

J P L . 1 0 1



THEY BEGIN LIFE AS NOTIONS,
as questions or hypotheses. In time they
turn into elaborate sculptures of metal,
epoxy and silicon. In sudden eruptions

of fire and billowing smoke they are
tossed up and out of the atmosphere,
out into the cold void between worlds.

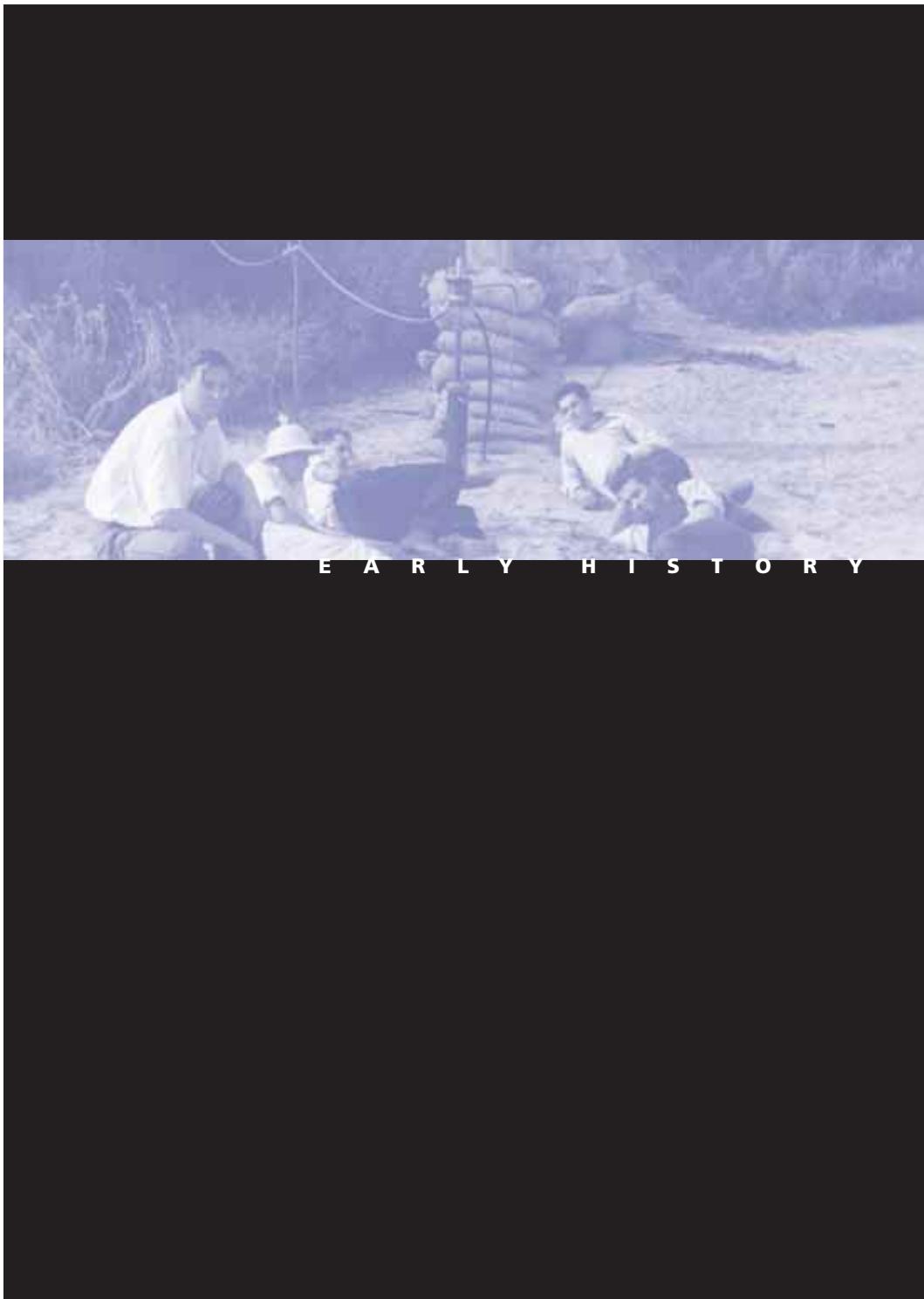
Streaking like bullets across the im-
mense expanses of the solar system,
they carry armadas of instruments to
catalog and analyze all that they pass —
chattering away back to their human
parents with tiny electronic voices
across hundreds of millions of miles.

These are the mechanical offspring of
the Jet Propulsion Laboratory, the
probes and robotic craft sent on explora-
tion voyages over the past four decades.

JPL spacecraft built for NASA have
explored every known planet except
Pluto, and a few have looked out into the
universe beyond our local planets. In the
past quarter century they have also
taken up orbiting stations monitoring the
environment of Earth itself.

Behind them stand thousands of
engineers, scientists and other
professionals who have spent part —
or, in many cases, all — of their
careers at the leafy, campus-like
Laboratory in the Southern California
foothills. In addition to the legacy of
space missions, their crisscrossing
paths have created a culture, a body
of lore and sagas.

The science that JPL has brought to
the country and the world can be
found in the astronomy textbooks that
the Laboratory's missions have
caused to be rewritten in the past
decades. In these pages are a few
stories of what it has been like to have
been at the Lab at various stages in its
history — the human face behind the
metallic struts and columns of data.
In many cases, the personalities and
adventures have been as remarkable
as the worlds their probes have
visited.



E A R L Y H I S T O R Y



EARLY HISTORY

The von Kármán Legacy

PL may be pulling the world into a new era, but to understand its roots you must visit the old world — Budapest in the 1880s, the childhood home of Theodore von Kármán. Budapest was a burgeoning city of government buildings and horse-drawn carriages, an ancient crossroads between eastern and western Europe astride the banks of the Danube River. Theodore was the third of five children born to university professor Maurice von Kármán and his wife, Helene. From an early age it was apparent that Todor, or Theodore, was a mathematical prodigy. The elder von Kármán guided his son into engineering.

While working on his doctorate in Germany, Theodore von Kármán was visiting Paris in 1908 when friends suggested capping an all-night party by observing a flight attempt by Henri Farman, a pioneer French aviator. Farman managed to complete a 2-kilometer (1.25-mile) course in a biplane, and in the process unknowingly launched von Kármán's lifelong devotion to aeronautics.

Von Kármán settled in Aachen, Germany, where he directed an aeronautical institute. In 1930, with the rise of Hitler and anti-Semitism, von Kármán, who was Jewish, accepted an invitation by the California Institute of Technology to come to Pasadena to lead an aeronautical laboratory named for Daniel Guggenheim, a mining industrialist who endowed aeronautical departments at a half dozen universities across the country.

Interestingly, although he laid the groundwork for JPL's legacy in space, von Kármán's ideas were mostly in the realm of aviation, of fluid dynamics and vehicles moving through air. A pioneer in the use of mathematics and basic sciences in aeronautics, he was involved

through the course of his career in projects as diverse as helicopters, gliders, wind tunnels, Zeppelins and jet planes.

Von Kármán was known to his colleagues as a colorful storyteller with the soul of a showman, who loved to relate risqué jokes in an almost theatrically rich Hungarian accent. He was not impeded by excessive modesty. "If you define a great scientist as a man with great ideas, then you will have to rate Einstein first. He had four great ideas," von Kármán once remarked. "In the history of science perhaps only Sir Isaac Newton is ahead of Einstein, because he had five or six ideas. All the other major scientists of our age are associated with just one, or at the most two, great ideas. In my case I have had three great ideas. Maybe more. Yes, perhaps three and a half great ideas."

At age 81 he was the recipient of the first National Medal of Science, bestowed in a White House ceremony by President John F. Kennedy.

A crater on the Moon is

**Theodore von
Kármán headed the
Laboratory from
1938
to 1944.**

named in his honor. Von Kármán, who never married, died while on a visit to Aachen, Germany, in 1963.





EARLY HISTORY

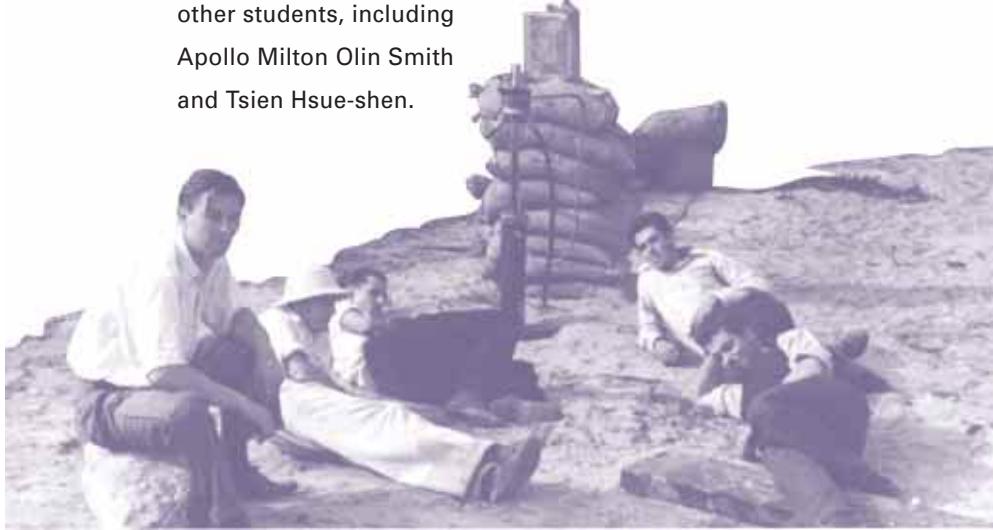
The Suicide Squad

**Five members
of the Suicide
Squad take a
break during
rocket testing in
the Arroyo Seco.**

One day in 1936, two young men appeared in the Caltech office of Professor Theodore von Kármán. The pair, neither of them students, wanted von Kármán's help in building rockets.

The visitors, John W. Parsons and Edward S. Forman, already had a local reputation as rocket hobbyists who had blown many potholes in Forman's backyard; they had corresponded with German researchers, including Willy Ley. Parsons and Forman were excited by a lecture on rocketry they had heard at Caltech. The graduate student who had given the talk, Bill Bollay, said he couldn't help them much more, but he referred them to his teacher, von Kármán. The professor in turn steered them toward one of his graduate students, Frank J. Malina, who would eventually write his doctoral thesis on rocket propulsion.

Malina, Parsons and Forman hit it off, and were soon joined by several other students, including Apollo Milton Olin Smith and Tsien Hsue-shen.



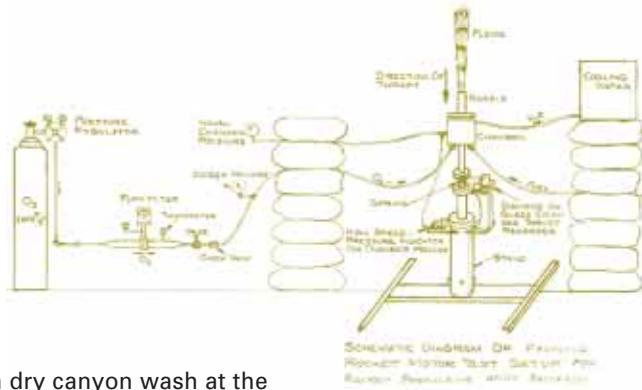
They carried out their first rocket firing on Halloween 1936 in the

Arroyo Seco, a dry canyon wash at the foot of the San Gabriel Mountains on the northwest edge of Pasadena.

They huddled behind sandbags as the motor burned for about three seconds before an oxygen hose broke loose, caught fire and snaked across the ground. A second day of testing, November 15, produced no better results, but likely did result in a photo that JPLers know as the "Nativity Scene," featuring five lounging rocketeers. Copper tubing replaced the rubber hose, resulting in the rocket motor firing for 20 seconds on November 28. Finally on January 16, 1937, the fourth try, the small motor fired long enough to heat its metal nozzle red.

Impressed by the tests, von Kármán set up Malina with a rocket test facility adjacent to a campus building. Parsons and Forman were part-time hired hands who operated the test facility almost on a volunteer basis. Twice their experiments resulted in explosions, the second so great that it propelled a piece of a gauge deep into a wall. Campus wags dubbed them "the Suicide Squad." Soon after they were told to seek another place for their tests.

This sent the group back to the Arroyo Seco, where they leased land from the city of Pasadena. Eventually, the experimenters began comparing different fuel mixtures and motor designs. From this modest beginning in the Arroyo Seco, JPL would begin to take form.





EARLY HISTORY

Taking Flight

In 1938 Caltech's aeronautical lab, headed by Theodore von Kármán, got a surprise visit from General Henry "Hap" Arnold, chief of the U.S. Army Air Corps. Arnold was intrigued with the group's rocket work, and invited von Kármán and his student Frank J. Malina to a meeting in Washington to discuss the Army's research needs as war loomed. Among the research problems Arnold listed was the development of some form of assisted takeoff with rockets for large heavy bombers from short runways — for example, on islands in the South Pacific. The representative of another university sniffed that the Caltechers could take the "Buck Rogers job"; he preferred to work on deicing aircraft windows. This eventually led to Guggenheim Aeronautical Laboratory, California Institute of Technology Project No. 1 — an effort to develop jet-assisted takeoff. The Army issued a contract for \$1,000, followed by another a year later for \$10,000 — substantial money in those days. Von Kármán persuaded Caltech to lease several acres of land from the city of Pasadena on the west bank of the Arroyo Seco.

