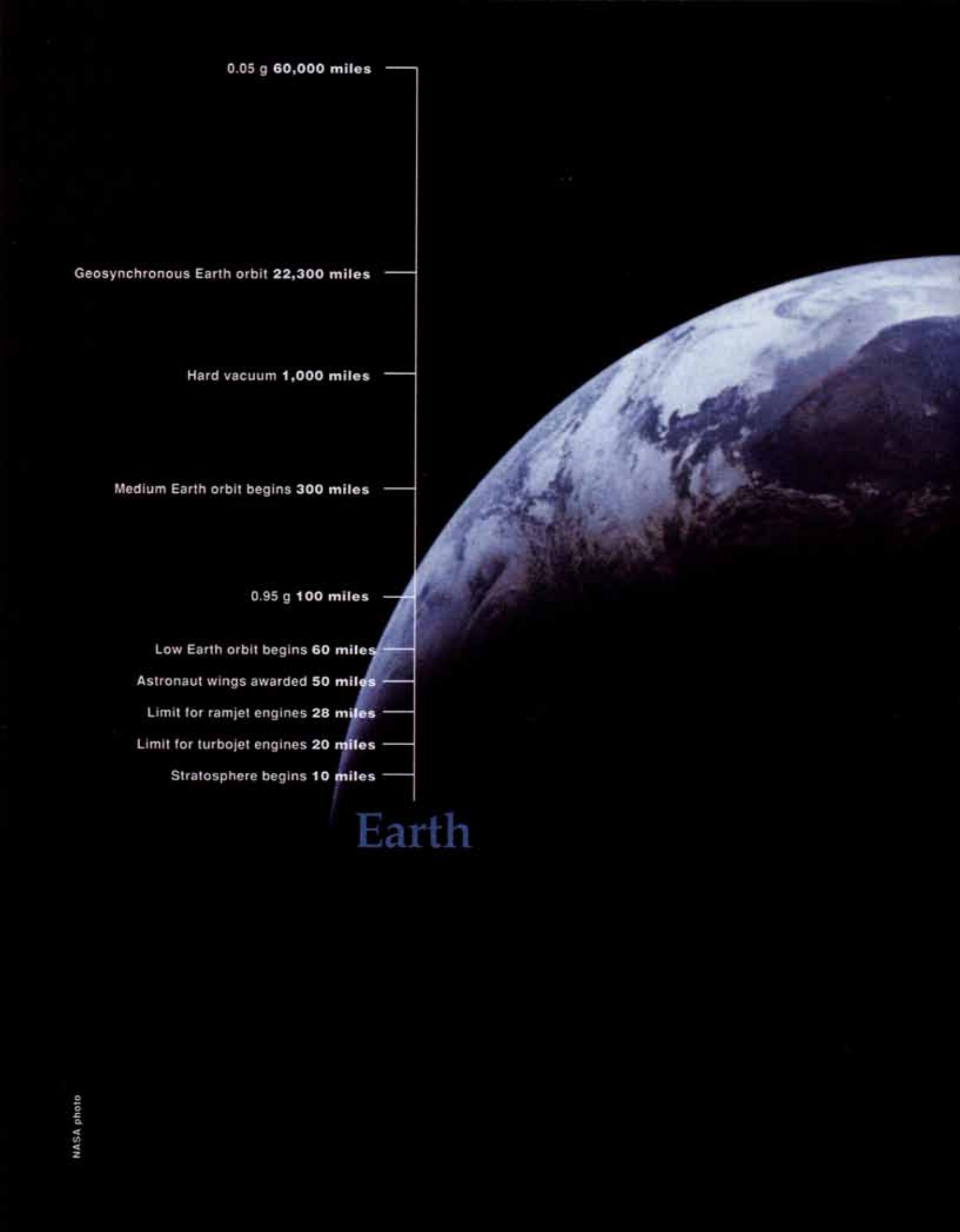
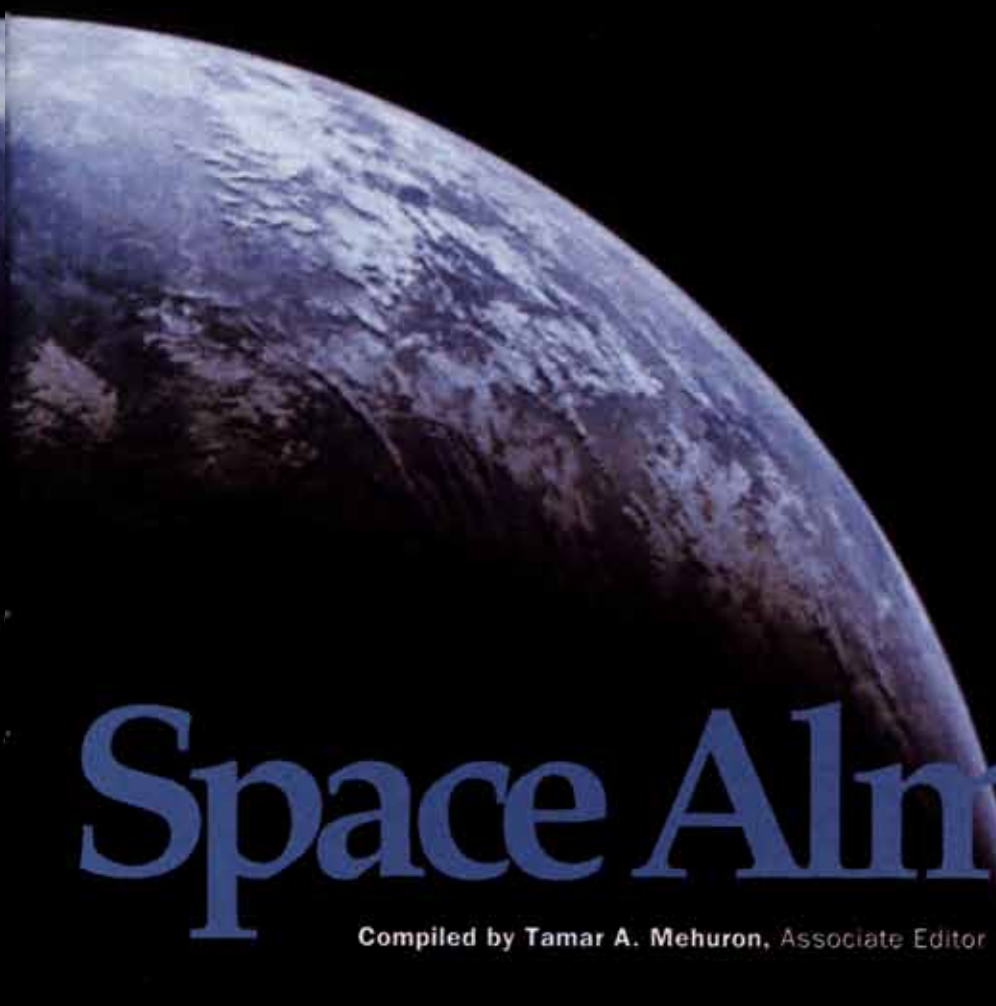

0.05 g 60,000 miles
Geosynchronous Earth orbit 22,300 miles
Hard vacuum 1,000 miles
Medium Earth orbit begins 300 miles
0.95 g 100 miles
Low Earth orbit begins 60 miles
Astronaut wings awarded 50 miles
Limit for ramjet engines 28 miles
Limit for turbojet engines 20 miles
Stratosphere begins 10 miles
Earth

NASA photo



Space Almanac

Compiled by Tamar A. Mehuron, Associate Editor

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; Theresa Foley; 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.

