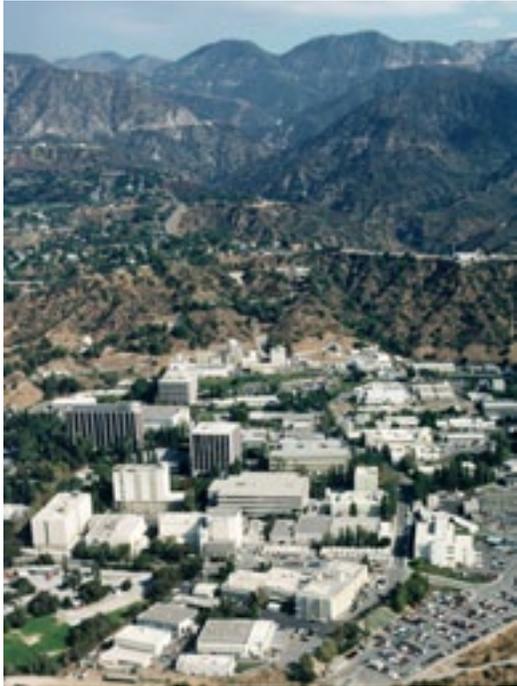




Jet Propulsion Laboratory



From the roar of pioneering Space Age rockets to the soft whir of servos on 21st century robot explorers on Mars, the Jet Propulsion Laboratory's spacecraft have blazed the trail to the planets and the universe beyond for more than 50 years.

The United States first entered space with the 1958 launch of the satellite Explorer 1, built and controlled by JPL. From orbit, Explorer 1's voyage yielded immediate scientific results – the discovery of the Van Allen Radiation Belt – and provided new perspective for studying Earth as a planet. This pivotal space flight led to the creation of NASA and would be followed by decades of major discoveries about Earth and its neighboring bodies as JPL's robotic spacecraft have traversed the solar system.

Innovative technology from JPL has taken humanity far beyond regions of space where we can actually travel ourselves. The most distant human-made objects, Voyagers 1 and 2, were built and are operated by JPL. Now in their fourth decade of exploration, the Voyagers have pressed beyond our farthest planets and continue to return their findings about unexplored space through the antennas of the Deep Space Network, also managed by JPL. From JPL's labs and clean rooms come telescopes and cameras that have extended our vision to unprecedented depths and distances, peering into the hearts of clouds where new stars are born, and even toward the beginning of time at the edge of the universe.

Meeting the challenges of robotic space exploration has resulted in new knowledge that has kept JPL a world leader in science and technology. The tools JPL has developed for space exploration have also proved invaluable in providing new insights and discoveries in studies of Earth, its atmosphere, climate, oceans, geology and the biosphere. The ongoing invention of ever more-sensitive space sensors has also resulted in a myriad of technology applications widely used for medical, industrial and commercial uses on Earth.

JPL is a federally funded research and development facility managed by the California Institute of Technology for the National Aeronautics and Space Administration.

JPL's Beginnings

JPL's history dates to the 1930s, when Caltech professor Theodore von Kármán oversaw pioneering work in rocket propulsion. Von Kármán was head of Caltech's Guggenheim Aeronautical Laboratory. Several of his graduate students and assistants gathered to test a primitive rocket engine in a dry riverbed wilderness area in the Arroyo Seco, a dry canyon wash north of the Rose Bowl in Pasadena, California. Their first rocket firing took place there on October 31, 1936.

After the Caltech group's successful rocket experiments, von Kármán, who also served as a scientific adviser to the U.S. Army Air Corps, persuaded the Army to fund development of strap-on rockets (called "jet-assisted take-off") to help overloaded Army airplanes take off from short runways. The Army helped Caltech acquire land in the Arroyo Seco for test pits and temporary workshops. Airplane tests at nearby air bases proved the concept and tested the designs. By this time, World War II had begun and the rockets were in demand.