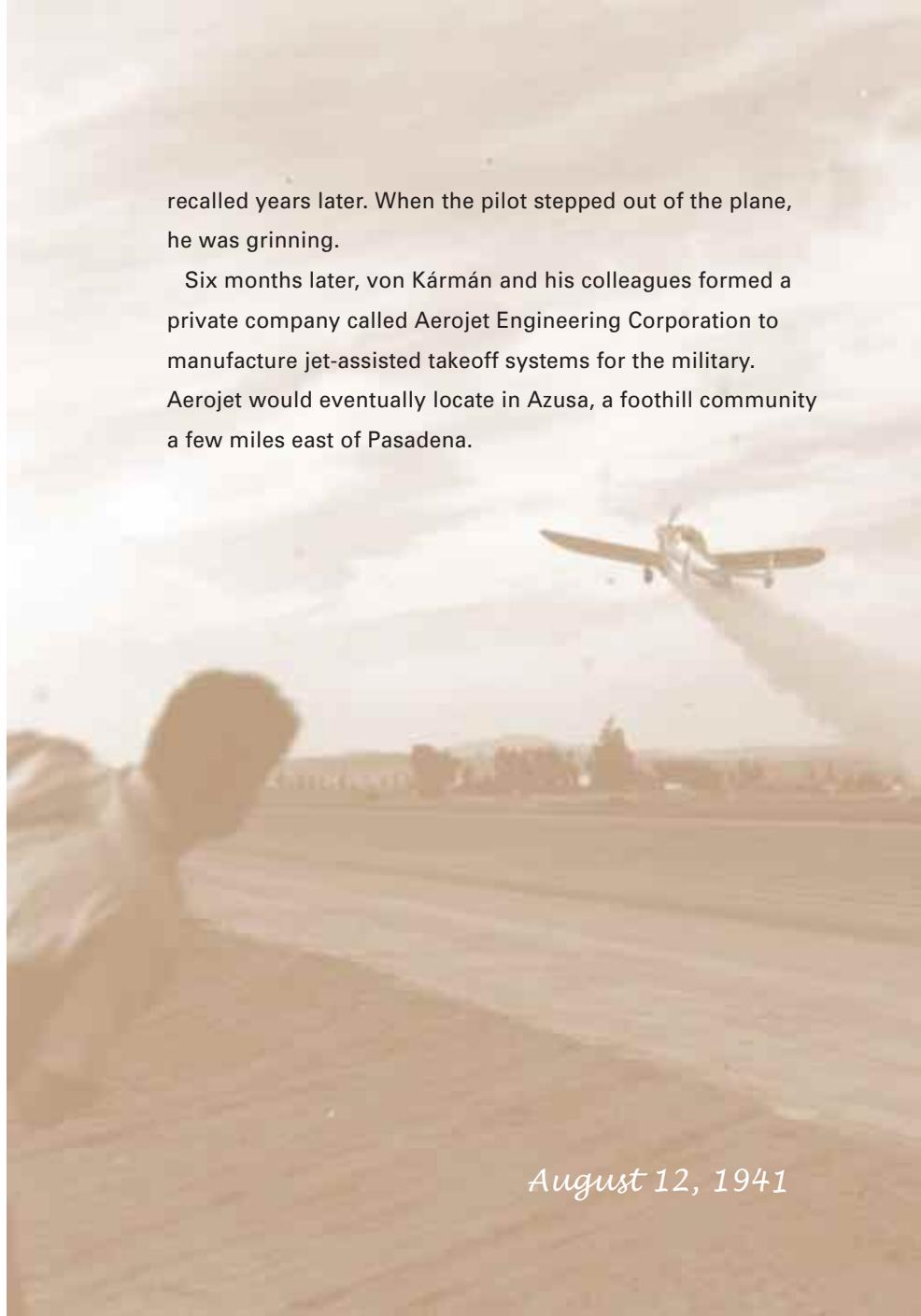
Von Kármán, surrounded by his engineering team, sketches a plan using the wing of an airplane.

In August 1941, the first jet-assisted takeoff tests were conducted with an Ercoupe airplane at March Field in Riverside, California. "The plane shot off the ground as if released from a sling-shot," von Kármán



recalled years later. When the pilot stepped out of the plane, he was grinning.

Six months later, von Kármán and his colleagues formed a private company called Aerojet Engineering Corporation to manufacture jet-assisted takeoff systems for the military. Aerojet would eventually locate in Azusa, a foothill community a few miles east of Pasadena.



Rocketing Away

On November 20, 1943, the Caltech group drafted a proposal to the military to fund work in developing missiles in response to Germany's V-2 rocket. This document — the first official memo in the U.S. missile program — was the first to use the name "Jet Propulsion Laboratory."

The following year, the Laboratory got to work on an 8-foot-long rocket called the Private A. This was test-flown in December 1944, achieving a range of 11 miles.

The researchers decided that their next project required a promotion, calling it the Corporal. But first they would create a smaller, slimmer

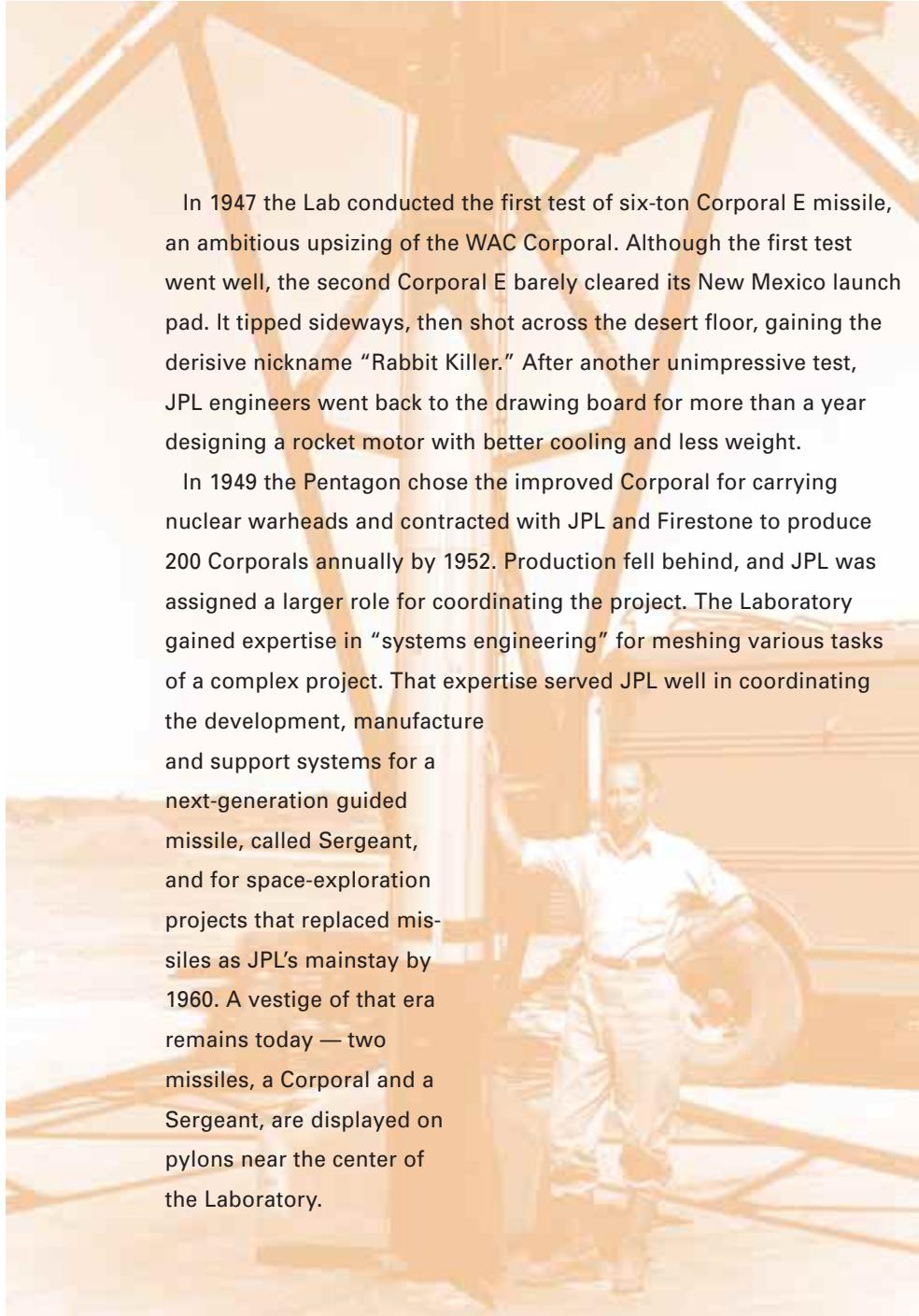


A WAC Corporal
is officially
weighed during
tests in 1945.

rocket that stood 16 feet tall and was called the WAC Corporal. This name was a double entendre. Officially, WAC stood for "without attitude control." But the ac-

ronym also echoed military nomenclature — the Women's Army Corps. In 1945 one of the WAC rockets reached an altitude of 250,000 feet. Four years later, one was launched from the nose of a reconstructed German V-2 rocket and climbed to an altitude of 244 miles — the first U.S. rocket to enter outer space.

At one point in the series from Private to Corporal and onward, a general asked von Kármán how far up in rank the JPLers would go in naming their missiles. "Certainly not over colonel," the professor replied. "This is the highest rank that works."



In 1947 the Lab conducted the first test of six-ton Corporal E missile, an ambitious upsizing of the WAC Corporal. Although the first test went well, the second Corporal E barely cleared its New Mexico launch pad. It tipped sideways, then shot across the desert floor, gaining the derisive nickname "Rabbit Killer." After another unimpressive test, JPL engineers went back to the drawing board for more than a year designing a rocket motor with better cooling and less weight.

In 1949 the Pentagon chose the improved Corporal for carrying nuclear warheads and contracted with JPL and Firestone to produce 200 Corporals annually by 1952. Production fell behind, and JPL was assigned a larger role for coordinating the project. The Laboratory gained expertise in "systems engineering" for meshing various tasks of a complex project. That expertise served JPL well in coordinating the development, manufacture and support systems for a next-generation guided missile, called Sergeant, and for space-exploration projects that replaced missiles as JPL's mainstay by 1960. A vestige of that era remains today — two missiles, a Corporal and a Sergeant, are displayed on pylons near the center of the Laboratory.

Where They Went

After World War II, fate took the original founders of JPL in various directions. All of them would eventually feel the chilling affects of the "Red Scare" of the 1950s. Theodore von Kármán left in 1944 to organize an Air Force scientific advisory board. He was a key advocate of the "containment" policy directed at the Soviet Union. Ironically, he came under investigation by the FBI simply because of his Hungarian birth — at the time Hungary was a member of the communist bloc. The investigation was quietly dropped after he protested. Von Kármán passed away on a visit to Europe in 1963.

Frank Malina, now disillusioned about the use of rockets for military purposes, left America in 1947 to work for the United Nations Educational, Scientific and Cultural Organization, or



**Frank J. Malina,
rocket pioneer and
one of the JPL
founders.**

UNESCO, in Paris. He later pursued a career as a studio artist, creating "kinetic sculpture" that included moving electric lights, and in the late 1960s founded an arts magazine. The Texas-born son of Czech immigrants died in 1981 at his home in Boulogne-sur-Seine, near Paris.

Other fates awaited two of the other JPL founders. Jack Parsons, the hobbyist who with Ed Forman originally approached von Kármán to pursue rocket experiments, made distinctive technical innovations that advanced early efforts. After the Caltech researchers formed the Aerojet Engineering Corpora-

tion in 1942, Parsons worked there until selling his ownership share two years later.



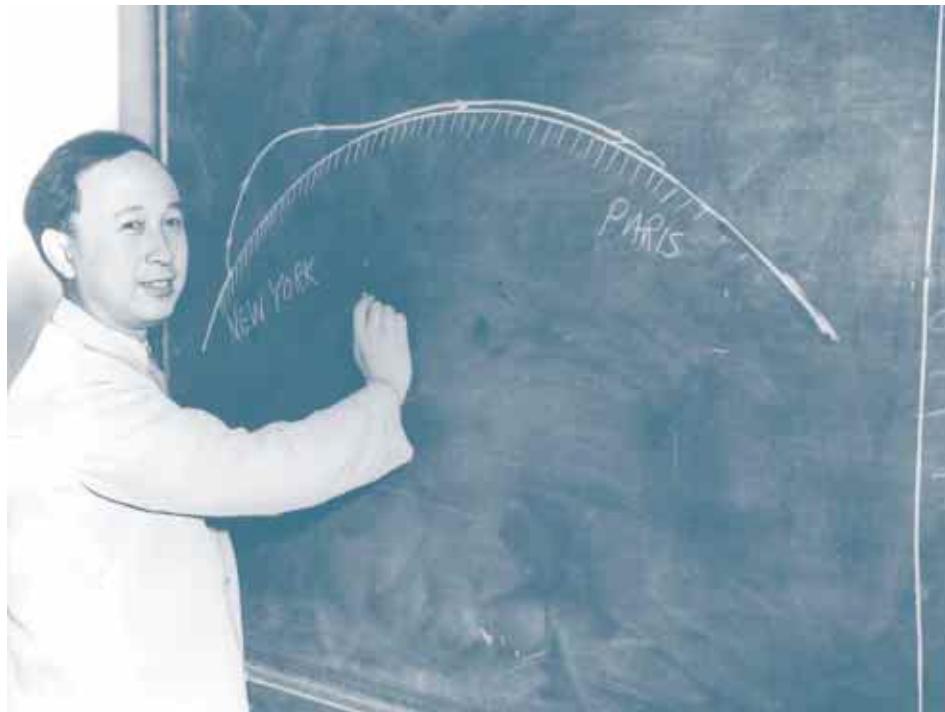
**Early rocketeer
Jack Parsons was
fatally injured in an
explosion.**

Von Kármán remembered Parsons as "an excellent chemist, and a delightful screwball... [with] penetrating black eyes which appealed to the ladies" who "loved to recite pagan poetry to the sky while stamping his feet." Parsons headed a local lodge of an esoteric order linked to a notorious occult group that spawned stories of drug use and sex orgies. After leaving Aerojet, Parsons worked for aircraft manufacturers and explosives makers. He, too, was investigated by the FBI, and eventually lost his security clearance. In 1952 he made plans to move to Mexico to get a new start, but a blast in a garage at his Pasadena apartment killed him at age 37. Police ruled it an accident. In 1972, a crater on the Moon was named for Parsons, one on the far side.

The Chinese-born Tsien Hsue-shen — or, as currently transliterated,

Qian Xue-sen — became an early member of the Caltech rocketry inner circle after arriving on campus in 1936 as a 25-year-old grad student. He and two others wrote the successful 1943 proposal to the U.S. Army that was the first document using the name Jet Propulsion Laboratory. With full security clearance and the rank of colonel, he interrogated Nazi rocketeer Wernher von Braun in 1945 on behalf of the U.S. military.