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. 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.

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.

Space Firsts

February 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.

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

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

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

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

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

December 17 First successful Atlas booster launch.

January 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.

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

February 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.

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

September 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.

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

August 12 First passive communications carried via Echo 1 satellite.

August 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.

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

February 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.

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

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

December 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 Early Bird communications satellite) orbits and "parks" over the Atlantic to become world's first geosynchronous satellite.

October 17 Vela Hotel satellite performs first spacebased detection of a nuclear explosion.

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

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

March 18, 1965 First spacewalk 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 spacewalk.

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

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

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.

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

January 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.

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

October 20, 1968 Soviet Cosmos 248 and Cosmos 249 spacecraft carry out first coorbital antisatellite test.

December 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.

November 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.

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

January 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.

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

November 2 Titan IIIC launches first Defense Satellite Communications System Phase II (DSCS 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.

December 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.

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

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

December 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.

December 20, 1982 First Defense Meteorological Satellite Program 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.

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

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

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

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

August 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.

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

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

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

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

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

January 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.

December 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.

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

February 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.

November 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.

February 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.

The Year in Space

July 2, 1996 At Jet Propulsion Laboratory in Pasadena, Calif., Vice President Al Gore and NASA Administrator Dan Goldin announce winner of X-33 reusable launch vehicle competition is Lockheed Martin's VentureStar.
July 24 First verifiable collision between working satellite and space junk occurs when suitcase-sized fragment from exploded third stage of Ariane rocket breaks stabilizing boom on Cerise, a British-built French military microsatellite.

The six-wheeled Sojourner rover rolled off the Mars Pathfinder lander onto the Martian surface July 5, 1997. It was designed to range up to 500 meters from the lander and still relay data effectively about the soil surface and rocks.

July 31 After flying and landing successfully for three flights, NASA's McDonnell Douglas–built Clipper Graham experimental, SSTO reusable rocket topples over and burns when one of its four landing legs fails to deploy after its fourth flight.
August 6 Indian Ocean Station, an Air Force Satellite Control Network tracking site on Mahe island in the Seychelles, ceases operations after more than 30 years.
August 7 Press conference at NASA headquarters in Washington, D.C., confirms *Space News* report of August 5 that scientists studying meteorite ALH84001 had detected what might be microscopic fossils of ancient Martian bacteria-like organisms.

August 21 Orbital Sciences Corp.'s L-1011, flying from Vandenberg AFB, Calif., launches Pegasus XL rocket carrying NASA's Fast Auroral Snapshot Explorer to investigate plasma physics of low-altitude auroral zone.
September 8 Atlas IIA from Cape Canaveral launches GE Americom's first satellite, GE-1, built by Lockheed Martin Astro Space to provide cable, broadcast, educational, government, and business communication services on Ku- and C-band frequencies.

September 16–26 *Atlantis* (STS-79) mission, using Global Positioning System (GPS) navigational signal for first time in space shuttle daily operations, focuses on fourth rendezvous with Russian space station Mir to pick up astronaut Shannon Lucid, who sets 188-day world record for longest duration spaceflight by a woman, and drop off her replacement, Col. John Blaha, USAF (Ret.).
September 27 First launch of Ballistic Missile Defense Organization (BMDO) Minuteman II Multi-Service Launch System from Vandenberg AFB results in successful release of five suborbital test targets and demonstrates feasibility of using deactivated solid-propellant intercontinental ballistic missiles as spacelifters.

September 30 After highly productive contributions to space science for nearly 19 years, NASA's International Ultraviolet Explorer receives final "shutdown" command.
September 30 Biggest change in history of space shuttle program occurs when NASA and United Space Alliance—a joint venture between Lockheed Martin and Rockwell International—sign $7 billion contract consolidating day-to-day shuttle operations under single company.
October 7–12 Corona meeting

of senior leaders at US Air Force Academy in Colorado Springs, Colo., results in decision to shift emphasis from an "air and space force" to a "space and air force" as the service enters twenty-first century.
November 7 Mars Global Surveyor, first in decade-long series of NASA orbiters and landers to explore the Red Planet, launches atop Delta II rocket from Space Launch Complex 17A at Cape Canaveral.
November 16 Russia's Mars 96 interplanetary spacecraft, with plutonium-powered energy sources, crashes back to Earth when fourth stage of Proton booster fails.
November 19–December 7 *Columbia* (STS-80) sets shuttle flight record of almost 18 days on mission that includes Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer, Shuttle Pallet Satellite, and Wake Shield Facility.
December 2 Astronaut Lucid becomes first scientist and first woman to receive Space Medal of Honor for her record 188 days aboard Mir.
December 3 BMDO spokesman Rick Lehner announces that Clementine spacecraft apparently has discovered frozen water in a deep crater at the moon's south pole.
December 4 Delta II rocket sends NASA's Mars Pathfinder from Cape Canaveral toward scheduled July 4, 1997, landing on Mars and deployment of 23-pound, six-wheeled robotic rover called Sojourner.
December 20 Titan IV boosts National Reconnaissance Office satellite into orbit from Vandenberg AFB, marking first time US government acknowledges, in advance, the launch of a reconnaissance satellite.
December 24, 1996–January 7, 1997 Russian Bion-11 mission sends two rhesus monkeys, Lapik and Multik, into space to test effects of weightlessness on vestibular and movement control systems, but Multik dies of cardiac arrest during removal of electrodes one day after return to Earth.
January 11 Geomagnetic storm that began five days earlier on sun's surface temporarily disables GOES-8 weather satellite and apparently destroys Telstar 401, disrupting television service to millions of viewers, including students on Air Force distance-learning network.
January 12–22 Shuttle *Atlantis* mission (STS-81) involves rendezvous with Mir to deliver 2,200 pounds of equipment and 1,400 pounds of drinking water, drop off mission specialist Navy Capt. Jerry Linenger, and pick up astronaut Blaha and 840 pounds of hardware and experiments belonging to the Russian Space Agency.
January 17 Delta II booster explosion at Cape Canaveral destroys first $35 million GPS Block IIR satellite, and subsequent accident investigation delays further Delta II launches until May 1997.
February 11–21 Shuttle *Discovery* (STS-82) crew performs second servicing mission to Hubble Space Telescope and completes emergency repairs after discovering numerous cracks and tears in the orbiting observatory's thin outer layer of insulation.
February 12 Japan launches Muses-B, subsequently renamed Highly Advanced Laboratory for Communications and Astronomy, from Kagoshima Space Center to study supermassive black holes found at center of some galaxies.
February 20 Flying within 363 miles of Jupiter's moon Europa, Galileo spacecraft transmits tantalizing images of iceberg-like formations, as well as relatively smooth white areas, which provide strongest evidence yet of life-sustaining ocean beneath frozen surface.
March 4 First launch from Russia's Svobodny Cosmodrome successfully places Ministry of Defense's Zeya test satellite into circular sun synchronous orbit.
March 22 One-year anniversary of continuous US human presence in space: Lucid, March 22–September 26, 1996; Blaha, September 16, 1996–January 22, 1997; and Linenger, beginning January 12, 1997.
March 31 NASA receives final signal from 25-year-old Pioneer 10, first human-made object to escape solar system, at distance of 6.2 billion miles from Earth.
April 4 Titan II rocket boosts last Block 5D-2 Defense Meteorological Satellite Program (DMSP) spacecraft into orbit from Vandenberg AFB.
April 4–8 Shuttle *Columbia* (STS-83) mission, originally scheduled to perform microgravity science experiments for 15 days, is shortened due to malfunctioning fuel cell.
April 15 As part of overall effort to merge DMSP and NOAA polar satellite systems, Fairchild Satellite Operations Center, Fairchild AFB, Wash., ceases its dedicated tracking and backup command and control of DMSP satellites.
April 17 NASA and Air Force Space Command announce partnership agreement to share assets and new technologies for overall cost savings and greater operational efficiencies.
April 21 Celestis, Inc., of Houston, Tex., 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 Linenger and Russian cosmonaut Vasily Tsibliev complete five-hour spacewalk outside Mir, the first such joint excursion in space history.
May 5 After January launch disaster at Cape Canaveral, Delta II rocket returns to service with launch of first five Iridium mobile telephone satellites from Vandenberg AFB.
May 15–24 *Atlantis* (STS-84) completes sixth shuttle docking mission with Mir to retrieve astronaut Linenger and deliver his replacement, C. Michael Foale.
May 20 First Delta II launch from Cape Canaveral since January disaster sends Norwegian Thor IIA satellite into orbit.
June 10–12 US Space Command, US Strategic Command, NRO,and Army Training and Doctrine Command jointly conduct "Space Game" exercise at Redstone Arsenal, Ala., to determine how best to use and protect satellites for warfare in 2020.
June 27 In first flyby of "dark, primitive main-belt" type asteroid, NASA's Near-Earth Asteroid Rendezvous spacecraft passes 253 Mathilde.
June 30 NASA's Foale and two Russian cosmonauts aboard Mir begin training for repair mission following June 25 crash in which unmanned cargo ship damaged Mir's solar array and Spektr module, cutting power generation capability in half.