As the group wound up the work on the jet-assisted takeoff rockets, the Army Air Corps asked von Kármán for a technical analysis of the German V-2 program just discovered by Allied intelligence. He and his research team proposed a U.S. research project to understand, duplicate and reach beyond the guided missiles beginning to bombard England. In the proposal, the Caltech team referred to their organization for the first time as "the Jet Propulsion Laboratory."

Funded by Army Ordnance, the Jet Propulsion Laboratory's early efforts would eventually involve technologies beyond those of aerodynamics and propellant chemistry, technologies that would evolve into tools for space flight, secure communications, spacecraft navigation and control, and planetary exploration.

The team of about 100 rocket engineers began to expand, and the team began tests in the California desert of small unguided missiles, named Private, that reached a range of nearly 18 kilome-

NASAfacts

ters (about 11 miles). They experimented with radio telemetry from missiles, and began planning for ground radar and radio sets. By 1945, with a staff approaching 300, the group had begun to launch test vehicles from White Sands, New Mexico, to an altitude of 60 kilometers (200,000 feet), monitoring performance by radio.

Control of the guided missile was the next step, requiring two-way radio as well as radar and a primitive computer (using radio tubes) at the ground station. The result was JPL's answer to the German V-2 missile, named Corporal, first launched in May 1947, about two years after the end of war with Germany.

Developing a missile that would fly and survive in the field involved testing its aerodynamic design and durability under vibration and other stresses. The team developed a supersonic wind tunnel and an array of environmental test technologies, all of which had wider use and came to support outside customers. Developing so complex a device as a missile to fly unaided and beyond reach of repair meant a new degree of quality, new test techniques and a new discipline called system engineering.

Subsequent Army work further sharpened the technologies of communications and control, of design and test and performance analysis. This made it possible for JPL to develop the flight and ground systems and finally to fly the first successful U.S. space mission, Explorer 1. The entire three-month effort began in November 1957 and culminated with the successful launch on January 31, 1958.

On December 3, 1958, two months after NASA was created by Congress, JPL was transferred from Army jurisdiction to that of the new civilian space agency. It brought to the new agency experience in building and flying spacecraft, an extensive background in solid and liquid rocket propulsion systems, guidance, control, systems integration, broad testing capability, and expertise in telecommunications using low-power spacecraft transmitters and very sensitive Earth-based antennas and receivers.

The Laboratory now covers some 72 hectares (177 acres) adjacent to the site of von Kármán's early rocket experiments.

Planetary Exploration

In the 1960s, JPL began to conceive and execute robotic spacecraft to explore other worlds. This effort began with the Ranger and Surveyor missions to the moon, paving the way for NASA's Apollo astronaut lunar landings. The successful Ranger missions were Ranger 7, 8 and 9, launched in 1964 and 1965, which took photos of the moon as they descended toward an intentional impact. In 1966 through 1968, Surveyor 1, 3, 5, 6 and 7 made soft-landings on the moon. During that same period and through the early 1970s, JPL carried out Mariner missions to Mercury, Venus and Mars.

Mariner 2 became the first spacecraft to fly by another planet following its launch August 27, 1962, to Venus (Mariner 1 was lost because of a launch vehicle error). Other successful planetary flybys were conducted by 1964's Mariner 4 to Mars, 1967's Mariner 5 to Venus, and 1969's Mariner 6 and 7 to Mars. In 1971, Mariner 9 became the first spacecraft to orbit another planet when it was sent to Mars.

Mariner 10 was the first spacecraft to use a "gravity-assist" boost from one planet to send it on to another – a key innovation in spaceflight that would later enable the exploration of outer planets that would have otherwise been unreachable. Mariner 10's launch in November 1973 delivered the spacecraft to Venus in February 1974, where a gravity-assist swingby allowed it to fly by Mercury in March and September that year.