In 1950, as McCarthyism swept the country, federal agents questioned Tsien about accusations of attending Communist meetings in the 1930s. He denied ever being a Communist. When his security

 **EARLY HISTORY**

Courtesy of University of Southern California, USC Specialized Libraries and Archival Collections

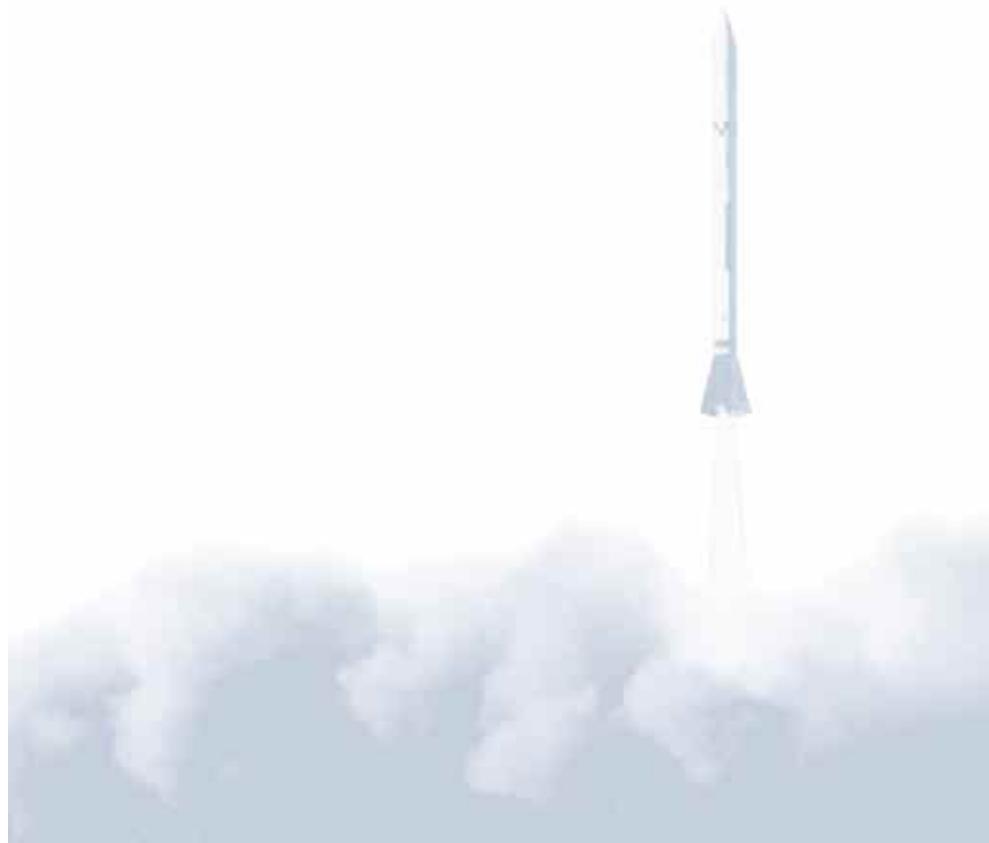
**Tsien Hsue-shen
left the United
States and
developed missiles
for China.**

clearance was revoked, Tsien decided to return to China — but U.S. officials concluded he knew too much, and kept him under virtual house arrest for five years with the aim of allowing his technical knowledge to become gradually outdated. During negotiations in 1955 on the return of American prisoners of war from Korea, the Chinese made the release of Tsien an explicit condition.

President Dwight Eisenhower personally agreed, and later that year Tsien left for China.

Tsien subsequently headed projects for China that developed the surface-to-ship "Silkworm" missile. He is widely acknowledged as the father of the Chinese missile program. In the 1970s he began developing a space program for China that put that country's first satellites into orbit.

Over the course of his career in China, Tsien met Mao Tse-tung six times and personally tutored the Chinese premier. He survived the Cultural Revolution of 1968 and supported the Tiananmen Square massacre in 1989. Tsien later withdrew to a life in seclusion in a guarded residential compound in Beijing. In December 2001, Frank Marble, a Caltech professor emeritus, visited Tsien in China and, at the request of Caltech President David Baltimore, presented him with a Distinguished Alumni Award that the Institute had presented to Tsien in absentia 23 years earlier.





Explorer 1, America's First Satellite

The Soviet Union's October 4, 1957, launch of the first orbiting spacecraft, Sputnik 1, stunned America, which was still just approaching the starting gate of the superpowers' space race.

The U.S. government had announced plans in 1955 to launch a scientific satellite during the International Geophysical Year (the "year" as scheduled ran for 18 months, from July 1957 to December 1958). The government chose between two proposals: a joint Army-JPL entry called Orbiter, and a

Navy entry called Vanguard. Vanguard won, partly because it relied less on military technology. Despite the decision, JPL continued developing some Orbiter technology, including a communications system, for use in tests of reentry heat shields for missiles.

The Sputnik surprise sparked acceleration of Vanguard; the JPL-teamed Orbiter, soon renamed Explorer, was approved for development as a backup. Vanguard exploded at launch in December 1957. JPL quickly built an



Explorer 1, America's answer to Sputnik.

Right: JPL engineers and a model of Explorer 1.

Earth satellite to go atop an Army-supplied booster rocket. This marked the Laboratory's shift in emphasis from rockets to what sits on top of them.

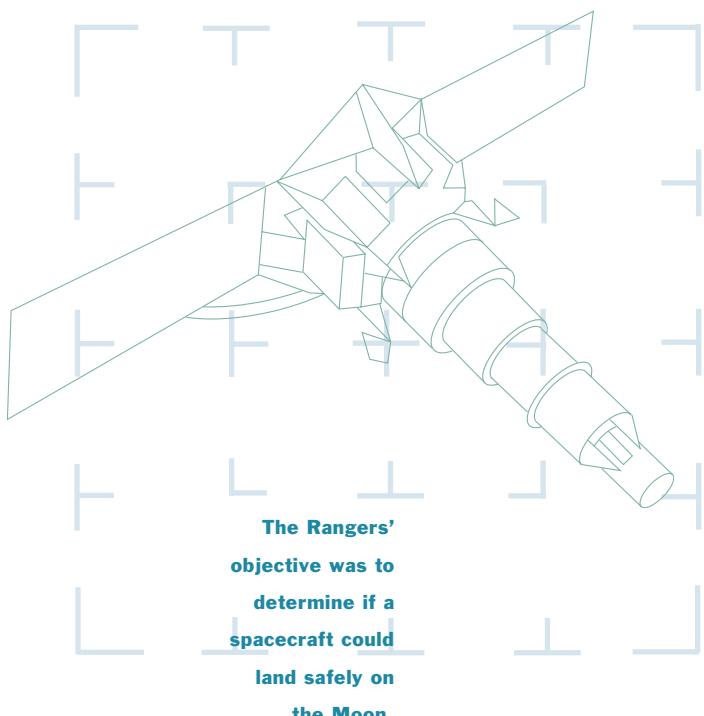
America joined the Space Age with the successful launch of Explorer 1 on January 31, 1958. The craft radioed information about temperatures, micrometeorites and radiation

as it circled Earth every 113 minutes. The radiation belts around Earth named for scientist James Van Allen were discovered with Explorer 1 and Explorer 3, launched two months later.



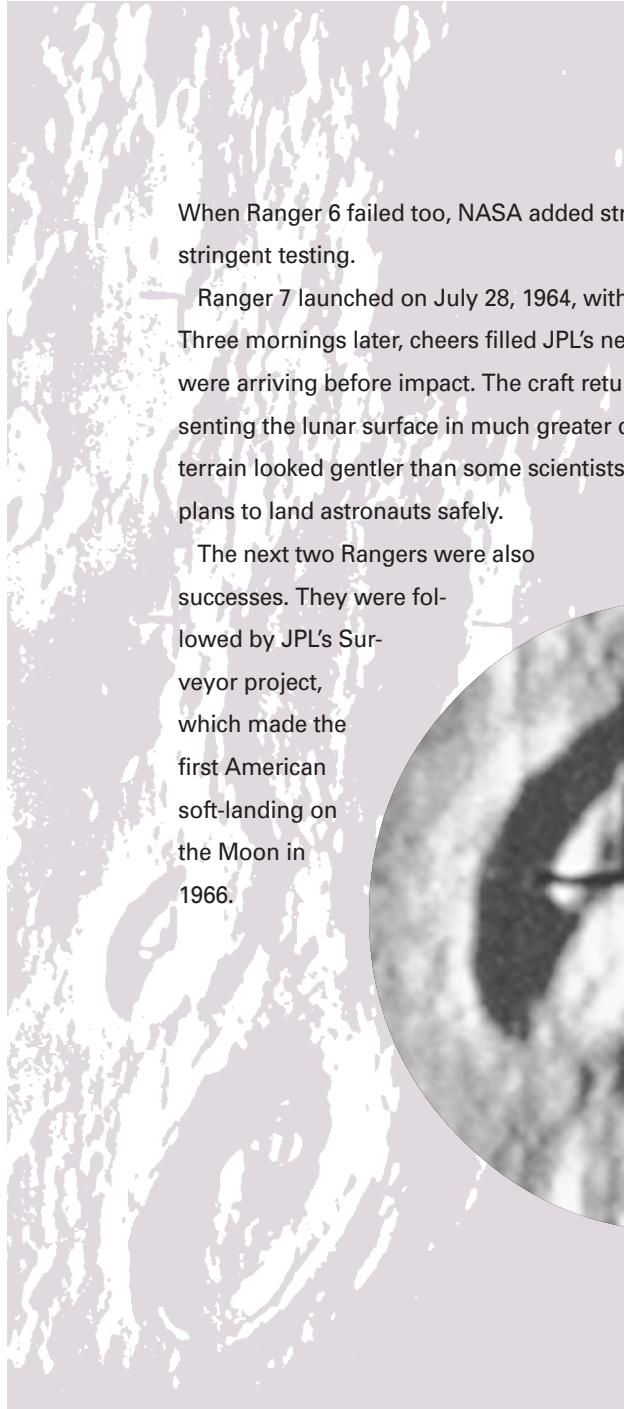
Rangers to the Moon

Newspaper reporters waited tensely at JPL at midnight February 2, 1964, in the final hour of America's sixth attempt to send a spacecraft on a controlled crash-dive onto the surface of the Moon. Five previous attempts had failed for various reasons, so there was a lot riding on Ranger 6. Its camera-monitoring circuit had improperly switched on and off shortly after launch three days earlier. Would the craft send a series of lunar close-ups as planned during the 13 minutes before it impacted in an area where Project Apollo wanted to send astronauts?



With no sign of video transmission 10 minutes before impact, engineers sent backup commands. Still nothing. Impact. No pictures sent.

Ranger 6 had followed more than a year of reviews, reorganization and testing after failures of the first five Rangers in 1961 and 1962. The string of unsuccessful missions marked a bleak time for JPL, an era of investigations and Congressional hearings.

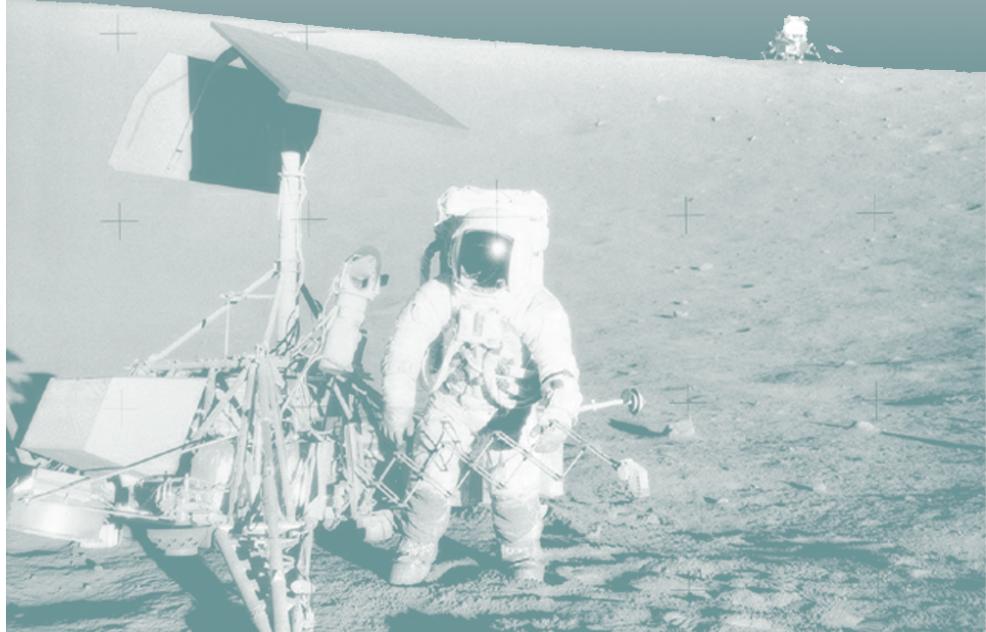


When Ranger 6 failed too, NASA added stronger oversight and even more stringent testing.

Ranger 7 launched on July 28, 1964, with a redesigned camera system. Three mornings later, cheers filled JPL's newsroom at word that video signals were arriving before impact. The craft returned more than 4,000 pictures, presenting the lunar surface in much greater detail than ever seen before. The terrain looked gentler than some scientists had expected — good news for plans to land astronauts safely.

The next two Rangers were also successes. They were followed by JPL's Surveyor project, which made the first American soft-landing on the Moon in 1966.

 INTO SPACE



Astronaut Meets Space Probe

JPL's robotic Surveyor 3

spacecraft had perched on the lunar surface for nearly 31 months when, in November 1969, the third and fourth men on the Moon walked over to it from their nearby landing site.

One goal of NASA's Apollo 12 mission was for astronauts Pete Conrad and Alan Bean to land close enough to fetch pieces of Surveyor 3 for analysis of how materials such as electronic components, metal and paint withstood the harsh environment of the lunar surface.

Before any humans stepped on the Moon, robotic explorers had helped determine where they should land and whether they would sink to their knees in powdery dust. Five successful Surveyors from 1966 to 1968 tested soft-landing techniques and examined the lunar surface. Surveyor 3 dug humankind's first test trenches on another world.

Inside the Surveyor camera that Conrad removed with cutting shears,

Travelers in
an alien world:
astronaut
Pete Conrad
approaches JPL's
Surveyor 3
Moon probe.

researchers later found one of the biggest surprises any Apollo mission brought home from the Moon: Earth bacteria had survived. Their survival for more than two years in an environment of no air, no water and extremely cold temperatures presaged a growing recognition in recent years that life can persist in more extreme conditions than expected.

Nose Job for a Rocket



On the eve of adventure: One of JPL's Mariners awaits liftoff at Cape Canaveral.