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-1 was destroyed in the January 1997 Delta rocket explosion. GPS IIR-2 was being readied for a July 12, 1997, launch. Five IIR launches are scheduled for Fiscal 1998.

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. Five DSCS satellites remain to be launched in 1997–2002. 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 February 7, 1994, and the second November 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 in 1998–2001. 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 jamproof 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 Spacebased Infrared System, 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)
Military weather satellites operating in LEO that 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 on 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; six are operational.

Leasesat
Spacecraft that have been providing Navy UHF satellite communications since first launch in 1984 to augment FLTSATCOM. Leasesat was decommissioned at the end of 1996.

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 in-theater warfighters. GBS will provide data to large populations of dispersed users with small, mobile receive 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. Satellites, which monitor Earth with radar, optical sensors and electronic intercept capability, have been treated as closely guarded secrets since the start of the space age. Even the names of satellites, like LaCrosse (radar imaging), Keyhole (optical imaging), White Cloud (ocean reconnaissance), and Aquacade (electronic ferret), are secret and cannot be confirmed by the intelligence agencies. However, the move to declassify space systems has begun, leading to the release of extensive information about one now-obsolete spy satellite called Corona. The Intelligence Community also will release selected archival images obtained by older spy satellites for scientific use. Some observers believe more military space secrets will be disclosed as the Cold War fades.

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.

International Telecommunications Satellite Organization (Intelsat)
Established in 1964 to own and operate a global constellation of communications satellites. Has 141 members and 24 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 INC, which will be given three to seven satellites for competitive services like broadcasting and data networking. The restructuring should be approved in early 1998 and implemented in the following months. 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.

Six TDRSS satellites now on orbit enable NASA to communicate with the space shuttles.

International Maritime Satellite (Inmarsat)
Established in 1979 to own and operate satellites for mobile communications. Has 79 member-countries. Inmarsat 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. Inmarsat 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.

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 and NOAA-14
Two 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.

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 Corp. and Teleglobe of Canada. Orbcomm's satellite constellation will comprise 28 satellites, with an additional eight satellites to serve as ground spares or to be launched at a later date. 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 in November, and SPOT 1 was reactivated to augment SPOT 2. SPOT 4 is scheduled for launch in early 1998 and SPOT 5 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, Tex., 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 satellites. Hughes is the contractor for TDRSS H, I, and J. The first will be launched in July 1999.

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
Operate groundbased and spacebased systems to provide solar/geophysical support to the warfighter. Operate weather satellites to provide data on worldwide and local weather systems affecting combat operations. NOAA will take over flight operations of weather satellites from the Air Force in May 1998. USAF will continue to provide backup satellite command and control of weather satellites.

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 intercontinental ballistic missiles. 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.

Major US Agencies in Space

National Imagery and Mapping Agency (NIMA)
Headquarters: Fairfax, Va.
Established: October 1, 1996
Director (acting): Rear Adm. Joseph J. Dantone, Jr.

Mission, Purpose, Operations
Provide timely, relevant, and accurate imagery intelligence and geospatial information to support national security objectives. This DoD-chartered combat support agency was formed through the consolidation: Defense Mapping Agency, Central Imagery Office, and Defense Dissemination Program Office, in their entirety; National Photographic Interpretation Center, which is now under NIMA's operational control; and the imagery exploitation, dissemination, and processing elements and programs of the CIA, Defense Intelligence Agency, National Reconnaissance Office, and Defense Airborne Reconnaissance Office. This 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., Missouri, and California, 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 research and development.

Structure
Ten centers around the US: Johnson Space Center, Houston, Tex.; Marshall Space Flight Center, Huntsville, Ala.; Kennedy Space Center, Fla.; Lewis Research Center, Cleveland, Ohio; 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 19,700
Contractors 169,000

National Oceanic and Atmospheric Administration (NOAA)
Headquarters: Washington, D.C.
Established: October 3, 1970
Director: 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
Headquarters
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..... 825
Other NOAA employees..... 11,560
Total..... 12,385

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 35-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. Five offices and three directorates reporting up to the level of the director. Offices are management services and operations, plans and analysis, systems applications, space launch, and operational support. Directorates are signals intelligence systems acquisition and operations, communications systems acquisition and operations, and imagery systems acquisition and operations.

Personnel
Staffed by CIA (37 percent), USAF (51 percent), Navy (seven percent), Army (one percent), and National Security Agency (four 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.

Air Force Space Command Headquarters, Peterson AFB, Colo.

(As of July 1, 1997)

Commander
Gen. Howell M. Estes III

- **Space Warfare Center** • Falcon AFB, Colo.
  Commander **Brig. Gen. Glen W. Moorhead 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,** Falcon 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.
- **321st Missile Group,** Grand Forks AFB, N.D.
- **341st Missile Wing,** Malmstrom AFB, Mont.

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]
- **Phillips Laboratory,** Kirtland AFB, N.M.