The first search for life on Mars was conducted in 1975 when NASA launched the Viking mission's two orbiter spacecraft and two landers. The elaborate mission was divided between several NASA centers and private U.S. aerospace firms,

with JPL building the Viking orbiters, conducting mission communications and eventually assuming responsibility for management of the mission.

Credit for the single mission that has visited the most planets goes to JPL's Voyager project. Launched in 1977, the twin Voyager 1 and Voyager 2 spacecraft flew by the planets Jupiter (1979) and Saturn (1980-81). Voyager 2 then went on to an encounter with the planet Uranus in 1986 and a flyby of Neptune in 1989. Early in 1990, Voyager 1 turned its camera around to capture a series of images assembled into a "family portrait" of the solar system. Still communicating their findings as they speed out toward interstellar space, the Voyagers are expected to have enough power to continue communicating information about the Sun's energy field until approximately the year 2025. In February 1998, Voyager 1 passed NASA's Pioneer 10 to become the most distant human-made object in space.

In 1989 and 1990 NASA's space shuttle helped launch three JPL-managed solar system exploration missions: Magellan to Venus, Galileo to Jupiter and Ulysses to study the Sun's poles.

Magellan used a sophisticated imaging radar to pierce the cloud cover enshrouding Venus and map the planet's surface. Magellan was carried into Earth orbit in May 1989 by space shuttle Atlantis. Released from the shuttle's cargo bay, Magellan was propelled by a booster engine toward Venus, where it arrived in August 1990. It completed its third 243-day period mapping the planet in September 1992. Magellan mapped variations in Venus's gravity field before the mission ended in October 1994. At the conclusion of the mission, flight controllers commanded Magellan to dip into the atmosphere of Venus in a test of aerobraking – a technique for using atmospheric drag to slow spacecraft that has since been used in other planetary missions.

The Galileo mission began in October 1989 when it was carried into Earth orbit on space shuttle Atlantis and then sent on its interplanetary flight path via an Inertial Upper Stage booster. Relying on gravity assist swingbys to reach Jupiter, Galileo flew past Venus once and Earth twice. Along the way Galileo flew by the asteroid Gaspra in October 1991 and the asteroid Ida in August 1993. On its final approach to the giant planet, Galileo observed Jupiter being bombarded by fragments of the broken-up comet Shoemaker-Levy 9. On July 12, 1995, Galileo separated from its atmospheric probe and the two spacecraft flew in formation to their final destination.

On December 7, 1995, Galileo fired its main engine to enter Jupiter orbit and collected data radioed from the probe during its parachute descent into the planet's atmosphere. During its two-year prime mission, Galileo conducted 10 targeted flybys of Jupiter's major moons. In December 1997, the spacecraft began a first extended mission, which featured eight flybys of Jupiter's icy moon Europa and two of the volcanic moon Io. A second extended mission began in early 2000, including flybys of the moons Io, Ganymede and Callisto, plus coordinated observations with the Cassini spacecraft as Cassini flew past Jupiter in December 2000 for a gravity assist to reach Saturn. On September 21, 2003, after 14 years in space and eight years orbiting Jupiter, Galileo ended its mission by plunging into the giant planet's atmosphere – a maneuver designed to avoid any chance of Galileo contaminating Jupiter's moons with bacteria from Earth.

NASA's shuttle fleet again launched a probe bound for other parts of the solar system when the space shuttle Discovery carried aloft Ulysses in October 1990. A joint mission between NASA and the European Space Agency, this project for the first time sent a spacecraft out of the ecliptic – the plane in which Earth and other planets orbit the Sun – to study the Sun's north and south poles. Ulysses first flew by Jupiter in February 1992, where the giant planet's gravity flung it into an unusual solar orbit nearly perpendicular to the ecliptic plane. Ulysses made a total of three passes by the sun's north and south poles in 1994-5, 2000-1 and 2006-7. After it operated for 18 years, final communication with Ulysses took

place in June 2009.