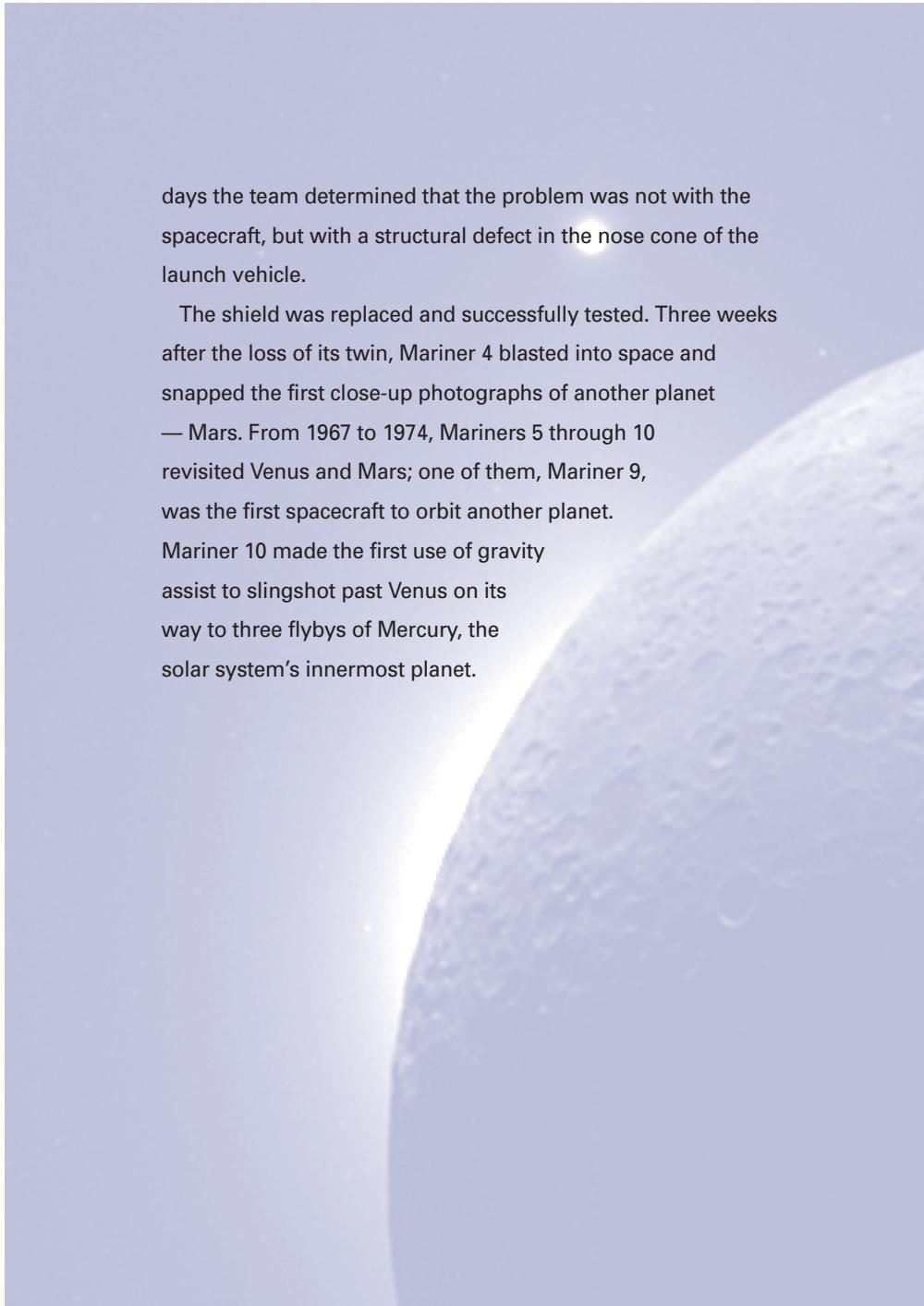
While the Rangers and Surveyors were on their way to Earth's Moon, JPL engineers were setting their sights farther afield with Mariner, a series of robotic craft designed to journey to the closest neighboring planets — Venus and Mars. Success was an on-again, off-again proposition in those pioneering days. Mariner 1 went into the Atlantic when a stray semicolon in guidance software put its launch vehicle off-course. Mariner 2 became the first spacecraft to visit another planet when it flew past Venus on December 14, 1962. Mariner 2 was last heard from on January 3, 1963, but it is assumed still to be in orbit around the Sun.

The next pair in the series, Mariner 3 and 4, were targeted toward Mars. Mariner 3 lifted off on November 5, 1964, but its mission ended only nine hours after its launch. The nose cone that protected the spacecraft as it traveled upward through Earth's atmosphere did not jettison.

Its twin, Mariner 4, was left waiting on the launch pad at the Kennedy Space Center. It was ready to go, but had to sit still until engineers figured out what had gone wrong with Mariner 3.

The race against the clock had begun and engineers had only one month to get it ready to depart for the red planet. The next few days became what some outside observers hail as JPL crisis engineering at its best.

Working with contractors and partners, JPL created what in engineering parlance is known as a "tiger team" — a small, nimble group of its best people with a mission to quickly diagnose and fix a problem. In just four



days the team determined that the problem was not with the spacecraft, but with a structural defect in the nose cone of the launch vehicle.

The shield was replaced and successfully tested. Three weeks after the loss of its twin, Mariner 4 blasted into space and snapped the first close-up photographs of another planet — Mars. From 1967 to 1974, Mariners 5 through 10 revisited Venus and Mars; one of them, Mariner 9, was the first spacecraft to orbit another planet. Mariner 10 made the first use of gravity assist to slingshot past Venus on its way to three flybys of Mercury, the solar system's innermost planet.



I N S I D E M I S S I O N S

Is There Life on Mars?

When the Viking landers touched down on the ocher surface of Mars in 1976, humanity was on the edge of its seat with one question on its collective tongue: Is there life on our planetary neighbor?

The answer from Viking seemed to be “no.” As two JPL-built orbiters stood sentinel overhead, the two NASA Langley Research Center landers set down, each carrying four biology experiments. Of these, three produced results that everyone agreed were negative. The fourth experiment was designed to look at the release of gases when a sort of chicken soup — a liquid with biological nutrients — was spritzed onto a sample of Martian soil.

Although gas release was detected, it did not continue, as would be expected if it were the output of Martian bacteria feasting on takeout. Given the fact that other experiments showed no organic materials of any kind on Mars’ surface, most scientists concluded that the released gas was the result

not of life but of a simple chemical reaction of superoxidation, sort of a speeded-up process of rust.

**Future JPL
rovers will probe
the Martian
surface.**

But that did not put the question to bed. If anything, scientists today are more intrigued than ever by the possibility of life on Mars — or, more exactly, within the planet.

Their interest is prompted by two developments over the past two decades. First, researchers who study life on Earth have come to realize how ubiquitous and tenacious it is. Life clings to the most extreme and inhospitable environments, from deep-sea hot vents to iced-over Antarctic lakes — in fact, anywhere there is water and it is minimally liquid.

Second, JPL’s recent Mars orbiters have been delivering more and more evidence suggesting that the planet was warmer and wetter in its past. The most recent results appear to confirm theories that much of that water went

into the soil and is locked up underground. While much of it may be frozen as ice, areas around hot vents could have hidden pools.

Future missions in the Mars program will capitalize on this lead, following the water trail to try to determine if even rudimentary life may have achieved a foothold on the planet.



Celestial Eruptions

In the last of nine straight daily press briefings at JPL during the Voyager 1 flyby of Jupiter, scientists recapped several discoveries about Jupiter and its moons. They said fresh-looking deposits on the moon Io suggested Io might have volcanoes.

They didn't know how right they were. The most dramatic discovery of the flyby, perhaps of the entire twin-spacecraft Voyager mission to four of the outer planets, was happening that same day — March 8, 1979 — elsewhere at JPL. Linda Morabito, a navigation engineer, looked at a picture of Io taken by the departing spacecraft intended to show navigators Io's exact position against background stars. She noticed a puzzling cloud. Scientists examined that picture and others over the next three days. They also found hot spots in Voyager's infrared observations of Io.

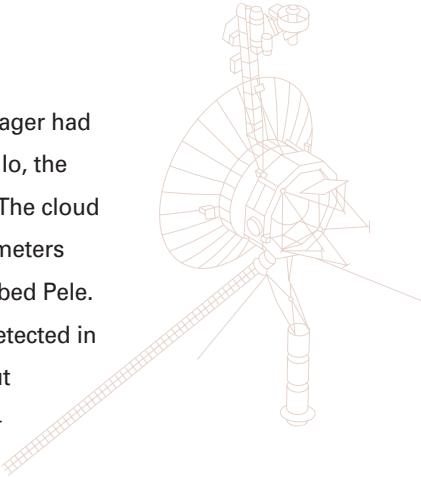
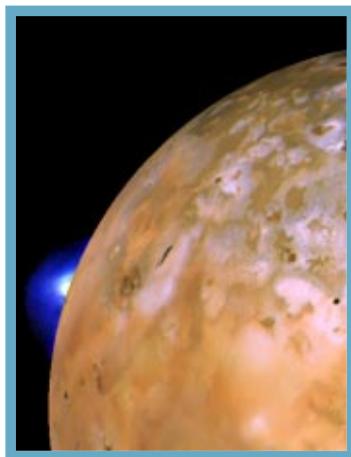


The news went out on March 12: Voyager had witnessed active volcanic eruptions on Io, the first ever seen anywhere but on Earth. The cloud was a plume lofted more than 250 kilometers (155 miles) high by a volcano later dubbed Pele. In all, 22 active volcanoes on Io were detected in Voyager 1 and Voyager 2 images. About 100 more have been found by the Jupiter-orbiting Galileo spacecraft since 1995 or with Earth-based telescopes.

The discovery was just one of an amazing array of new sights delivered by Voyagers 1 and 2 as they blazed a path into the outer solar system in the late 1970s and 1980s. With the information they sent home about four planets and some 50 moons, the twin Voyagers revealed the solar system's unexpected diversity. Instead of sets of geologically passive moons with ancient, cratered surfaces, they discovered a marvelous assortment of worlds with signs of vigorous past or present geological activity. Because

the Sun powers Earth's winds, scientists were amazed that Voyager 2 discovered stronger and stronger winds as it visited planets farther and farther from the Sun.

Among the Voyagers' discoveries — Jupiter's atmosphere has dozens of huge storms; Saturn's rings have kinks and spoke-like features; the hazy atmosphere of Saturn's moon Titan extends far above its surface; Miranda, a small moon of Uranus, has a jumble of old and new surfacing; Neptune has the fastest winds of any planet; and Neptune's moon Triton has active ice geysers.



[Galileo's Long Road to Jupiter]

When the Galileo craft braked into orbit in 1995 to begin more than six years examining Jupiter and its surprising moons, it was the culmination of the longest and most arduous effort to launch and deliver a spacecraft in JPL's history. One public television documentary, in fact, depicted it as the "rocky road to Jupiter."

First there was the launch-vehicle shuffle. Depending on what year you looked in on the mission in the early 1980s, it was going to be lofted on any one of several different rockets and boosters. At one point the Galileo orbiter and its descent probe were to be launched separately on two different rockets. It was finally decided to launch the combined spacecraft from the cargo bay of the space shuttle in 1986. That was put on hold, however, when the

"Failure" is not in the Galileo flight team lexicon.

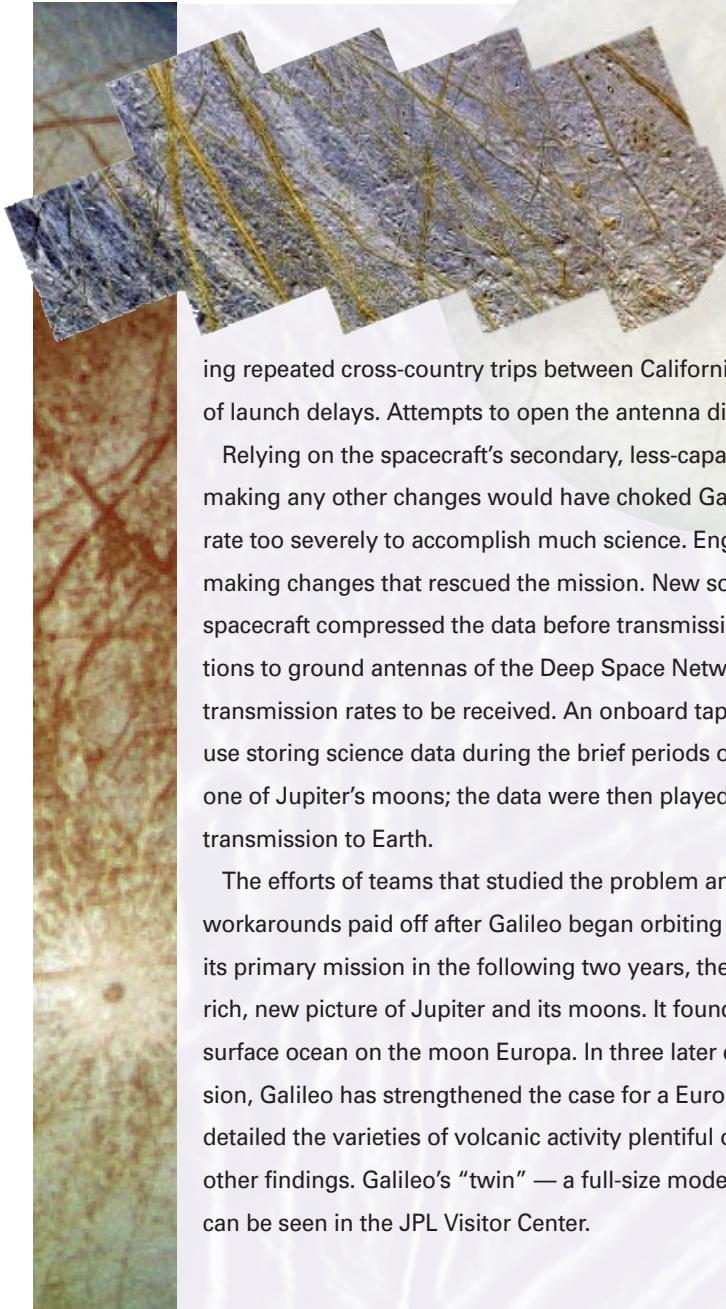
Despite the loss of the high-gain antenna, Galileo endured and triumphed.

Challenger disaster occurred at the beginning of that year. NASA then decided to cancel any use of liquid-fuel boosters on the shuttle because of potential risks to astronauts. That might have deep-sixed the Galileo mission, until planners came up with a novel way to get to Jupiter using gravity-assist flybys of Venus and twice by Earth — a looping flight plan that was unprecedented. This scheme allowed Galileo to be launched on a less-powerful solid-fuel booster from

the space shuttle.