Air Force Program Executive Office • Washington, D.C.
Air Force Acquisition Executive **Arthur L. Money**

Program Executive Officer for Space Programs
Brent R. Collins

- **MILSATCOM JPO**
- **Launch SPO (formerly Titan)**
- **Spacebased Infrared SPO**
- **Evolved Expendable Launch Vehicle SPO**

[1]System(s) Program Office [2]Joint Program Office

Russian Space Activity, 1996

	Launches	Spacecraft
Communications	7	12
Photoreconnaissance	1	1
Unmanned space station resupply	3	3
Space station module	1	1
Navigation	3	3
Military ocean surveillance	1	1
Electronic intelligence	1	1
Manned flight	2	2
Science	3	6
Commercial	2	2
Atmospheric density/radar calibration	1	1
Total	**25**	**33**

Russian Launch Site Activity, 1996

Spacecraft	Number of launches
Baikonur Cosmodrome, Tyuratam, Kazakhstan	
Proton-K	8
Soyuz-U	5
Zenit-2	1
Tsyklon-M	1
Total	**15**
Plesetsk Cosmodrome, Plesetsk, Russia	
Tsyklon-3	1
Kosmos-3M	4
Soyuz-U	2
Molniya-M	3
Total	**10**

Russian Operational Spacecraft, 1996

Mission	Type	Number
Communications	Kosmos (Strela-3)	30
	Gonets-D	3
	Raduga/Raduga-1	9
	Gorizont	11
	Molniya-1	8
	Molniya-3	8
	Kosmos (Geizer)	2
	Kosmos (Luch)	2
	Luch-1	1
	Ekran-M	1
	Ekspress	2
	Gals	2
	Radio Rosto	1
Navigation	Kosmos GLONASS	24
	Kosmos (military)	6
	Kosmos (civil)	4
Meteorology	Meteor-2	2
	Meteor-3	2
	Elektro (GOMS)	1
Early warning	Kosmos (Oko)	8
	Kosmos (Prognoz)	1
Electronic intelligence	Kosmos (Tselina-2)	3
	Kosmos (EORSAT)	3
Photoreconnaissance		0
Remote sensing	Okean-O	2
	Resurs-O1	1
	Sich	1
Geodesy	Kosmos (Etalon)	2
	Kosmos (GEO-IK)	1
Radar calibration	Kosmos (Romb)	1
Atmosphere density	Kosmos (Yug)	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	Bion	1
	Coronas-I	1
	Granat	1
	Interball	2
	MAGION 4 (Czech satellite)	2

Older spacecraft sometimes are placed in orbital standby mode.

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	107	4,914
1976	4,074	2,443	142	6,659
1977	3,440	2,412	131	5,983
1978	3,623	2,738	157	6,518
1979	4,030	3,036	178	7,244
1980	4,680	3,848	160	8,688
1981	4,992	4,828	158	9,978
1982	5,528	6,679	234	12,441
1983	6,328	9,019	242	15,589
1984	6,648	10,195	293	17,136
1985	6,925	12,768	474	20,167
1986	7,165	14,126	368	21,659
1987	9,809	16,287	352	26,448
1988	8,302	17,679	626	26,607
1989	10,098	17,906	444	28,448
1990	12,142	15,616	387	28,145
1991	13,036	14,181	566	27,783
1992	13,199	15,023	624	28,846
1993	13,077	14,106	559	27,742
1994	13,022	13,166	465	26,653
1995	12,543	10,644	489	23,676
1996	12,569	11,514	707	24,790
Total	**229,089**	**243,266**	**10,243**	**482,598**

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. (Fiscal 1996 figures are preliminary.)

Worldwide Launches by Site, 1957–96

Launch Site	Nation	Launches
Plesetsk	Russia	1,436
White Sands Missile Range, N.M.	US	1,087
Tyuratam/Baikonur	Russia	1,002
Vandenberg AFB, Calif.	US	516
Cape Canaveral AS, Fla.	US	509
Poker Flat Research Range, Alaska	US	271
JFK Space Center, Fla.	US	99
Kapustin Yar	Russia	83
Kourou	French Guiana	90
Tanegashima	Japan	28
Shuang Cheng-tzu/Jiuquan	China	23
Wallops Flight Facility, Va.	US	22
Uchinoura	Japan	21
Xichang	China	19
Indian Ocean Platform	Kenya	9
Sriharikota	India	7
Edwards AFB, Calif.	US	5
Hammaguir	Algeria	4
Yavne	Israel	3
Woomera	Australia	2
Taiyun	China	2
Total		**5,238**

Military vs. Civilian Launches

	Military		Civilian	
Year	US	Russia	US	Russia
1957	0	0	0	2
1958	0	0	7	1
1959	6	0	5	3
1960	10	0	6	3
1961	19	0	10	6
1962	31	5	21	15
1963	26	7	12	10
1964	32	15	25	15
1965	28	25	35	23
1966	32	27	41	17
1967	24	46	34	20
1968	20	49	25	25
1969	16	51	24	19
1970	15	55	14	26
1971	10	60	22	23
1972	11	53	20	21
1973	8	58	15	28
1974	6	52	18	29
1975	7	60	21	29
1976	7	74	19	25
1977	9	69	15	29
1978	8	60	24	28
1979	4	60	12	27
1980	5	64	8	25
1981	5	59	13	39
1982	6	68	12	33
1983	7	58	15	40
1984	12	63	10	34
1985	6	64	11	34
1986	3	63	3	28
1987	6	62	2	33
1988	6	53	6	37
1989	13	42	5	32
1990	13	45	14	30
1991	9	30	9	29
1992	12	32	16	22
1993	13	26	10	21
1994	12	26	14	22
1995	9	15	18	17
1996	11	8	22	17
Total	**477**	**1,604**	**613**	**917**

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

Payloads by Mission, 1957–96

Category	US	Russia
Platforms	**0**	**480**
Earth orbital science	**221**	**210**
Automated lunar, planetary	**58**	**86**
Moon	25	34
Mercury	1	0
Venus	8	33
Mars	11	19
Outer planets	4	0
Interplanetary space	9	0
Applications	**420**	**499**
Communications	291	285
Weather	99	74
Geodesy	20	34
Earth resources	8	96
Materials processing	2	10
Piloted activities	**149**	**236**
Earth orbital	99	88
Earth orbital (related)	13	140
Lunar	20	0
Lunar (related)	17	8
Launch vehicle tests	**11**	**22**
General engineering tests	**57**	**4**
Reconnaissance	**427**	**1,081**
Photographic	248	796
Electronic intelligence	93	130
Ocean electronic intelligence	39	82
Early warning	47	73
Minor military operations	**44**	**161**
Navigation	**82**	**211**
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	**2**	**1**
Total	**1,491**	**3,583**

Spacefarers

(As of end of 1996)

Nation	Persons	Nation	Persons
Afghanistan	1	Mexico	1
Austria	1	Mongolia	1
Belgium	1	Netherlands	1
Bulgaria	2	Poland	1
Canada	5	Romania	1
Cuba	1	Russia	85
Czechoslovakia	1	Saudi Arabia	1
France	7	Switzerland	1
Germany	8	Syria	1
Hungary	1	United Kingdom	1
India	1	United States	223
Italy	3	Vietnam	1
Japan	4	**Total**	**354**

Payloads in Orbit

(As of end of 1996)