The mission of Mars Observer, launched aboard a Titan III rocket in September 1992, ended with disappointment in August 1993 when contact was lost with the spacecraft shortly before it was to enter orbit around Mars. Some science instruments from Mars Observer were later flown on Mars Global Surveyor.

The next JPL planetary launches were those of Mars Global Surveyor and Mars Pathfinder, launched in November and December 1996, respectively. Mars Pathfinder put a lander and rover on the surface of the red planet in a highly successful landing July 4, 1997; the project fulfilled all the objectives of its prime mission and lasted considerably longer than originally designed before the lander fell silent in September 1997. Mars Global Surveyor went into orbit around the red planet in September 1997, and spent a year and a half lowering its orbit using the technique of aerobraking. The spacecraft made highly detailed maps of the Martian surface until its last communication with Earth in November 2006.

A disappointment at Mars occurred in late 1999, with the loss of the orbiter and lander developed and launched under the Mars '98 project – named Mars Climate Orbiter and Mars Polar Lander, respectively. Climate Orbiter entered the planet's atmosphere too low and did not survive orbit insertion in September 1999. Polar Lander and two Deep Space 2 microprobes piggybacking on it to Mars were lost during arrival at the planet in December 1999.

An orbiter named Mars Odyssey was launched in April 2001, and arrived at the red planet in October of that year. After completing its four-year prime mission, Odyssey has continued to orbit the planet, examining what Mars is made of, detecting water and shallow buried ice, and studying the radiation environment in space.

The next mission to that planet, the Mars Exploration Rover project sent a pair of robotic geologists to sites halfway around Mars from each other. Spirit was launched in June 2003 and landed in January 2004 inside a Connecticut-sized crater named Gusev. Opportunity was launched in July 2003 and landed in January 2004 inside a backyard-sized crater informally called "Eagle." Originally designed to operate for three months, the rovers far exceeded their expected lifetimes and distances traveled. Each has found evidence of long-ago Martian environments where water was active and conditions may have been suitable for life.

The next Mars mission was Mars Reconnaissance Orbiter, launched in August 2005 with the most powerful telescopic camera ever to another planet, plus five other scientific instruments. In 2008, the Mars Phoenix lander set down on the frozen terrain near the planet's north pole, and spent the next five months digging trenches with a robotic arm – establishing that there is in fact a phenomenal amount of water locked up in the form of ice near the Martian north pole. JPL is preparing a highly sophisticated next-generation rover, called Curiosity, to be launched under the Mars Science Laboratory mission in fall of 2011.

JPL designed, built and is flying the Cassini-Huygens mission to Saturn, launched in October 1997. Carrying a record number of 12 instruments, Cassini arrived at Saturn in June 2004, and began an intensive study of Saturn's rings, its moons and magnetosphere. Shortly after its arrival, Cassini discovered new moons, a new ring and a new radiation belt around Saturn. Cassini delivered a probe named Huygens, provided by the European Space Agency, which descended to the surface of Titan, Saturn's largest moon, in January 2005. Titan appears to boast organic chemistry possibly like that which led to the existence of life on Earth. En route to Saturn, Cassini flew by Venus in April 1998 and June 1999 and conducted a Jupiter flyby in December 2000. In 2010, the mission was extended until 2017.

In 1999, NASA launched a JPL-teamed mission called Stardust under the space agency's Discovery program of low-cost missions. Flying by comet Wild-2 in

January 2004, Stardust collected dust and volatile materials that were returned to Earth in a capsule that parachuted to a landing on a dry lake bed in Utah in January 2006. The spacecraft was then reprogrammed to carry out an extended mission, called Stardust-NExT, that took it on a flyby of comet Tempel 1 in February 2011.

JPL also provided project management for another Discovery mission, Genesis. Launched in August 2001, Genesis collected samples of charged particles in the solar wind and returned them to Earth in September 2004. Although the capsule's parachutes did not deploy, scientists achieved most of their science objectives with samples recovered from the capsule.