JPL engineers were all smiles until disaster struck anew. A year and a half after launch, as Galileo flew outward from the Sun, controllers commanded the spacecraft to unfurl its umbrella-like main antenna that would beam data back to Earth.





The antenna stuck partway open, rendering it useless — the lubricant apparently had been worn away during repeated cross-country trips between California and Florida because of launch delays. Attempts to open the antenna did not work.

Relying on the spacecraft's secondary, less-capable antenna without making any other changes would have choked Galileo's communication rate too severely to accomplish much science. Engineers responded by making changes that rescued the mission. New software sent to the spacecraft compressed the data before transmission to Earth. Adaptations to ground antennas of the Deep Space Network enabled faster transmission rates to be received. An onboard tape recorder was put to use storing science data during the brief periods of each close flyby of one of Jupiter's moons; the data were then played back more slowly for transmission to Earth.

The efforts of teams that studied the problem and developed the workarounds paid off after Galileo began orbiting Jupiter in 1995. During its primary mission in the following two years, the spacecraft delivered a rich, new picture of Jupiter and its moons. It found evidence for a subsurface ocean on the moon Europa. In three later extensions of its mission, Galileo has strengthened the case for a Europan ocean and detailed the varieties of volcanic activity plentiful on the moon Io, among other findings. Galileo's "twin" — a full-size model of the spacecraft — can be seen in the JPL Visitor Center.

The Hubble Rescue

When engineers are hired by JPL, their job descriptions normally do not include expertise in optometry.

But in the early 1990s, some JPL engineers and scientists were called on to serve as cosmic optometrists when a crisis popped up with the Hubble Space Telescope. The schoolbus-size orbiting observatory was a product of several NASA centers and private contractors; JPL's contribution was one of several science instruments attached to the telescope, a camera that would focus and record pictures.

After Hubble was launched in 1990, disheartened scientists learned that its primary mirror — a 2.4-meter-diameter (2.6-yard) chunk of glass that reflects light onto the science instruments — had been misground by a tiny increment one-fiftieth the thickness of a sheet of paper. Small as this might seem, it meant that the telescope could not focus light from an object to a single sharp point; instead, objects looked like fuzzy halos. This rendered the telescope almost useless for the requirements of science observations.

To solve this unprecedented problem and save the mission, JPL engineers found a clever way to fit Hubble with a pair of astronomical eyeglasses. The plan all along was for JPL to build a second-generation camera, called the Wide-Field and Planetary Camera 2, that would be





One of the best-known Hubble images featured luminescent cloud pillars in the Eagle Nebula.



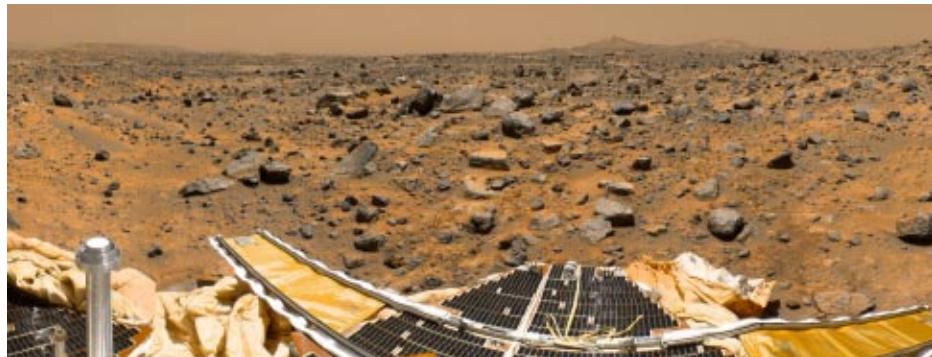
installed on Hubble a few years after launch. Rather than try to fix the enormous primary mirror, JPLers could engineer in an optical correction to the new camera they were then designing. The camera was completed and installed on Hubble in 1993 by spacewalking shuttle astronauts.

Voilà! Equipped with the new camera, Hubble began beaming to Earth dazzling, colorful images of

swirling galaxies; towering pillars of cosmic gas and dust; views of the faraway sky brimming with billions of galaxies; and clear views of Mars, Jupiter and other planets. In short, the camera made possible the amazing streak of discoveries and images that Hubble churned out over the following years.

The Little Rover That Could

To a skeptic, it sounded like a scheme out of Rube Goldberg. A rocket was going to propel a payload directly into the atmosphere of Mars, where a parachute would slow its descent. When onboard radar detected the ground below looming up, huge airbags not unlike a safety system on a car would abruptly inflate, and the whole thing would come bouncing to a stop on the planet's surface.



A panorama of the landing site and Sojourner rover as seen by the stereo camera on the lander.

The fact that many breaths were held made the mood all that more ecstatic when Mars Pathfinder beamed back its first signal from the red planet on July 4, 1997 — the first American visitor there in more than 20 years.

As luck would have it, the lander came to rest on Mars' surface in just the right configuration to allow it to get to work as quickly as possible. In addition to science instruments on the lander it-

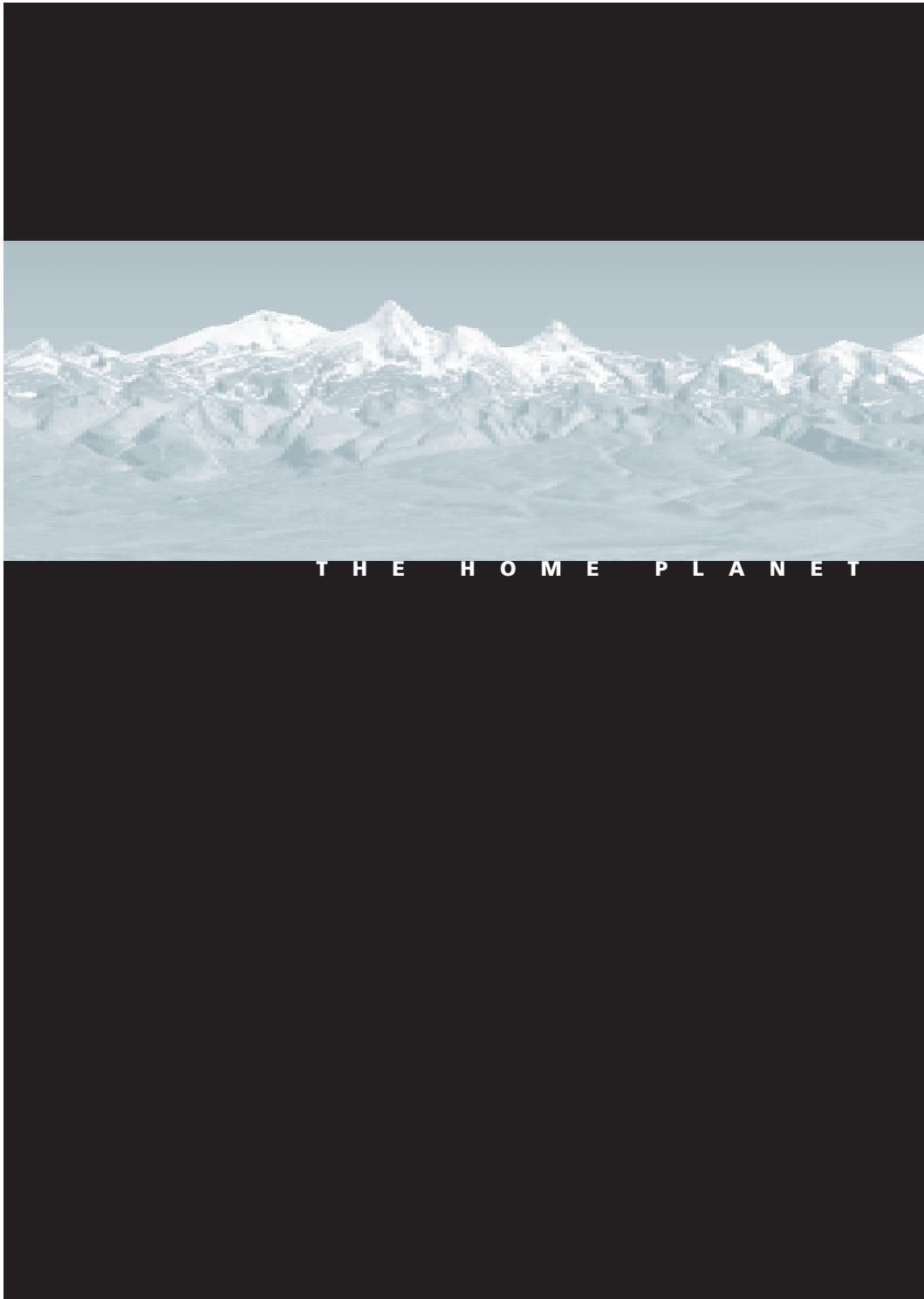
self, the craft rolled out a six-wheeled rover, named Sojourner after the American abolitionist Sojourner Truth. The rover would rack up about a 110-meter (360-foot) sojourn around the lander in what was supposed to be a seven-day lifetime that extended into some three months of exploration.

Sojourner's encounters with the various rocks in its vicinity led to a whimsical naming system among the science team. First they decided to call one



rock Yogi, and then another after the cartoon bear's sidekick, Boo-Boo. Barnacle Bill and the Couch, Flat Top and a group called the Rock Garden also made the list. In all, dozens of rocks were identified and studied. On the horizon stood a pair of hills that scientists dubbed Twin Peaks.

Mars Pathfinder, priced at less than the cost of many Hollywood blockbusters, won the hearts of the world. It also revitalized NASA's Mars program, which now envisions a variety of missions with gradually increasing ambitions in the years to come.

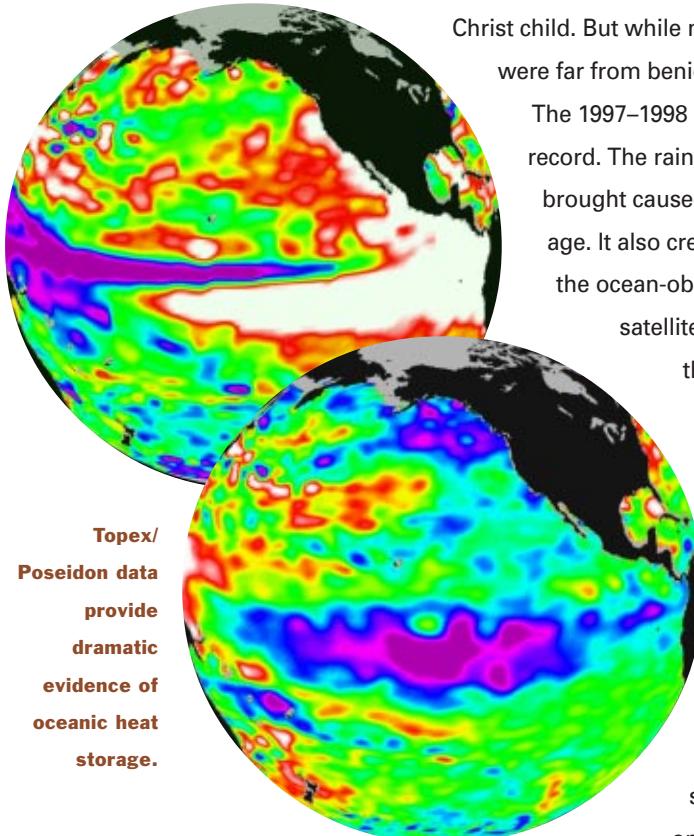


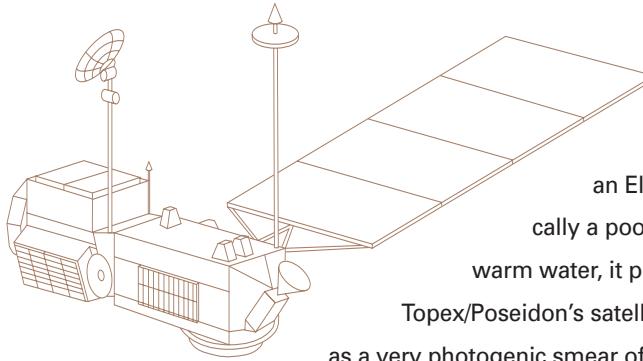
T H E H O M E P L A N E T

The Ocean's Not-So-Childlike Hand

For the past four centuries, fisherman, sailors and farmers on the west coast of South America have noticed that the climate would go out of whack every few years, with unusually warm seas, changes in currents and torrential rains. A hundred years ago the phenomenon, which peaked in December around Christmas time, was named "El Niño" in honor of the Christ child. But while named for a child, its effects were far from benign.

The 1997–1998 El Niño was the largest on record. The rains, floods and mudslides it brought caused billions of dollars in damage. It also created a new media star — the ocean-observing Topex/Poseidon satellite. Millions of people saw the satellite's colorful images of the Pacific Ocean on the evening news, in newspapers and in magazines as reporters tried to explain the climate phenomenon. Launched in 1992, the U.S.–French Topex/Poseidon measures sea-surface height, which is one way of seeing how heat is stored in the ocean. Because





an El Niño is basically a pool of unusually warm water, it pops out in Topex/Poseidon's satellite images as a very photogenic smear of white surrounded by brilliant scarlet in a benign sea of

green. People around the world watched as Topex/Poseidon showed the 1997–1998 El Niño march across the Pacific and grow to cover an area of the ocean about one-and-one-half times the size of the continental United States.

El Niño proved to have another half — a rebound effect of unusually cool water, which attracted the name “La Niña.” When this trend showed up in 1999, Topex/Poseidon was there to record it. This time, the satellite’s images featured brilliant blues and purples of cooler-than-normal water stretching across the middle of the Pacific.

When the next large El Niño appears, two ocean altimeters will be watching its progress and sharing their unique perspective with the public. The venerable Topex/Poseidon has been joined in its ocean vigil by Jason 1, launched in 2001.

The Probes with X-ray Eyes

In the 1960s B-movie "X: The Man with the X-Ray Eyes," Ray Milland plays a scientist who is driven to madness when he suddenly achieves the ability to see through solid objects. At JPL, spacecraft instruments endowed with similar capabilities have found happier — and more scientifically fruitful — endings.

Using the technique of imaging radar, JPL scientists have been able to produce sharp, detailed pictures of the planets, including Earth, that look very much like photographs — with a few important differences. Unlike conventional photography, radar can see through the dark, dust and clouds.