Launcher/operator	Objects	Launcher/operator	Objects
Argentina	2	Luxembourg	6
Australia	6	Malaysia	2
Brazil	6	Mexico	5
Canada	17	NATO	8
China	16	Norway	1
Czechoslovakia	3	Portugal	1
ESA	30	Russia	1,353
France	30	Saudi Arabia	7
France/Germany	2	South Korea	4
Germany	14	Spain	4
India	14	Sweden	5
Indonesia	8	Thailand	2
Israel	2	Turkey	2
Italy	7	United Kingdom	25
ITSO[1]	50	United States	701
Japan	57	**Total**	**2,390**

[1]International Telecommunications Satellite Organization

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 42 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 Taiyun. 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, the 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. Believed to have been launched from Yavne 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 49 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-1 has begun to replace 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	
Total	**10**	**44**	**49**	**84**	**7**	**3**

Space and Missile Badges

Space/Missile Badge

Senior Space/Missile Badge

Master Space/Missile Badge

Astronaut Pilot*

Senior Astronaut Pilot

Command Astronaut Pilot

Missile Badge

Senior Missile Badge

Master Missile Badge

Missile Badge with Operations Designator

Senior Missile Badge with Operations Designator

Master Missile Badge with Operations Designator

*The astronaut designator indicates a USAF rated officer qualified to perform duties in space (fifty 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.

Recent Space Issues and Developments

■ **Space Master Plan**
The Space Master Plan to guide military space spending during the next 25 years produced a set of "guidestars," or guiding principles, to assure that military services work together and acquire space systems that are efficient, nonredundant, and work in an integrated fashion. The guidestars include such notions as technical superiority, customer focus, and cooperation. The Joint Space Management Board approved the classified plan, which was created by the Deputy Under Secretary of Defense for Space, an organization set up in 1994 to provide top-level oversight of space matters within the DoD and Intelligence Communities.

■ **Space architecture**
The DoD Space Architect office, headed by Air Force Maj. Gen. Robert S. Dickman, issued its first product—an architecture for future military communications satellite systems—in fall 1996. The architecture recommended that DoD continue to buy three to four lines of specialized spacecraft to fulfill needs met by the current Milstar, DSCS (Defense Satellite Communications System) and UHF Follow-on satellites, plus an EHF system for communications over the poles. The architecture recommended against commercial leasing of systems to fill those requirements on the basis that leasing would be more expensive than buying for the military. In the case of satellites to replace the DSCS, the architecture recommended adapting satellites from a commercial production line to carry the DoD X-band payload, plus adding military Ka-band frequencies. The DSCS replacements would be launched beginning in 2002–06. DoD has spent $50 billion during the last 20 years on military satellite equipment, and the new architecture would cost $45 billion to $54 billion over the next 20 years, depending on the number of upgrades included.

■ **Commercial remote sensing**
In 1998, 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., was to orbit its first satellite, capable of providing imagery with three-meter resolution, in June 1997, followed by a one-meter-resolution spacecraft by mid-1998. Space Imaging, Inc., their leading competitor, was to launch its first satellite, capable of one-meter imagery, in December 1997. Several other companies have obtained remote-sensing satellite licenses from the Commerce Department and hope to launch satellites in the future, but EarthWatch and Space Imaging were the clear front-runners in the new commercial space application. 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.

■ **Advanced technology launchers: X-33, X-34, EELV**
The nation's efforts to develop new, lower cost launch vehicles continued to receive funding support and achieve programmatic progress, which will lead to test flights of NASA's X-33 and X-34 reusable launch vehicles around 1999 and first flights of the Air Force's Evolved Expendable Launch Vehicle in 2001 and 2003. USAF narrowed the field from four to two competitors in late 1996 and will select a single winner in mid-1998. The service has budgeted $2 billion through 2004 for the effort, including funds for three test flights. EELV is aimed at evolving current launcher systems—either the Atlas made by Lockheed Martin Corp. or the Delta made by McDonnell Douglas—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 2001, and the first heavy launch is scheduled for 2003. USAF has begun manifesting satellites on EELV, with plans to phase out use of Titan 4, Atlas, and Delta when the new rocket becomes operational.

Pioneer X-15 pilots (l–r) Joe Walker, USAF Maj. Bob White, and Scott Crossfield helped pave the way for today's astronauts. Walker and White, among other X-15 pilots, earned astronaut wings for flights above 264,000 feet in the X-15, which was designed to explore the identifiable problems of atmospheric flight at very high speeds and altitudes.

Proposals and Prospects

Launcher Concepts

■ **Sea Launch**
Sea Launch Co., a partnership among Boeing Commercial Space Co., Kvaerner a.s. of Norway, RSC Energia of Moscow, and NPO Yuzhnoye of the Ukraine, has made major progress toward developing the Sea Launch commercial satellite launching operation. Launch services will commence in June 1998 when Sea Launch will utilize the three-stage Zenit SL rocket to place payloads of up to 5,900 kilograms (13,000 pounds) into GTO from a floating platform at sea. The launch site will be equatorial, near Christmas Island in the Pacific, with a home base in Long Beach, Calif. Construction of the launch platform and assembly and command ship continues, and both vessels are scheduled to arrive at the home port in early 1998. Hughes Space and Communications has purchased 13 launches, and Space Systems/Loral ordered five. Sea Launch is fully booked through 2000, with a launch rate of three missions in 1998 and six a year thereafter.

■ **X-33**
Lockheed Martin Corp. is developing an experimental reusable launch vehicle (RLV), called the X-33 or VentureStar, after being selected by NASA in July 1997 for a cooperative program to demonstrate technology for a single-stage-to-orbit rocket for use in the next century. NASA is putting nearly $1 billion into the effort, with Lockheed Martin committing some $220 million. Flight tests are scheduled for 1999, leading to a decision by 2001 on whether to proceed with an operational version. The terms of the project call for Lockheed Martin to use private financing to build the operational VentureStar, which is estimated to cost another $5 billion to complete. With it, launch costs should drop to a few hundred dollars per pound, compared to $10,000 to $12,000 per pound using current launchers like the space shuttle.

■ **X-34**
In June 1996, Orbital Sciences Corp. (OSC) won a $60 million contract from NASA to design and build a technology demonstration vehicle and operate two flight tests. The flight tests are scheduled in the latter half of 1998. The contract also allows NASA to exercise an option for up to 25 additional test flights. The options are not included in the original $60 million contract. The subscale test vehicle will be taken aloft by an L-1011 aircraft, dropped from the airplane, and then test-flown at speeds up to Mach 8. The test vehicle will have no payload capability. Its goal is to have a recurring flight cost of $500,000. NASA had no plan to build an operational small reusable launcher based on X-34 after the tests, but OSC was contemplating whether to invest its money in a new small RLV. Technology from the program will feed into the decision on whether to build an operational X-33/VentureStar launcher.

This computer concept shows Lockheed Martin's VentureStar RLV, chosen for NASA's X-33 technology demonstration program, docking with Japan's National Development Agency space station.

■ **Delta III**
A new intermediate-class launcher, the Delta III is being developed without government support by McDonnell Douglas Corp. for a first launch in 1998. Delta III will be able to boost 8,400 pounds to GTO, more than twice Delta II's maximum payload. Its LEO capability will be 18,400 pounds. The rocket will have a new cryogenic upper stage and a larger fairing. The initial customer is Hughes Space and Communications, which has a contract for 10 launches plus additional options through 2005. Space Systems/Loral also has ordered five Delta IIIs.