In addition, JPL managed a Discovery mission called Deep Impact that propelled a large copper projectile into the surface of comet Tempel 1, creating a crater to reveal the composition and structure of the comet nucleus. Launched in January 2005, Deep Impact arrived at the comet in July of that year. The spacecraft was then redirected to carry out an extended mission called EPOXI, under which it made observations in search of planets orbiting other stars and was directed to fly by comet Hartley 2 in late 2010. A comet is also the destination for a JPL instrument called the Microwave Instrument on the Rosetta Orbiter, or Miro, which is carried by a European Space Agency craft launched in February 2004.

A large asteroid and a dwarf planet are the destinations for Dawn, the first spacecraft ever designed to orbit two different bodies after leaving Earth. This mission under NASA's Discovery program launched in September 2007; it is scheduled to arrive at Vesta in July 2011, where it will orbit for a year before departing to arrive at Ceres in 2014.

Another major initiative that has led to a new breed of NASA spacecraft is New Millennium, designed to flight-test new technologies so that they can be reliably used in science missions of the 21st century. The first New Millennium spacecraft, Deep Space 1, was launched in October 1998 to test an ion engine and 11 other new technologies. Deep Space 1 tested autonomous navigation and two advanced science instruments when it flew by the asteroid 9969 Braille in July 1999. After its primary mission, Deep Space 1 gathered images and other information from a bonus September 2001 flyby of comet Borrelly. Under Deep Space 2, two microprobes to test the Martian soil for water vapor piggybacked on Mars Polar Lander, but were lost at arrival in December 1999. The New Millennium program also includes deep space and Earth orbiting missions managed by other NASA centers.

In addition to directing spacecraft that visit planets, asteroids and comets, JPL scientists are active in many programs of observations from the ground. The Laboratory created the Near-Earth Asteroid Tracking system, an automated system used at an Air Force observatory in Hawaii to scan the skies for asteroids or comets that could threaten Earth. In 1999, the project made its first observations from a second site, the 1.2-meter-diameter (48-inch) Oschin telescope on Palomar Mountain, California. In 1998, NASA designated JPL as home of the agency's Near-Earth Objects Office to coordinate observations of Earth-crossing asteroids and comets by various NASA scientists.

Earth Science

In the late 1970s, JPL engineers and scientists realized that the sensors they were developing for interplanetary missions could be turned upon Earth itself to better understand our home planet. This has led to a series of highly successful Earth-monitoring missions that have evolved into a major segment of the Laboratory's activities, now sponsored by NASA's Science Mission Directorate.

In 1978, JPL built an experimental satellite called Seasat to test a variety of oceanographic sensors including imaging radar, altimeters, radiometers and scatterometers. Many of the later Earth-monitoring instruments developed at JPL

owe their legacy to the Seasat mission.

The imaging radar flown on Seasat led to a pair of missions flown on the Space Shuttle, 1981's Shuttle Imaging Radar-A and 1984's Shuttle Imaging Radar-B. These were followed by Spaceborne Imaging Radar-C, an experiment teamed with the German/Italian X-Band Synthetic Aperture Radar and flown on the Space Shuttle twice in 1994. This mission's goal was to study a variety of scientific disciplines – geology, hydrology, ecology and oceanography – by comparing the radar images to data collected by teams of people on the ground. Imaging radar was reflown on the Space Shuttle under the Shuttle Radar Topography Mission in February 2000 to create the world's most accurate topographic map.

Seasat also tested an altimeter that measured sea level heights from space. This concept led to a full-scale satellite mission, Topex/Poseidon, developed jointly by JPL and the French space agency. The oceanographic satellite, launched in August 1992 on an Ariane 4 rocket from Kourou, French Guiana, provided scientists with unprecedented insight into global climate and ocean interactions, currents, eddies, and new details about the global ocean seafloor before its mission ended in 2005. It was followed by two follow-on collaborations with France, the Jason 1 and 2 satellites, launched in 2001 and 2008, respectively, and both currently operating.

