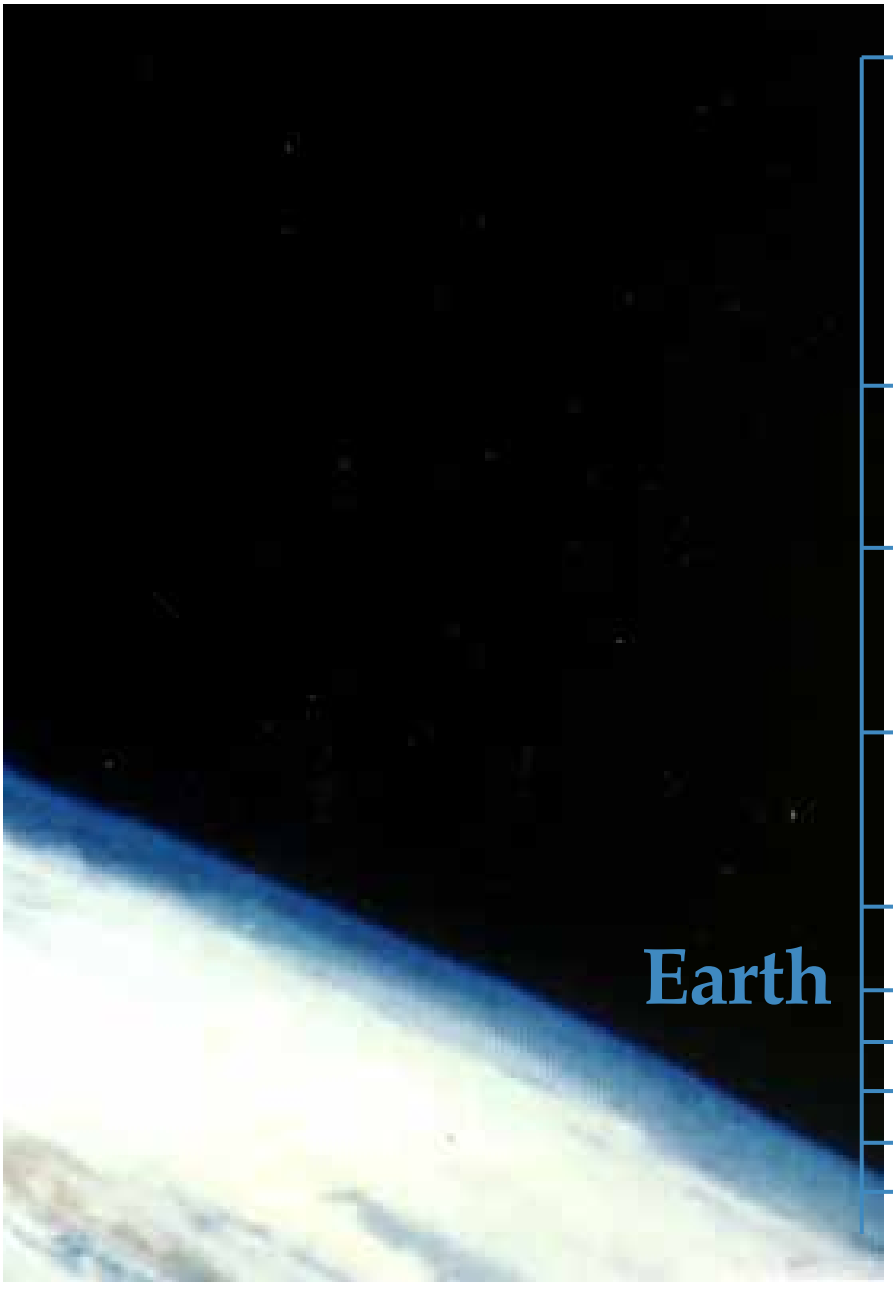
Space/Missile Badge

Astronaut Pilot*

Missile Badge

Missile Badge with Operations Designator

*The astronaut designator indicates a USAF rated officer qualified to perform duties in space (50 miles and up) and who has completed at least one operational mission. Pilot wings are used here only to illustrate the position of the designator on the wings.



Space Terms

Aerospace. A physical region made up of Earth's atmosphere and the space beyond.

Aerospace plane. A reusable spacecraft able to operate effectively in both the atmosphere and space. Also known as a "transatmospheric vehicle" or, more currently, "spaceplane."