■ **Med Lite**
McDonnell Douglas has a contract with NASA for Medium Light Expendable Launch Vehicle services, which is to provide launches to fill the gap between small- and medium-class launchers. Med Lite's objective is to support NASA science, including the Discovery and Surveyor programs. Launch vehicles include the Delta II and OSC's Taurus XL.

■ **Atlas IIAR RD-180 Engine**
Lockheed Martin will introduce the Atlas IIAR rocket in mid-1998. The new Atlas version has several propulsion upgrades that will allow it to carry 8,900 pounds to orbit. On the first stage, the Atlas IIAR will use one NPO Energomash–Pratt & Whitney RD-180 engine, built either in Russia or the US, to replace seven US-designed engines currently used on the Atlas IIAS. The Centaur upper stage will have one RL-10E engine instead of two RL-10 engines in the current configuration. The Atlas IIAR also is the basis for much of the design of the Evolved Expendable Launch Vehicle proposed by Lockheed Martin to the Air Force as the nation's future family of low-cost launchers.

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 is to take responsibility for the Defense Meteorological Satellite Program (DMSP). Operational control at the primary site in Suitland, Md., is to begin in mid-1998, with the backup site at Falcon AFB, Colo., to be operational in the third quarter. 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 December 1998, December 1999, November 2000, and October 2001.

■ **Spacebased 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 HEO 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 sat-

ellites 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 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 commissioned a study scheduled for completion this month that will provide intelligence leaders and the Secretary of Defense with options on how to proceed with NRO's adoption of small satellites.

USAF's Phillips Laboratory is a leader in the development of advanced technology for small satellites. Phillips is involved in the Space Test Experiments Platform series of satellites, having successfully launched the STEP/Technology for Autonomous Operational Survivability satellite, which just passed its third anniversary. Additionally Phillips Laboratory is developing the Clementine 2 Micro-Satellites mother ship, which will be launched within the next two years, and a new, inexpensive series of spacecraft known as MightySat, the first of which is to be launched in July 1998. In the past year Phillips Laboratory integrated and launched MSTI (Miniature Sensor Technology Integration) III spacecraft. Phillips also has a program called the Integrated Space Technology Demonstration, which supports the integration and demonstration of technologies critical to the warfighter. The lab is also involved in NASA's Lewis and Clark and New Millenium small-satellite projects.

US Space Command

	Personnel	Budget, Fiscal 1998	Activities
US Space Command Peterson AFB, Colo.	786	$18.2 million	Responsible for placing DoD satellites into orbit and operating them; supports unified commands with spacebased 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.
Component			
Air Force Space Command Peterson AFB, Colo.	37,625	$1.7 billion	Operates military space systems, groundbased missile-warning radars and sensors, missile-warning satellites, national launch centers, and ranges; tracks space debris; operates and maintains the USAF ICBM force (as a component of US Strategic Command). Budget includes funding for 11,100 contractor personnel and operations and maintenance for six bases and 50 worldwide sites.
Naval Space Command Dahlgren, Va.	562	$70 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.	652	$51 million	Provides input for DoD space plans; manages Joint tactical uses of DSCS; conducts planning for national and theater missile defense; operates the Army Theater Missile Defense Element force projection Tactical Operations Center; exploits leading-edge space technologies in support of warfighter needs; manages the Army Astronaut Program; and operates Joint Tactical Ground Station.

NASA astronauts C. Michael Foale (left) and Navy Capt. Jerry M. Linenger pose aboard the Mir before Linenger returned from his nearly six-month stay aboard the Russian space station. Foale began training with his Russian counterparts on June 30 to repair the Mir, which was damaged June 25.

Selected NASA Projects Fiscal 1998 Proposal

Current Dollars

■ **AXAF, $92.2 million.** Space science. The Advanced X-Ray Astrophysics Facility space-craft to study the composition and nature of galaxies, stellar objects, and interstellar phe-nomena. Scheduled for launch aboard the space shuttle in August 1998.

■ **Cassini, $9.0 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 universe. Scheduled for launch in October 1997.

■ **Discovery, $106.5 million.** Space science. Spacecraft missions Mars Pathfinder and Near-Earth Asteroid Rendez-vous (NEAR). Mars Pathfinder landed successfully on Mars on July 4, 1997. NEAR success-fully launched in February 1996, now en route for a year-long rendezvous with asteroid 433 Eros in February 1999. Lunar Prospector is scheduled for launch in September 1997 and will search for resources on the moon, especially for water in the shaded polar regions. The Stardust mission, sched-uled for launch in February 1999, is de-signed 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.

■ **Earth Observing System, $679.7 million.** Mission to Planet Earth environmental project. Series of satellites to document global climatic change and observe environ-mental processes. Scheduled launches start in 1998.

■ **Explorer, $142.7 million.** Space science. Four missions and spacecraft development. Study of X-ray sources, solar corona, and organic com-pounds in interstellar clouds. Scheduled launches each year from 1997 to 2000.

■ **Galileo, $29.8 million.** Space science, planetary ex-ploration. Funds to support op-erations of mission to explore Jupiter and its moons.

■ **Mars Surveyor, $139.7 mil-lion.** Space science. Launch of the Mars Global Surveyor orbiter occurred in November 1996. It is due to arrive in September 1997. Development of spacecraft for new Mars exploration strat-egy. Mapping, in-situ climate and soil mea-surements, 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 Space-craft, $75.7 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. Demonstration flight test expected in 1998.

■ **Relativity (Gravity Probe-B), $45.6 million.** Space science. Major test of Einstein's general theory of relativ-ity. Development of a gravity probe. Launch is scheduled for October 2000.

■ **Space shuttle, $3.0 billion.** Spaceflight. Program empha-sizes continuing improvement of safety margins, fulfillment of the flight manifest, reduction of costs, and launch of seven flights for Fiscal 1998 and eight in Fiscal 1999.

■ **Space station, $2.1 bil-lion.** 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 May 1998. Efficien-cies gained through design changes and parti-cipation of the Russians in an interna-tional partnership.

■ **US/Russian Cooperative Program.** (Funding ended in Fiscal 1997, but activities still ongoing.) Spaceflight. Pro-gram provides for contract with Russian Space Agency for services and hardware and joint activities with Russia on the Mir. The eighth and ninth joint shuttle-Mir missions are scheduled for Fiscal 1998.

■ **Other space operations, $507.4 million.** Space science. Operation of Hubble Space Telescope, the AXAF program, the Global Geospace Science program, the Compton Gamma Ray Observatory, and the Collaborative Solar-Terrestrial Research program. Support of planetary missions includes Galileo, NEAR, Mars Surveyor, and Mars Pathfinder.

Current US Launchers

Titan II

Titan IV

Atlas II

Titan II (Lockheed Martin Astronautics)

Modified ICBM. Fourteen missiles have been modified; six have been launched successfully. Puts 4,200 pounds into polar LEO. The Air Force used it for DMSP launches. Titan II is launched from Vandenberg AFB, Calif. It launched the Clementine I 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 Astronautics)

Heavy-lift launcher, adapted from an ICBM as an expendable launch system. First launch in 1989. Due to be phased out by about 2003 when the EELV becomes operational. Carries DSP, Milstar, and classified satellites and will launch NASA's Cassini to Saturn this fall. 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 on February 23, 1997. The Air Force has contracted for 41 Titan IVs; 20 have flown as of late April 1997. Lockheed Martin will complete production of all Titan IVs by 1999 but will continue to launch them through 2003.