Seasat showed the value of Earth-orbiting imaging radar for global monitoring.

Radar images show the fissured cones of volcanoes that would be hidden from a camera's view by smoke and ash and the intricate tracings of rivers beneath tropical rain clouds. Imaging radar can distinguish between different types of rock and can even see through 2 meters (6-1/2 feet) of Saharan sand to show the bedrock beneath.

JPL first took imaging radar aloft on airplanes in the late 1960s. An oceanography mission gave scientists their first glimpse of how well it might work from space and how much it might also reveal about a planet's geology, water and vegetation. Designed and built by JPL to monitor ocean waves and sea ice, the imaging radar on board the 1978 Seasat satellite returned tantalizing images of Earth's land surface during its three-month mission. These were followed by a series of space shuttle radar missions between 1981 and 1994.





**Imaging radar
enabled Magellan
to look through
the opaque
atmosphere of
Venus.**

While the shuttle missions were providing exciting new views of Earth from space and testing new radar techniques, imaging radar arrived at Venus in 1990 on the Magellan spacecraft. The highly detailed maps it produced were the best ever made of the cloud-shrouded planet, better than any available for Earth.

Until, that is, the Shuttle Radar Topography Mission in February 2000. Fly-

ing two radar antennae, one on the space shuttle and the other at the end of a 60-meter (200-foot) mast, the mission mapped more than 80 percent of Earth's landmass, creating the most complete and accurate map of our home planet.

JPL's Biggest Mission

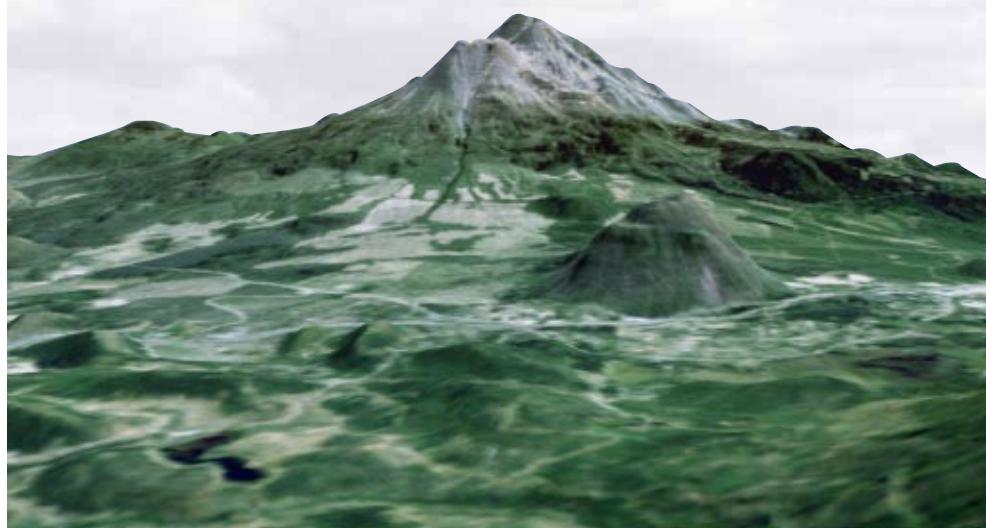
Getting creative with leftovers can lead to some very successful results. In JPL's case, it also led to the Laboratory's biggest mission — in terms of size.

When it flew in early 2000, the 60-meter (200-foot) mast extending from the side of Space Shuttle Endeavour during the Shuttle Radar Topography Mission was the largest rigid structure ever flown in space.

The mission grew from the realization that hardware left over from a 1994 shuttle radar mission could be used to map Earth's contours. While

out of sight in a storage facility far from the Lab, the still flightworthy hardware was not out of mind. JPL engineers and scientists came up with a novel idea. Why not put one imaging radar antenna at the end of a mast attached to the space shuttle and use the existing antenna on the shuttle's cargo bay at the same time? Together the two radars could make detailed three-dimensional topographic measurements of most of Earth's land surface in one 11-day flight. The

A 3-D perspective view of California's Mount Shasta. Black Butte is in the foreground.



**The extendable
mast balked
when retracting
into the shuttle
payload bay.**



Shuttle Radar Topography Mission was born. Besides the leftover radar, it also used secondhand parts from two astronomy missions and spare tanks left over from the Cassini mission.

The design of the extendable mast itself was borrowed. It was designed to hold solar panels for the International Space Station. During launch, the 290-kilogram (640-pound) mast remained folded origami-like inside a canister within the shuttle's payload bay. Once the shuttle was in orbit, the cable-festooned mast extended to its full length and locked into place.

Getting the mast to fold itself back in the box for the flight home proved a bit more problematic. On the first try, it simply did not want to come the final four inches. The shuttle could not land safely without the mast completely stowed away.

Mission control juiced up the power on the second and third tries to stow the mast, but no luck. Then on the fourth try, it slipped home. The problem? Cold cables. It was like trying to curl up a frozen garden hose. The fix was a heater that softened them up.

In Search of Lost Cities

For more than 1,500 years, the lost Arabian city of Ubar, a center of ancient incense trade, was the stuff of legends. It was said to have been a paradise swallowed up by the desert as divine punishment for wicked living. It didn't go, however, without a leaving a trace, one that JPL scientists found with the help of remote sensing.

Visible and infrared images from the Landsat satellite and radar images taken from the space shuttle were keys to locating the site of this old fortress. They revealed a regional network of tracks, some used by camels more than 2,000 years ago and by four-wheel-drive vehicles today, that pinpointed the city's probable location.

Cambodia's temple complexes, surrounded by rainforest, date to the 9th century.

Thousands of miles away, images from another space shuttle mission hinted at previously unknown structures in the ancient city of Angkor in Cambodia,

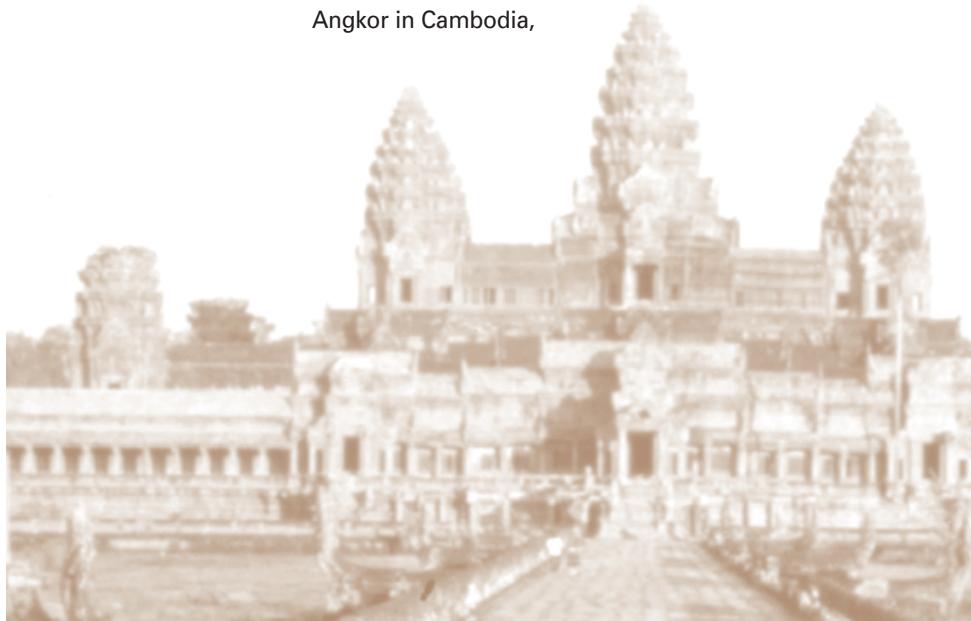
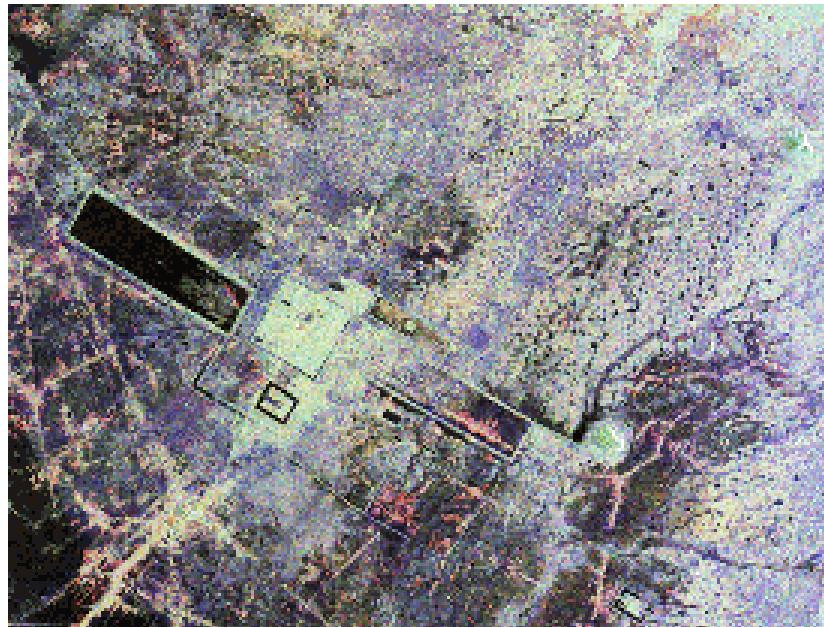


Photo: John H. Stubbs, World Monuments Fund



Angkor was the spiritual center for the Khmer people until abandoned in the 15th century.

prompting JPL's airborne imaging radar to go in for a closer look. A huge complex of more than a thousand temples covering more than 160 square kilometers (60 square miles), Angkor may have held a million people at its height. Today much of the city is hidden beneath dense jungle growth.

The radar picked out irrigation canals north of the main temple area, showing that the city had extended farther than had been known before, and remains of a civilization even older than the one that built the city's most famous temples.

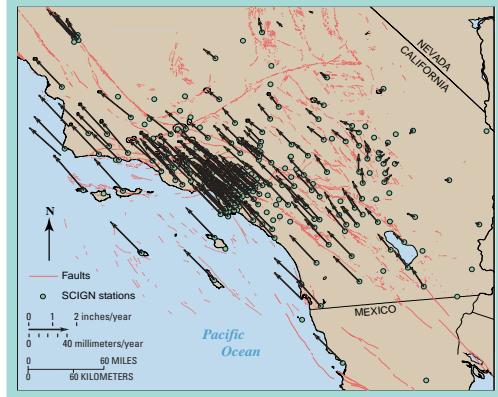
The radar data became an important tool for the World Monuments Fund and researchers in their study of the how the city grew, flourished and died over an 800-year period before becoming one of the world's great archaeological ruins.

Feeling the Earth Move

Southern California may have a Mediterranean-like climate, but relatives on the East Coast are quick to point out the downsides of living in our part of the world: fires, floods and, especially, earthquakes. Although most Angelenos shrug that jittery ground comes with the territory, some JPL researchers are

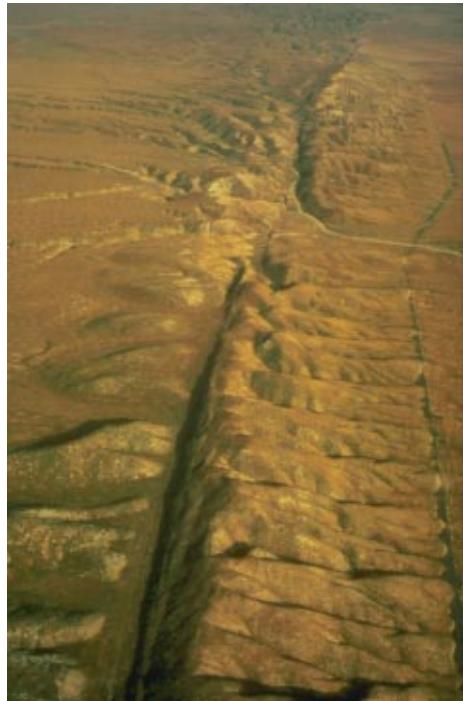
doing something about it.

Though they were viewed centuries ago as expressions of the wrath of deities, scientists now know that earthquakes are occasional traumas caused by the grinding and sliding of tectonic plates, the slow-moving slabs that make up Earth's surface. In the past few decades, researchers started using the tools of surveyors — the level and compass — to track motions of Earth's plates.



Motions of the North American and Pacific plates are tracked by monitoring stations (small circles).

That task got a space-age boost in recent years when the U.S. Department of Defense introduced the Global Positioning System, a constellation of two dozen satellites orbiting Earth that send out specially coded signals with highly precise time tags. A handheld receiver on the ground can use signals from four of the satellites to pinpoint its position three-dimensionally on Earth's surface. Though originally designed as a military tool, GPS receivers have found their way into the hands of hikers, boaters and drivers. And earthquake scientists.