Apogee. The point of greatest distance from Earth (or the moon, a planet, etc.) achieved by a body in elliptical orbit. Usually expressed as distance from Earth's surface.

Atmosphere. Earth's enveloping sphere of air.

Boost phase. Powered flight of a ballistic missile—i.e., before the rocket burns out.

Burn. The process in which rocket engines consume fuel or other propellant.

Circumterrestrial space. "Inner space" or the atmospheric region that extends from 60 miles to about 50,000 miles from Earth's surface.

Constellation. A formation of satellites orbiting for a specific combined purpose.

Deep space. All space beyond the Earth–moon system, or from about 480,000 miles altitude outward.

Eccentric orbit. An extremely elongated elliptical orbit.

Ecliptic plane. The plane defined by the circle on the celestial sphere traced by the path of the sun.

Elliptical orbit. Any noncircular, closed spaceflight path.

Exosphere. The upper limits of Earth's atmosphere, ranging from about 300 miles altitude to about 2,000 miles altitude.

Expendable Launch Vehicle (ELV). A launch vehicle that cannot be reused after one flight.

Ferret. A satellite whose primary function is to gather electronic intelligence, such as microwave, radar, radio, and voice emissions.

Geostationary Earth orbit. A geosynchronous orbit with 0° inclination in which the spacecraft circles Earth 22,300 miles above the equator and appears from Earth to be standing still.

Geosynchronous Earth Orbit (GEO). An orbit at 22,300 miles that is synchronized with Earth's rotation. If a satellite in GEO is not at 0° inclination, its ground path describes a figure eight as it travels around Earth.

Geosynchronous Transfer Orbit (GTO). An orbit that originates with the parking orbit and then reaches apogee at the GEO.

Ground track. An imaginary line on Earth's surface that traces the course of another imaginary line between Earth's center and an orbiting satellite.

High Earth Orbit (HEO). Flight path above geosynchronous altitude (22,300 to 60,000 miles from Earth's surface).

High-resolution imagery. Detailed representations of actual objects that satellites produce electronically or optically on displays, film, or other visual devices.

Inertial Upper Stage (IUS). A two-stage solid-rocket motor used to propel heavy satellites into mission orbit.

Ionosphere. A region of electrically charged thin air layers that begins about 30 miles above Earth's atmosphere.

Low Earth Orbit (LEO). Flight path between Earth's atmosphere and the bottom of the Van Allen belts, i.e., from about 60 to 300 miles altitude.

Magnetosphere. A region dominated by Earth's magnetic field, which traps charged particles, including those in the Van Allen belts. It begins in the upper atmosphere, where it overlaps the ionosphere, and extends several thousand miles farther into space.

Medium Earth Orbit (MEO). Flight path between LEO, which ends at about 300 miles altitude, and GEO, which is at an average altitude of 22,300 miles.

Mesosphere. A region of the atmosphere about 30 to 50 miles above Earth's surface.

Orbital decay. A condition in which spacecraft lose orbital altitude and orbital energy because of aerodynamic drag and other physical forces.

Orbital inclination. Angle of flight path in space relative to the equator of a planetary body. Equatorial paths are 0° for flights headed east, 180° for those headed west.

Outer space. Space that extends from about 50,000 miles above Earth's surface to a distance of about 480,000 miles.

Parking orbit. Flight path in which spacecraft go into LEO, circle the globe in a waiting posture, and then transfer payload to a final, higher orbit.

Payload. Any spacecraft's crew or cargo; the mission element supported by the spacecraft.

Perigee. The point of minimum altitude above Earth (or the moon, a planet, etc.) maintained by a body in elliptical orbit.

Period. The amount of time a spacecraft requires to go through one complete orbit.

Polar orbit. Earth orbit with a 90° inclination. Spacecraft on this path could pass over every spot on Earth as Earth rotates under the satellite's orbit (see orbital inclination).

Remote imaging. Images of Earth generated from a spacecraft that provide data for mapping, construction, agriculture, oil and gas exploration, news media services, and the like.

Reusable Launch Vehicle (RLV). A launch vehicle that can be reused after flight.

Rocket. An aerospace vehicle that carries its own fuel and oxidizer and can operate outside Earth's atmosphere.

Semisynchronous orbit. An orbit set at an altitude of 12,834 miles. Satellites in this orbit revolve around Earth in exactly 12 hours.