Another mission with heritage in Seasat was the JPL-built NASA Scatterometer, an instrument that measures near-surface ocean winds from space. This instrument was launched in August 1996 on the Advanced Earth Observing Satellite prepared by Japan's National Space Development Agency, and continued operating until the satellite failed in early 1997. JPL prepared a rapid replacement, QuikScat, which was launched in 1999 from Vandenberg Air Force Base, California, carrying a scatterometer called SeaWinds that collected data until 2010. A follow-on SeaWinds scatterometer was launched on a Japanese satellite in 2002, but the host satellite stopped functioning later that year.

JPL also designed and built an instrument called the Microwave Limb Sounder that studies the chemistry of Earth's upper atmosphere, relaying important data on topics such as ozone depletion. Early versions flew as payloads on the Space Shuttle, followed by an instrument onboard NASA's Upper Atmosphere Research Satellite launched in September 1991. Currently, a new-generation version of the instrument is flying on NASA's Aura satellite launched in 2004 as part of the agency's Earth Observing System program.

JPL is responsible for several other instruments being flown under the Earth Observing System program. They include the Multi-angle Imaging Spectro Radiometer, launched on NASA's Terra satellite in December 1999 to study the role of clouds in global climate; the Advanced Spaceborne Thermal Emission and Reflection Radiometer, also carried on the Terra satellite to image Earth in various parts of the color spectrum; the Atmospheric Infrared Sounder, launched aboard NASA's Aqua satellite in May 2002, which relays data on temperature and humidity in the atmosphere in order to help understand how heat is exchanged between land, air, sea and the atmosphere; and the Tropospheric Emission Spectrometer, launched in 2004 aboard the Aura satellite, which is studying the troposphere – the lowest region of Earth's atmosphere – and tracking trends in atmospheric chemistry on a global basis.

The Active Cavity Radiometer Irradiance Monitor, or Acrim, is an instrument that measures the Sun's total output of optical energy from ultraviolet to infrared wavelengths – called the total solar irradiance – an important factor in the study of Earth's climate. The instrument was flown on several shuttle missions and satellites in the 1980s and 1990s. A dedicated satellite called AcrimSat was launched in December 1999.

Clouds are the object of study for the CloudSat satellite launched in 2006 – the

first spacecraft to examine clouds on a global basis.

A JPL-teamed mission called the Gravity Recovery and Climate Experiment, or Grace, launched twin satellites in March 2002 to conduct global high-resolution studies of Earth's gravity field.

JPL provided project management for the Solar Mesosphere Explorer, a satellite launched in 1981 to investigate the processes that create and destroy ozone in Earth's upper atmosphere.

Three JPL-developed missions under NASA's Earth System Science Pathfinder program are due for launch. The Orbiting Carbon Observatory was designed to make the first space-based measurements of atmospheric carbon dioxide to gauge its impact on climate. The satellite was launched in 2009, but was lost when the launch vehicle's nose cone, or fairing, failed to open properly; a replacement mission is in preparation. A collaboration with Argentina, the Aquarius mission will provide the first-ever global maps of salt concentration at the ocean surface, improving our understanding of how heat is transported and stored in the ocean. The Soil Moisture Active-Passive mission will provide the first global measurements of soil moisture and surface freeze/thaw information to improve our understanding of how water, energy and carbon are exchanged between Earth's land and atmosphere.

Astronomy and Physics

In addition to studying Earth itself and other bodies within the solar system, other JPL missions extend our view deeper into the universe. Many of these have focused on examining the cosmos using infrared light invisible to the human eye

JPL was U.S. manager of the Infrared Astronomical Satellite, a joint project with the Netherlands and the United Kingdom. Launched in 1983, the mission was an Earth-orbiting telescope that mapped the sky in infrared wavelengths. Its data have led to a wealth of discoveries about the formation of galaxies, stars and planets, including the first-ever direct evidence of an emerging planetary system around a star besides the Sun – material orbiting Vega, 26 light-years away.