Atlas II (Lockheed Martin Astronautics)

Modified version of nation's first ICBM carries DSCS satellites and NASA and commercial payloads. The range of payloads Atlas II through IIAS can lift into GTO from Cape Canaveral AS, Fla., is 4,900 to 8,200 pounds and 13,650 to 15,900 pounds to LEO from Vandenberg AFB. The 100th Atlas-Centaur launch occurred in April 1996. A new configuration, the Atlas IIAR (with a Russian-designed RD-180 engine), will be used starting in mid-1998. It will increase the payload capability to 8,900 pounds to GTO.

Lockheed Martin Launch Vehicle (Lockheed Martin Astronautics)

Family of commercially developed boosters with varying configurations of solid motors that allow payloads weighing one to four tons to be placed into LEO or on interplanetary trajectories. The LMLV-1 rocket, a two-stage version, failed on its first launch attempt in August 1995. A second launch attempt was still unscheduled. The design is for "stack and shoot," which means the rocket can be launched within 15 days of arrival at the SLC-6 launch site at Vandenberg AFB or LC-46 at Cape Canaveral AS. Although to date no military use has been contracted for, Lockheed Martin had sold seven LMLVs to commercial, foreign and US government customers by spring 1997.

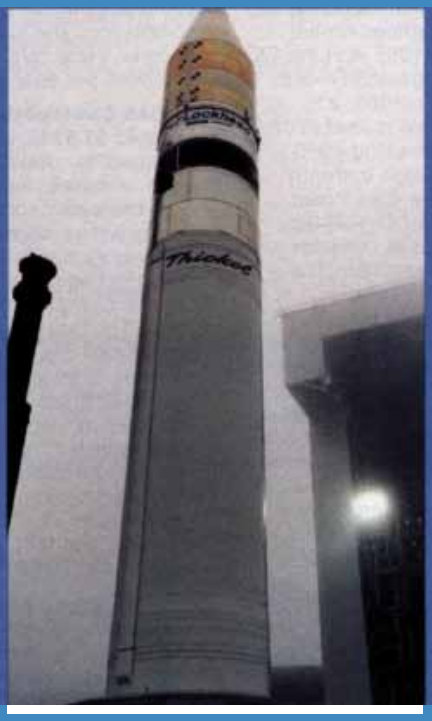
Multiservice Launch System (Lockheed Martin Astronautics)

Launcher is based on refurbished Minuteman II ICBMs. First launch of the MSLS occurred on September 27, 1996, with a suborbital targeting test payload. Lockheed Martin's contract calls for four suborbital flights in support of BMDO objectives in 1997 and 1998, with three more options for other missions available. MSLS can launch up to 830 pounds on suborbital missions with a range of 4,100 nautical miles, approximately 400 pounds into 100-nautical-mile polar orbit. MSLS orbital configurations are under consideration in support of Air Force follow-on contract competitions for more refurbished Minuteman IIs to be converted to space launchers in 1997.

Delta II (McDonnell Douglas)

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. Latest model lifts 11,100 pounds to LEO, 4,010 pounds to GTO. Has successfully launched 27 GPS satellites for USAF. On January 17, a Delta rocket exploded seconds after liftoff when one of its nine strap-on solid motors developed a split casing. The failure destroyed a GPS IIR satellite and grounded the system

Delta II



Lockheed Martin Launch Vehicle

Space Shuttle

for more than three months. The Delta II successfully launched a commercial satellite in May 1997 and was slated to launch another GPS in July.

Space Shuttle (NASA)

Manned space transportation system operated by United Space Alliance, a venture between Lockheed Martin and Boeing North American, under contract to NASA. Launched from Kennedy Space Center, Fla., lifts 46,000 pounds to 160-nautical-mile, 28.5°-inclined orbit. The delta-winged orbiter has flown more than 80 missions since its first use April 12, 1981. The shuttle carries science payloads and experiments and will be used to assemble the international space station starting in 1998.

Pegasus, mounted under an L-1011

Pegasus (Orbital Sciences Corp.)

Winged small launcher, dropped from a B-52 to carry payloads weighing 850 to 1,050 pounds to LEO of 100 nautical miles, 28.5° inclination. Two versions, priced at $11 million to $15 million, are available, including the more powerful XL. Pegasus flew its fifteenth mission on April 21, 1997. Of the 15 missions, two flights failed, one in 1994 and one in 1995. In November 1996, after a flawless flight to the targeted altitude, a Pegasus component malfunctioned and was unable to separate the two on-board satellites, resulting in a mission failure for the payloads. Orbital plans five more launches in 1997 and seven in 1998.

Taurus (Orbital Sciences Corp.)

Ground-launched, four-stage rocket with some Pegasus commonality and a Peacekeeper or Castor 120 motor as the first stage. Capable of boosting 3,200 pounds to LEO of 100 nautical miles, 1,130 pounds to GTO with a Star 37 perigee kick motor. The rocket flew its first mission March 13, 1994. Taurus's next mission is planned for late 1997. It will carry the Ball Aerospace–built GeoSat Follow-on space-craft, as well as two Orbcomm satel-lites as secondary payloads. A late 1997 launch of a classified payload is also planned. Price is $19 million to $21 million.

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 15,000 acres. Cape Canaveral also provides range operations for NASA's shuttle, Navy ballistic missiles, and some research and development 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, 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 USAF on 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 1960 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, and EER operates a launch site for its Conestoga vehicles. 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 (SFA), 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 landbased testing of the Trident II fleet ballistic program. The Naval Ordnance Test Unit will maintain launch capability for future programs. Lockheed Martin is scheduled to launch NASA's Lunar Prospector in September 1997 on its LMLV-2, a dual-stacked Castor 120 solid rocket motor. 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 proposed dual-use commercial launch facility will be sited on 3,100 acres at Kodiak Island, Alaska. Construction for the Kodiak Launch Complex to begin in 1997. The target date for initial operational capability is summer 1998, with an eventual capacity for nine launches per year. 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. Ground- breaking for construction of the commercial launch facility is expected in 1997. The flight center can currently accomo-date some small ELVs using up to a Castor 120 powerplant 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 LMLV-3.

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/Goddard Space Flight Center, Wallops Flight Facility. Only US launch facility currently in polar region. World's largest landbased 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 271 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 February 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 conducting commercial orbital launches.

NASA Spending on Major Space Missions

Fiscal Year 1998 Proposal, Current Dollars

Project Office	Millions
Spaceflight	$5,326.5
Space sciences	2,043.8
Mission to Planet Earth	1,417.3
Aeronautics	1,469.5
Mission communication services	400.8
Life and microgravity sciences	214.2
Safety and mission assurance	37.8
Total	**$10,909.9**

Upcoming Shuttle Flights

Fiscal Year 1998 Proposal

Month/Year, Mission, Name

10/1997, **STS-87,** *Columbia*

12/1997, **STS-88,** *Endeavour*

1/1998, **STS-89,** *Discovery*

3/1998, **STS-90,** *Columbia*

5/1998, **STS-91,** *Discovery*

7/1998, **STS-92,** *Endeavour*

8/1998, **STS-93,** *Columbia*

The Golden Age of NASA

Name	**Project Mercury**
Duration	**November 3, 1958–May 16, 1963**
Cost	$392.1 million (cost figures are in current 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 suborbital trip of 15 minutes. **February 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	**January 15, 1962–November 15, 1966**
Cost	$1.3 billion
Distinction	First program to explore docking, long-duration flight, rendezvous, spacewalks, 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 spacewalk. **August 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. **September 15, 1966** Conrad and Richard F. Gordon, Jr., make first successful automatic, computer-steered reentry.