Single-Stage-To-Orbit (SSTO) system. A reusable single-stage rocket that can take off and land repeatedly and is able to boost payloads into orbit.

Stratosphere. That section of atmosphere about 10 to 30 miles above Earth's surface.

Sun synchronous orbit. An orbit inclined about 98° to the equator and at LEO altitude. At this inclination and altitude, a satellite's orbital plane always maintains the same relative orientation to the sun.

Thermosphere. The thin atmosphere about 50 to 300 miles above Earth's surface. It experiences dramatically increased levels of heat compared to the lower layers.

Transfer. Any maneuver that changes a spacecraft orbit.

Transponder. A radar or radio set that, upon receiving a designated signal, emits a radio signal of its own.

Troposphere. The region of the atmosphere from Earth's surface to about 10 miles above the equator and five miles above the poles. This is where most clouds, wind, rain, and other weather occurs.

Van Allen belts. Zones of intense radiation trapped in Earth's magnetosphere that could damage unshielded spacecraft.

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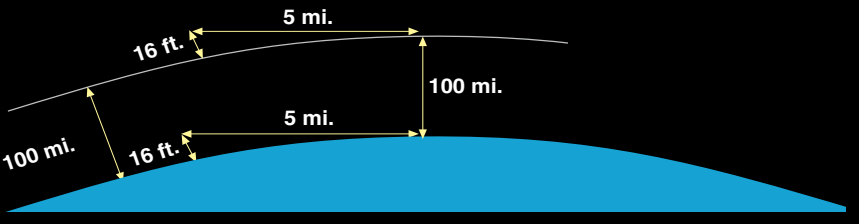
Orbits

Orbits result from the mutual attraction of any two bodies with a force proportional to the product of their individual masses and inversely proportional to the square of the distance between them. The curvature of the Earth, on average, drops 16 feet below the horizontal over a distance of about five miles. A spacecraft circling above would "fall" that same amount over the same distance. It travels five miles in one second if gravitational pull equals one g. Therefore, spacecraft velocity of five miles per second (18,000 mph) produces perpetual orbit at sea level, unless the spacecraft's flight is upset by perturbations, such as solar wind or mechanical anomalies.

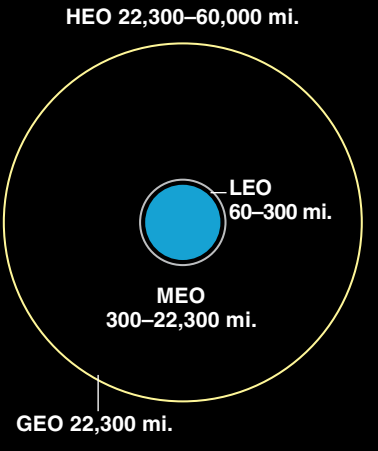


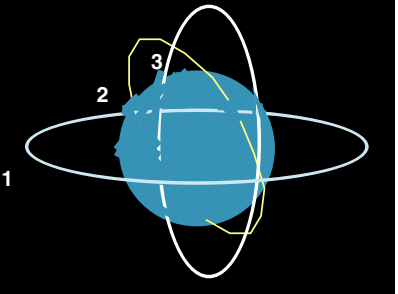
Orbital Altitude

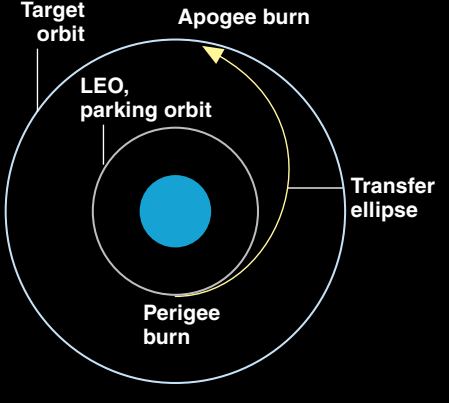
LEO Low Earth Orbit
MEO Medium Earth Orbit
GEO Geosynchronous Earth Orbit
HEO High Earth Orbit

Orbital Inclinations

1 Equatorial
2 Sun synchronous
3 Polar







It is common procedure to pick an initial "parking" orbit, usually at LEO, then boost payloads to higher altitude. Engines are fired first (at perigee) to reach the apogee of an elliptical transfer orbit and then are fired again to put the spacecraft into a circular orbit at that higher altitude.

Illustrations are not drawn to scale.