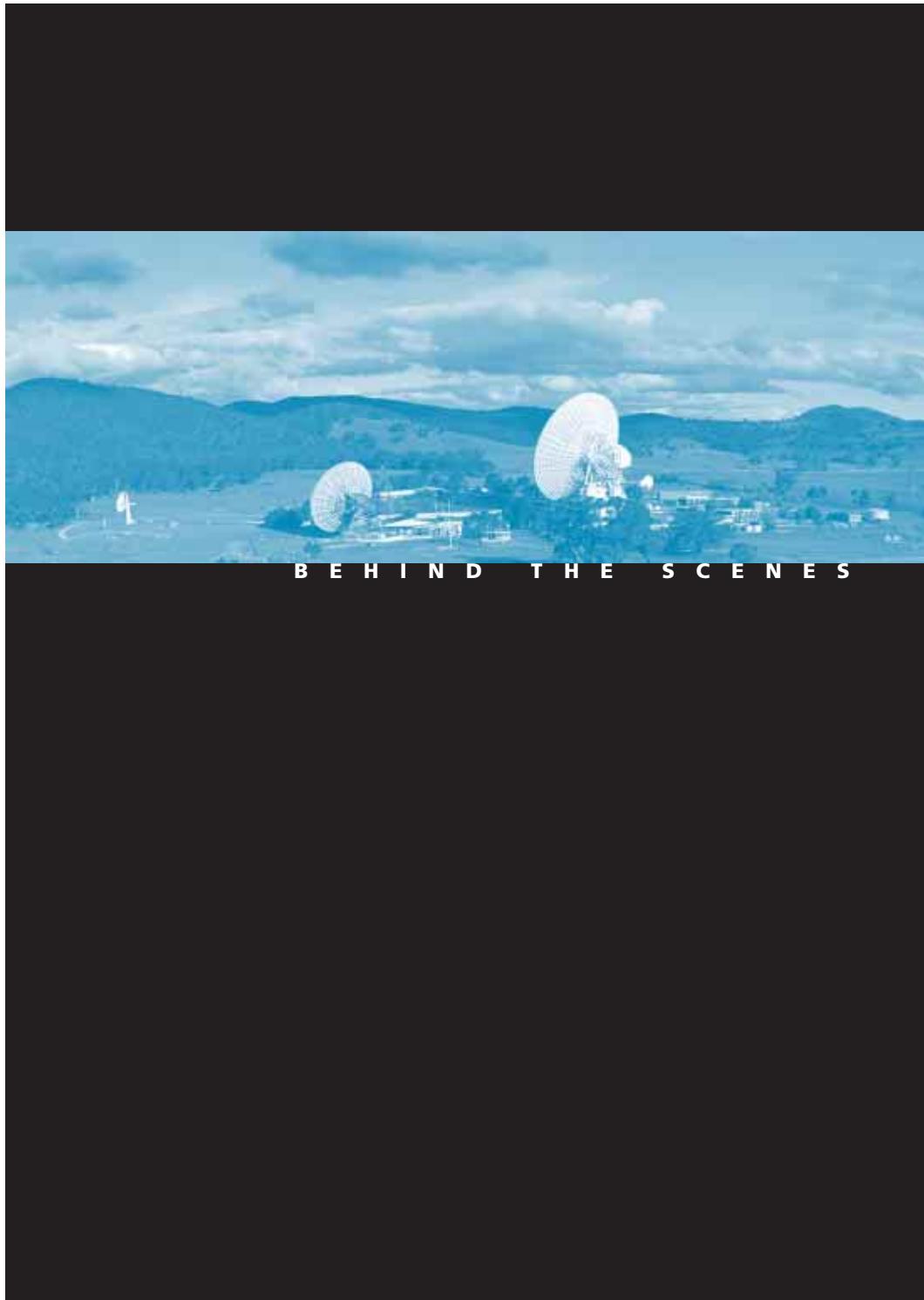
California's San Andreas fault is part of an extensive coastal fault network.

JPL engineers designed an advanced GPS receiver that improves the accuracy of measurements, making it possible to pinpoint locations to fractions of an inch. That gave them an important new tool to use in measuring the slow shifts of the ground we live on.

JPL scientists announced, for example, that two years after

the 6.7-magnitude Northridge, California, earthquake in January 1994, motions continued in a "quiet" way and adjacent hills had risen about 12 centimeters (roughly 4-1/2 inches) since the primary quake event.

The Lab signed on as a partner in a multiagency network of automated GPS ground stations around Southern California to track tectonic motions, both when quakes are occurring and when they're not. The consortium met a goal of building a network of 250 ground stations. In time the work could help refine knowledge of when and where quakes are likely to occur.



B E H I N D T H E S C E N E S



BEHIND THE SCENES

How the Deep Space Network Works

All the versatile science instruments on NASA missions rocketing around the solar system would work in vain if the spacecraft they ride couldn't send their pictures and other information back to Earth.

The Deep Space Network, developed and managed by JPL, captures those important messages. The network's dish-shaped antennas point skyward from three sites around the world. Radio transmissions they receive provide information about the health and precise location of each spacecraft, as well as data from the instruments aboard. The same antennas also have transmitters that send up commands to the distant robots.

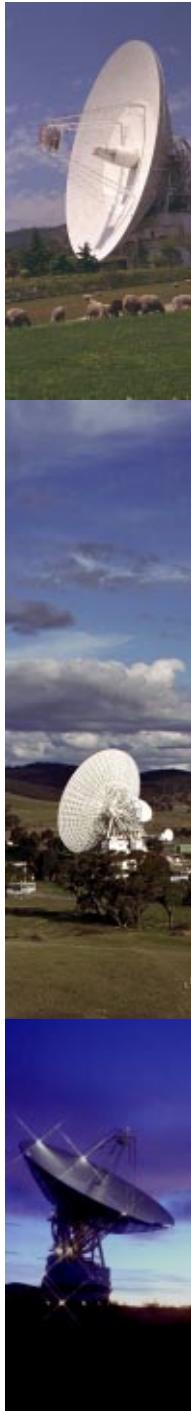
The network's sites near Canberra, Australia; Madrid, Spain; and Barstow, California, sit about one-third of the way around the world from each other.

That way, as Earth turns, most spacecraft will always have a site facing them.

Because the small, lightweight radios on board the spacecraft send weak signals, antennas on the ground must be extrasensitive. Interplanetary craft typically

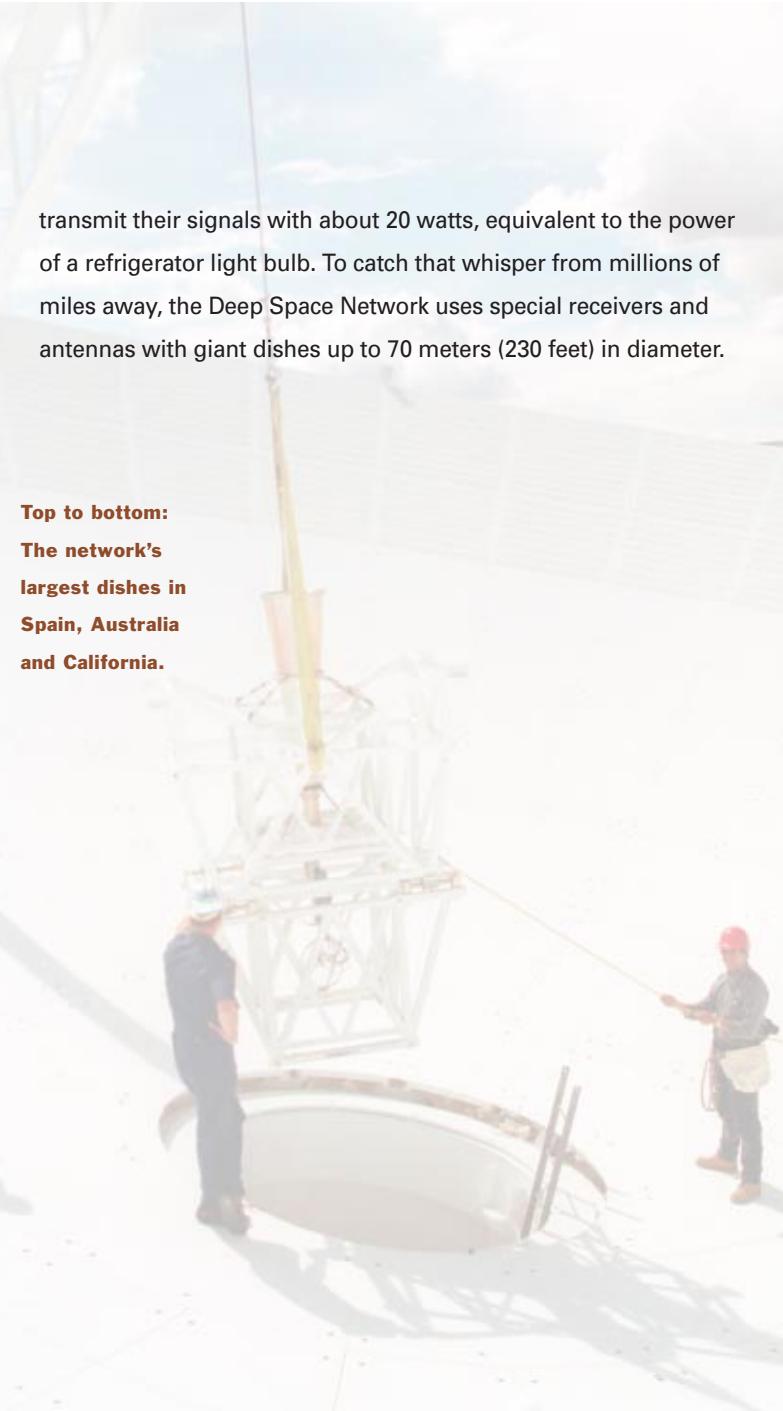


The Deep Space Network spans the globe.



transmit their signals with about 20 watts, equivalent to the power of a refrigerator light bulb. To catch that whisper from millions of miles away, the Deep Space Network uses special receivers and antennas with giant dishes up to 70 meters (230 feet) in diameter.

Top to bottom:
The network's
largest dishes in
Spain, Australia
and California.



Mars in Your Backyard

Mars Pathfinder airbag tests were performed in an earlier version of the Mars Yard.

Except for the oxygen-rich atmosphere and the balmy temperatures — well, and the sport utility vehicles driving by — it's almost like being on Mars.

JPL's Mars Yard is a celebrated piece of real estate that captures the imaginations of visitors and television news crews alike. In essence it's a simulated landscape of Mars, complete with rocks, boulders and sand. Aesthetics aside, it is a facility developed by JPL's robotics and Mars exploration technology programs for testing rovers and robotics technology for future Mars surface exploration.

The yard itself measures about 20 square meters (215 square feet) and is located in the northeast corner of the Lab. The extraterrestrial terrain consists of about 250 tons of washed sand, topped by 25 tons of decomposed granite, 10 tons of brick dust, 5 tons of small red cinders and 20 tons of volcanic rocks of different types, color and texture. The rocks, placed around the yard to resemble the terrain seen by the Viking landers, were distributed by hand by robotic researchers during lunch hours, evenings and weekends.

A local artist was commissioned to create a mural on the walls around the yard that is evocative of the landscapes photographed by the Mars Pathfinder lander.

Besides its handiness as a crowd-pleasing attraction during JPL Open House, the Mars Yard is used frequently by robotic researchers and is an active testbed for future missions to Mars.





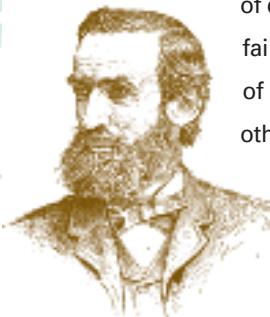
Planetary Rim Shots

You would think Minnesota Fats was haunting the control room. JPL flight engineers routinely send spacecraft not only to a single planet at a time, but bank-shooting across the solar system from one world to another. First accomplished in 1973 with Mariner 10's streak past Venus on its way to flybys of Mercury, the trick enabled Voyager 2 to conduct a grand tour of the outer solar system, visiting Jupiter, Saturn, Uranus and Neptune in one go. The technique, called "gravity assist," is not just a display of navigation prowess, but an ingenious way of stealing energy from the planet to help speed the spacecraft on its way.

The concept dates back at least to the mid-1800s, when American scientist Hubert Newton was trying to explain the motion of comets. He recognized that as a comet passed fairly close to a large body like a planet, the gravity of each would have an effect, large or small, on the other. A small object like a comet might be sped up or slowed down considerably as the gravity of a planet tugs on it as the comet passes. The comet also tugs on the planet, causing the massive body to lose or gain a bit of its orbital energy, but unless the comet was huge, the effect on the planet would be negligible.

The idea percolated for about a century, assisted along the way by numerous researchers from around the world. It came to JPL in the early 1960s, when two graduate students — one each from UCLA and Caltech — who were working at the Lab during the summers wrote noted papers advocating use of the scheme in mission design. Before gravity assists were considered, mission designers believed it would be

Hubert Newton
studied the
paths of
comets.



necessary to develop huge rockets with nuclear reactors to travel to the outer solar system.

JPL has launched half a dozen missions that depend on gravity assist, with more on the way.



The Cassini-Huygens spacecraft takes a winding path to Saturn.



BEHIND THE SCENES

Hooray for the Brown, Yellow and Purple

Color may be in the eye of the beholder — especially if you are on Mars.

When NASA Langley Research Center's Viking landers set down on Mars in 1976, America's bicentennial year, scientists and engineers realized that the pictures of the flag painted on the spacecraft would not appear in red, white and blue. The Martian atmosphere is not the same as Earth's, so light is not reflected in the same way and things look, well, downright alien.

In fact, in the first images sent back from Mars showing the American flag on the lander, the red stripes were brown, the white stripes and stars were yellow and the blue field was purple. But it stepped JPL's

**Image processing
corrected the
camera's view
so we could
see our flag's
familiar colors.**

image-processing wizards, who employed digital legerdemain to deliver different versions of the images — Mars as it would be seen on Earth and Mars as it would be seen on Mars.

It was a relatively easy assignment for the imaging specialists, who developed many innovations in working with pictures from JPL spacecraft missions. When the Rangers

impacted the Moon in the 1960s, their television cameras sent to Earth analog pictures that technicians converted to digital data so that the images could be enhanced for further study. Mariner 4 to Mars in 1965 was the first craft to carry a digital camera.

Over the years, JPLers pioneered many image-processing techniques, including image restoration, mosaic effects, map projections and three-dimensional "fly-through" animations. These same technologies are widely used today for biomedical research and analysis, science, finance, geographic information systems and even the movies.

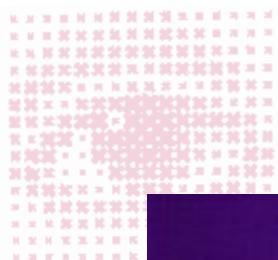
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113	135	150	136	118	127	153	154	147	123	125	139



The Invisible Universe

It is a form of light we cannot see with our eyes. Yet firefighters use it to find people in smoke-filled buildings, military pilots use it for night vision and astronomers use it to peer through cosmic dust to observe stars, galaxies and other objects. It is infrared, a form of light that lies beyond the red portion of the visible spectrum.

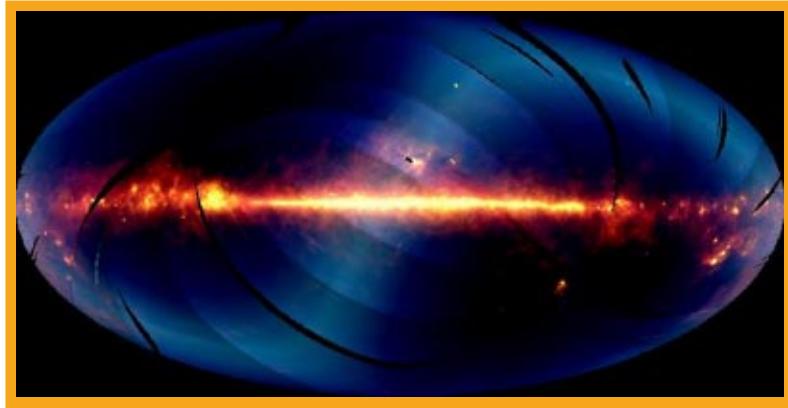
For decades, infrared astronomy was confined to narrow atmospheric windows from ground-based telescopes. In 1983, JPL helped lift the technology to new heights, literally, with the launch of the Infrared



Astronomical Satellite. The satellite, a joint mission with the United Kingdom and the Netherlands, orbited high above the absorbing effects of Earth's atmosphere. Using infrared, astronomers discovered dust discs around doz-

ens of stars, including Vega and Fomalhaut, two stars that appear bright in our nighttime sky. The discoveries strongly suggested that planetary systems might exist around other stars. That raised the question "Might there be a life-bearing planet like Earth around another star?"