That mission initiated a rich history of involvement with infrared at the laboratory. JPL in conjunction with Caltech operates the Infrared Processing and Analysis Center, which has processed data for several infrared missions, both spaceborne and ground-based.

That expertise also prepared JPL to develop and manage the Spitzer Space Telescope, a sibling to the Hubble Space Telescope. Spitzer, along with the Hubble Space Telescope, the Chandra X-ray Observatory and the Compton Gamma Ray Observatory, were conceived as part of NASA's Great Observatories Program, designed to study the universe at various wavelengths. Launched August 25, 2003, Spitzer produced a long string of discoveries, ranging from views of the earliest stars in the universe to the revelation that the stuff that comets and planets are made of is common throughout our galaxy. Perhaps most memorably, Spitzer was the first telescope ever to directly capture light from planets orbiting other stars; previously, astronomers could only tell planets were there by their gravitational effect on their parent star. In 2009, Spitzer's coolant was depleted, and it shifted to a new, "warm" mission helping to refine estimates of Hubble's constant, or the rate at which our universe is stretching apart. Astronomers also planned to use it to assess hazards from near-Earth asteroids.

The Two Micron All-Sky Survey was astronomy's most thorough high-resolution digital survey of the entire sky, completed by twin infrared telescopes. Operations began in Arizona in June 1997 and in Chile in March 1998, and observations concluded in February 2001. The survey produced catalogues brimming with nearly half a billion objects. The bonanza of astronomical discoveries includes hundreds of brown dwarfs, or cool, failed stars, enabling scientists to define new classes of stars; maps of the Milky Way's structure and dust distribution, and

largescale structure in the nearby universe; and observations of numerous dust-obscured galaxies in the distant universe.

In December 2009, NASA launched the JPL-managed Wide-field Infrared Survey Explorer, or WISE, designed to detect hundreds of millions of objects from asteroids to distant galaxies as it maps the entire sky. A thousand times more sensitive than the celebrated Infrared Astronomical Satellite of the 1980s, WISE is snapping 1.5 million images – one every 11 seconds – and mapping the sky eight times over during its 10-month mission. Among the 100,000 new asteroids that WISE is expected to discover, perhaps 400 are expected to fall in the category of rocks that pass relatively close to Earth.

Among yet other infrared missions, JPL provided key technologies for the European Space Agency's Herschel and Planck spacecraft, which rode together into space on a single rocket following their launch on an Ariane rocket in May 2009. Both are orbiting an invisible spot in space called the Lagrange 2 point, four times farther from Earth than the moon. Herschel is studying star-forming clouds – the “slow cookers” of star ingredients – to trace how life-forming molecules like water form. Planck is taking the sharpest portrait ever of the residue of the Big Bang, known as the cosmic microwave background. JPL is also developing the Mid-Infrared Instrument for NASA's James Webb Space Telescope, a successor to Hubble that will look back in time over more than 90 percent of the history of the universe.

Other JPL spacecraft and instruments have been designed to study other portions of the energy spectrum. JPL designed and built the Wide Field/Planetary Camera, the main observing instrument on NASA's Hubble Space Telescope. After a flaw was discovered in the space telescope's main mirror, JPL created a second-generation camera, the Wide Field and Planetary Camera 2, that compensated for the optical problem – essentially like fitting Hubble with a set of corrective eyeglasses. Spacewalking astronauts installed this second camera during a shuttle mission in December 1993, allowing Hubble to fulfill its promise in producing unprecedented views of the cosmos. The camera was removed by astronauts and returned to Earth during a shuttle mission in May 2009.

In April 2003, NASA launched the Galaxy Evolution Explorer. This Caltech-JPL mission, developed under NASA's Small Explorer Program, uses ultraviolet wavelengths to study the history of star formation. It is observing a million galaxies across 10 billion years of cosmic history to help astronomers determine when the stars we see today had their origins.