Name	**Project Apollo**
Duration	**July 25, 1960–December 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. **January 27, 1967** Lt. Col. Virgil I. "Gus" Grissom, Lt. Cmdr. Roger B. Chaffee, and White die in a command module fire in ground test. **October 11–22, 1968** First manned Apollo flight proves "moonworthiness" of spacecraft. **December 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. **December 7–19, 1972** Final Apollo lunar flight produces sixth manned moon landing.

Reading About Space

Boyne, Walter. *Beyond the Wild Blue: A History of the United States Air Force, 1947–97.* New York: St. Martin's Press, 1997.

Burrows, William E. *Deep Black.* New York: Berkley Publishers Group, 1988.

Canan, James W. *War in Space.* New York: Harper & Row, 1982.

Chaikin, Andrew. *A Man on the Moon: The Voyage of the Apollo Astronauts.* New York: Viking Penguin, 1994.

Cochran, Curtis D., John D. Dumoulin, and Dennis M. Gorman, eds. *Space Handbook.* Maxwell AFB, Ala.: Air University Press, 1985.

Collins, John. *Military Space Forces.* Washington, D.C.: Pergamon-Brassey's, 1989.

Cruikshank, Dale, ed. *Neptune and Triton.* Tucson, Ariz.: University of Arizona Press, 1995.

Dauber, Philip, and Richard Muller. *The Three Big Bangs: Comet Crashes, Exploding Stars, and the Creation of the Universe.* Reading, Mass.: Addison-Wesley Publishing Co., 1996.

Fleeter, Rick. *Micro Space Craft.* Order from: Edge City Press, 10912 Harpers Square Ct., Reston, VA 22091. 1995.

Grinspoon, David H. *Venus Revealed: A New Look Below the Clouds of Our Mysterious Twin Planet.* Reading, Mass.: Addison-Wesley Publishing Co., 1997.

Hobbs, David. *Space Warfare.* Englewood Cliffs, N.J.: Prentice Hall, 1986.

Koppeschaar, Carl. *Moon Handbook: A 21st Century Travel Guide.* Chico, Calif.: Moon Publications Inc., distributed by Publishers Group West, 1995.

Launius, Roger D. *NASA: A History of the US Civil Space Program.* Melbourne, Fla.: Krieger Publishing Co., 1994.

Launius, Roger D., ed. *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue.* San Diego, Calif.: American Astronautical Society, Univelt Inc., 1995.

Logsdon, John M., ed., with Dwayne Day and Roger Lanius. *Exploring the Unknown: Selected Documents in the History of the US*

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Space Leaders

(As of July 1, 1997)

Directors, National Reconnaissance Office

Joseph V. Charyk	Sept. 6, 1961–Mar. 1, 1963
Brockway McMillan	Mar. 1, 1963–Oct. 1, 1965
Alexander H. Flax	Oct. 1, 1965–Mar. 11, 1969
John L. McLucas	Mar. 17, 1969–Dec. 20, 1973
James W. Plummer	Dec. 21, 1973–June 28, 1976
Thomas C. Reed	Aug. 9, 1976–Apr. 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–Mar. 5, 1993
Jeffrey K. Harris	May 19, 1994–Feb. 26, 1996
Keith R. Hall (acting)	Feb. 27, 1996–Mar. 27, 1997
Keith R. Hall	Mar. 28, 1997

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–Mar. 29, 1990
Lt. Gen. Thomas S. Moorman, Jr.	Mar. 29, 1990–Mar. 23, 1992
Gen. Donald J. Kutyna	Mar. 23, 1992–July 1, 1992
Gen. Charles A. Horner	July 1, 1992–Sept. 13, 1994
Gen. Joseph W. Ashy	Sept. 13, 1994–Aug. 26, 1996
Gen. Howell M. Estes III	Aug. 26, 1996

Civil Space Program, Volume II, External Relationships. Pittsburgh, Pa.: Government Printing Office, 1996.

Lovell, Jim, and Jeffrey Kluger. *Lost Moon: The Perilous Voyage of Apollo 13.* Boston: Houghton Mifflin, 1994.

Mather, John C., and John Boslough. *The Very First Light: The True Inside Story of the Scientific Journey Back to the Dawn of the Universe*. New York: Basic Books, 1996.

McDougall, Michael R. *The Heavens and the Earth: A Political History of the Space Age.* Baltimore, Md.: The Johns Hopkins University Press, 1997.

Pace, Scott, et al. *The Global Positioning System: Assessing National Policies.* Santa Monica, Calif.: RAND Critical Technologies Institute, 1995.

Parkinson, Brad, and James Spilker, Jr., eds. *Global Positioning System: Theory and Applications* (two volumes). Washington, D.C.: American Institute of Aeronautics and Astronautics, 1996.

Richelson, Jeffrey T. *America's Secret Eyes in Space.* New York: Harper & Row, 1990.

Sagan, Carl. *Pale Blue Dot: A Vision of the Human Future in Space.* New York: Random House, 1994.

Schultz, Richard H. Jr., and Robert L. Pfaltzgraff, Jr., eds. *Space: A New Strategic Frontier, The Future of Airpower in the Aftermath of the Gulf War.* Maxwell AFB, Ala.: Air University Press, 1992.

Seamans, Robert C., Jr., *Aiming at Targets: The Autobiography of Robert C. Seamans, Jr.* Washington, D.C.: Government Printing Office, 1996.

Shepard, Alan, and Deke Slayton, with Jay Barbree and Howard Benedict. *Moon Shot, the Inside Story of America's Race to the Moon.* Atlanta, Ga.: Turner Publishing Inc., 1994.

Slayton, Donald K., with Michael Cassutt. *Deke!: US Manned Space From Mercury to the Shuttle.* New York: St. Martin's Press, 1995.

Smith, Marcia S. *US Space Programs.* Washington, D.C.: Congressional Research Service, 1993.

Voyage Through the Cosmos: Outbound. Alexandria, Va.: Time-Life, Inc., 1989.

Stoker, Carol, and Carter Emmart, eds. *Strategies for Mars: A Guide to Human Exploration*. San Diego: Univelt for American Astronautical Society, 1996.

Stuhlinger, Ernst, and Frederick I. Ordway III. *Wernher von Braun: Crusader for Space,* combined edition. Melbourne, Fla.: Krieger Publishing Co., 1996.

Timnat, Y. M. *Advanced Airbreathing Propulsion*. Malabar, Fla.: Krieger Publishing Co., 1996.

Wilson, Andrew, ed. *Jane's Space Directory 1995–96.* Surrey, UK: Jane's Information Group Ltd., 1995.

Wolfe, Tom. *The Right Stuff.* New York: Bantam Books, 1980. ■