JPL managed flight project development of the Kepler, a space-based telescope designed to search for Earth-sized planets around other stars. Kepler accomplishes this by watching for changes in the light from stars as planets pass in front of them, concentrating on an area of the sky around the constellations Cygnus the Swan and Lyra the Lyre. Following launch in March 2009, JPL handed off science operations to NASA's Ames Research Center, home of the mission's principal investigator.

Telecommunications

To provide tracking and communications for planetary spacecraft, JPL designed, built and operates NASA's Deep Space Network of antenna stations.

Communications complexes are located in California's Mojave Desert, in Spain and in Australia. In addition to NASA missions, the network regularly performs tracking for international missions sending spacecraft to deep space. Ground stations also conduct experiments using radar to image planets and asteroids, as well as experiments using the technique of very long baseline interferometry to study extremely distant celestial objects.

The Deep Space Network is also playing a major role in Space Very Long Baseline Interferometry, a radio astronomy project teaming orbiting spacecraft with

ground antennas. Combining ground antennas with a Japanese spacecraft launched in 1997 approximately triples the resolving power previously achievable.

Technologies

In the decades it has led the nation's planetary exploration program, JPL has honed several skills and areas of innovation, including deep space navigation and communication, digital image processing, imaging systems, intelligent automated systems, instrument technology, microelectronics and more. Many of these disciplines found applications outside the planetary spacecraft field, from solar energy to medical imagery.

In the mid-1970s, in response to a world energy crisis, JPL worked to develop and apply alternate sources of electricity such as solar energy, for the Department of Energy, and electric vehicles and other alternative transport systems, for the Department of Transportation.

The Laboratory has also applied space-based operational, communication and information processing techniques to the needs of the Department of Defense, Federal Aviation Administration and other federal agencies. Its active technology transfer program with the industrial community dates back to the early days of the missile program.

JPL conducts technology development projects both for NASA and for sponsors other than NASA. Non-NASA projects at JPL have included Firefly, an aircraftborne infrared fire mapping system for the U.S. Forest Service; a document monitoring system to help the National Archives safeguard the U.S. Constitution, Declaration of Independence and Bill of Rights; medical projects such as robot-assisted microsurgery and medical imaging systems, and Internet-based telemedical systems; and varied projects in such fields as advanced spacecraft and sensor technology, microelectronics, supercomputing and environmental protection.

JPL work for the Department of Defense has included the Miniature Seeker Technology Integration, a satellite built and launched in November 1992 to demonstrate miniature sensor technology and a rapid development system. JPL also managed the U.S. Army's All Source Analysis System project, a battlefield information management system.

Research and development activities at JPL include an active program of automation and robotics supporting planetary rover missions and NASA's Space Station program. In supercomputing, JPL has pioneered work with new types of massively parallel computers to support processing of enormous quantities of data to be returned by space missions in years to come.

Institutional

In addition to the Laboratory's main Pasadena site and the three Deep Space Network complexes around the world, JPL installations include an astronomical observatory at Table Mountain, California, and a launch operations site at Cape Canaveral, Florida.

In 2011, JPL has a workforce of about 5,000 employees and on-site contractors, and an annual budget of approximately \$1.6 billion.

Dr. Charles Elachi, a researcher with a background in imaging radar and other remote-sensing technologies, became director of JPL on May 1, 2001. In addition to his JPL post he serves as a vice president of Caltech. Elachi's predecessors as head of the Laboratory were Dr. Edward C. Stone (1991-2001), Dr. Lew Allen Jr. (1982-1990), Dr. Bruce Murray (1976- 1982), Dr. William H. Pickering (1954-1976), Dr. Louis Dunn (1946-54), Dr. Frank Malina (1944-1946) and Dr. Theodore von Kármán (1944 and forerunner organization).