That prospect provided impetus for such missions as the Space

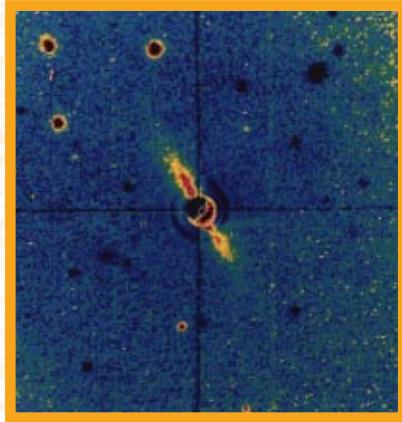


**An infrared
“all-sky” view;
the bright band
is the plane of
the Milky Way
galaxy.**

Infrared Telescope Facility, the last of NASA's Great Observatories. The orbiting observatory's infrared sensors are designed to look for planetary construction zones surrounding thousands of stars. Its infrared eyes can also help scientists understand when the first stars and galaxies formed and how they evolved.

In short, infrared astronomy helps us see the universe in a whole new light.

The Planet Hunters



Blocking the light from the central star revealed a surrounding dust disc.

There's no place like home on planet Earth. Or is there?

JPL is striving to answer that question, as part of the search for life elsewhere in the universe. Known for exploring the solar system, JPL is extending its research by hunting for planets around other stars.

In 1984, a JPL astronomer and his university colleague took a picture of Beta Pictoris that revealed a disc of dust around the star. In 1995,

Swiss astronomers made a breakthrough discovery when they found the first known planet orbiting another star, 51 Pegasi. Since then, numerous planets have been detected, but most are quite large and considered unlikely candidates for harboring life.

Scientists know that when it comes to cosmic real estate, Earth is a highly desirable chunk of property. It has all the right stuff to host life as we know it — water, certain chemicals and the right distance from our star, the Sun.

Armed with that knowledge, JPL engineers and scientists are setting their sights on finding Earthlike planets around other stars.



**Cosmic footprints
symbolize
humankind's
search for life in
the universe.**

Eventually, they will look for telltale chemical signatures of life on those planets. To do this, JPL is developing powerful optics for use on the ground and in space, and combining multiple telescopes to function as one giant virtual telescope. The technology is complex, the challenge is great, but the end result is tantalizing: to answer the age-old question, "Are we alone?"

Earthly Technologies



Used on deep space missions, aerogel is a promising candidate for commercial applications.

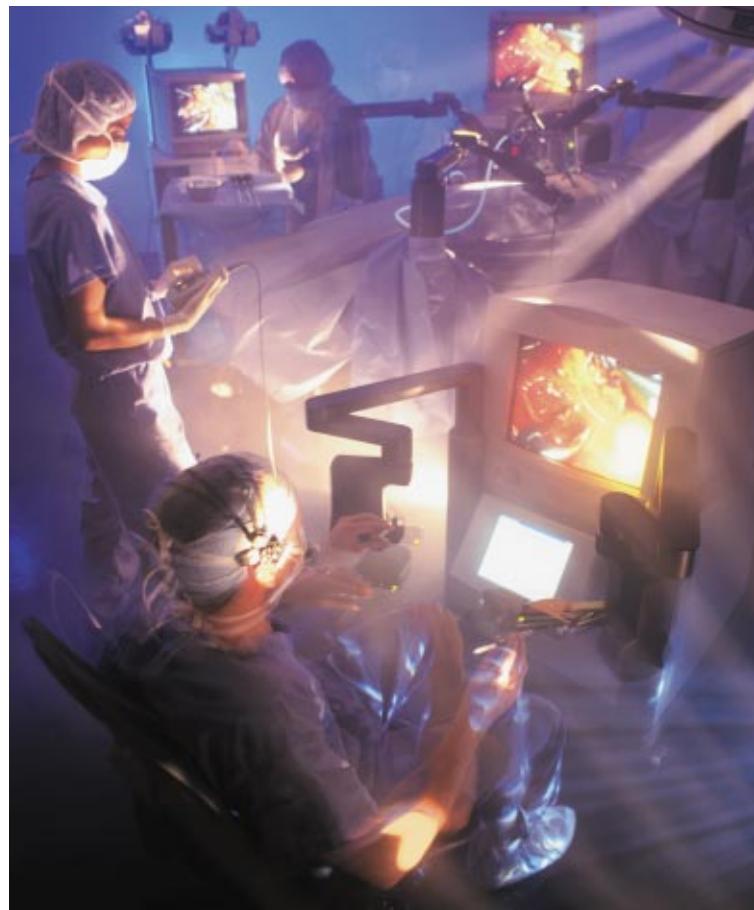
For millions of Americans, 1963 began with the New Year's Day Tournament of Roses Parade, led by Grand Marshal Dr. William Pickering, JPL's director. Pickering was followed by a float honoring JPL's Mariner 2, the first spacecraft to fly close to another planet.

That was also the year JPL's Commercial Technology Program was established to identify and transfer technologies for commercial use. Since then, more than 200 U.S. companies have taken advantage of JPL's innovations. Some of the most significant contributions have been in communications, digital imaging, miniaturization, remote sensing and robotics.

JPL has led the way in sending and receiving data within our solar system. This data transmission has required a long-term series of technology developments of deep space antennas, precision timing systems, signal detection and digital processing. Today, these technologies are widely used for wireless communications.

Digital image processing was pioneered at JPL beginning in the 1960s. Today, digital imaging has a wide range of applications, particularly in medicine. Well-known uses include "CAT" scanning, ultrasounds, brain or cardiac angiography and nuclear magnetic resonance.

Other contributions include a miniature infrared sensor that can locate cancerous tumors; a tiny camera chip placed in a pill that photographs inside the digestive system; and a robot arm that can perform extremely delicate microsurgery on a patient's brain, eye, ear, nose, throat, face or hand.



JPL has also developed technology that allows farmers to plow their fields more accurately, at night and during poor visibility, saving both time and money.

From space to down on the farm — many JPL technologies find their way home.

Appearances Can Be Deceiving

*G*ome may call them gizmos, gadgets and toys, but researchers call them prototypes, platforms and test beds. These devices may seem out of this world. Some researchers hope they will be.

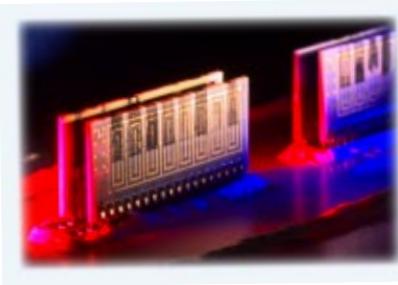
If you walk into a lab and see what resembles a gumball, it may be just that. But don't be fooled, it could be a sensor pod jammed with tiny sensors that act like satellites and telescopes to remotely monitor large areas.

In the low-gravity environments of small bodies in our solar system, hopping may be the preferred method of transportation. The Frogbot is a small robot that moves by combining rolls and hops to reach its desired destination.

Not all research projects are inspired by nature, a pet or toy; some happen by accident. The Tumbleweed rover was born when a three-wheeled rover with inflatable wheels lost a wheel and tumbled for miles. This led to a new fuel-free robotic device that may use the wind's energy to bounce around the surface of Mars.

The real cliffhanger, however, may be the Cliffbot rover. Able to reach rugged, science-rich areas, such as cliffs, the rover may one day give scientists a peek down a road or cliff they've never gone down before.

This and other research projects are nothing to sniff at, unless you have an electronic nose. The E-Nose can sniff out problems before





they start. It flew on a space shuttle mission to detect harmful chemicals. It may help detect a fire before it breaks, pinpoint landmines and warn of chemical spills.

When you step into one of these labs and see an item that resembles a child's toy, keep in mind that toys aren't always all play. For some, they're the stuff missions are made of.





BEHIND THE SCENES

Cobbling Together from Spare Parts

At the heart of the JPL community are researchers with enough creativity to make imaginative use of research dollars. They're the ones in the trenches, building rovers and other projects from spare parts.

In some cases, the hand-me-downs come from other space missions. Over the years it was standard procedure to order extra "flight spares" of critical parts or systems, and if they weren't needed for one spacecraft they became available for others. The Magellan craft, for example, bounced radar pulses off the surface of Venus using a spare antenna dish from the Voyager project. Other spacecraft have used a variety of spare parts left over from other missions.

In some cases, parts have come from more prosaic sources.

Urbie is a small, lightweight rover that is completely autonomous, with stereoscopic vision and the ability to climb over obstacles and up stairs, making it ideal for going where humans can't go. In one of its demonstrations, Urbie had to enter a building from 500 meters (1,640 feet) out in the rain. Urbie is not rainproof. The team was off to a local hardware store. Three hours later they had fitted Urbie with a raincoat to keep the parts

from frying, and continued with their demonstration.

With an improvised raincoat, Urbie the rover defied weather as well as stairs.

Rocky III was a prototype for the Sojourner rover that went to Mars in 1997. The Rocky III team used a case from an old Macintosh computer as the rover's body — the actual computer was removed and the case was filled with the rover's electronics and batteries. Whenever the news media saw the Mac, they assumed it controlled the rover. Eventually, the case was replaced with a brass box.

Another JPL invention is the Cryobot, a cylinder-shaped robot that melts the ice directly in its path. It may someday melt its way through the crust of Jupiter's icy moon Europa. The first prototype led engineers on another run to the hardware store, this time for PVC pipe to house the instruments.

Next time you find yourself at the hardware store researching a home improvement project, remember that JPL engineers may be there too, finding down-to-earth parts for some really far-out projects.

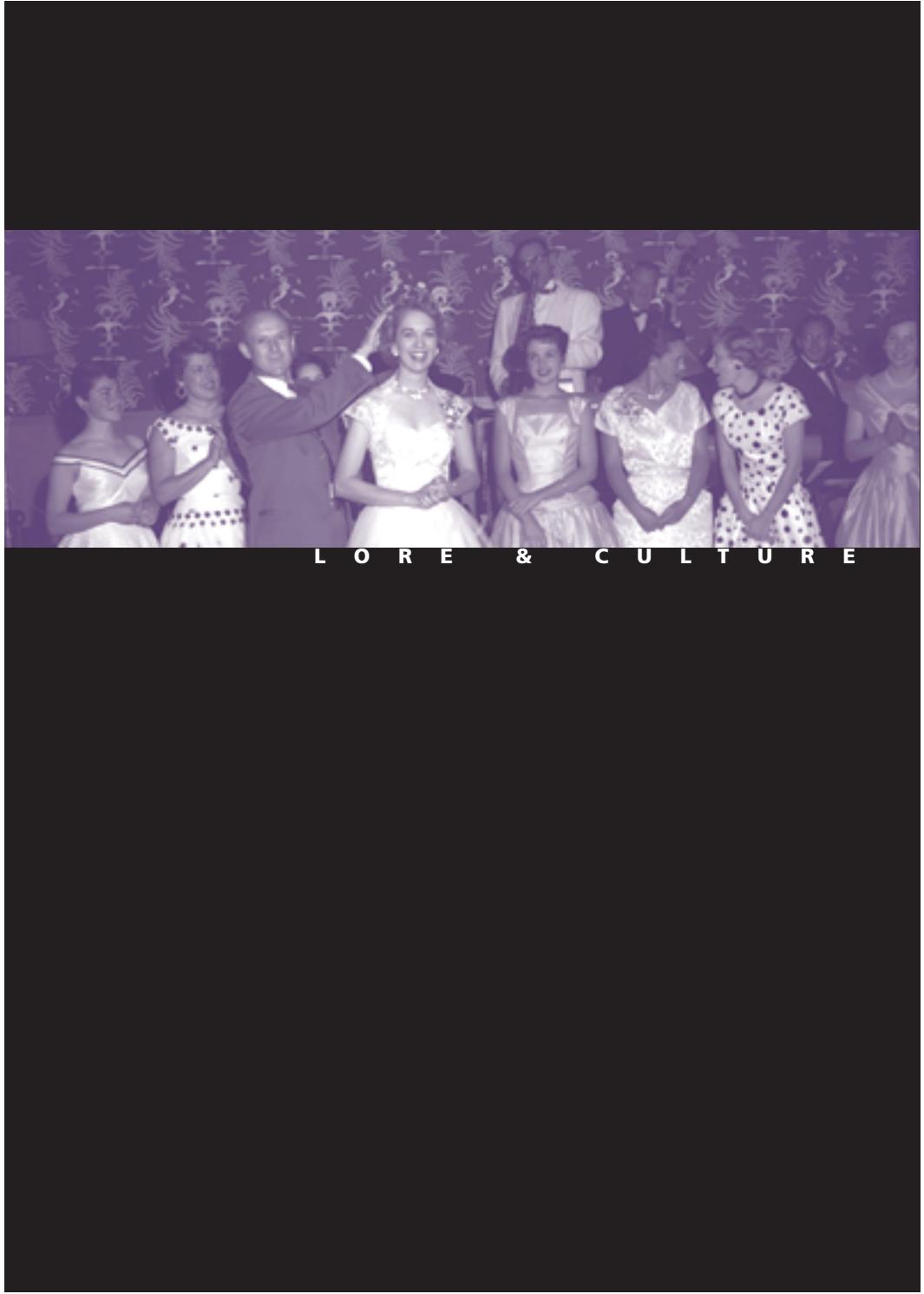


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L O R E & C U L T U R E

Lucky Peanuts

Good-luck peanuts made their first appearance in 1964 during the Ranger 7 mission. JPL had six failures prior to this effort, so the pressure was on to succeed. The Ranger 7 launch day arrived and with it came the peanuts.

"I thought passing out peanuts might take some of the edge off the anxiety in the mission operations room," recalled Dick Wallace, who served then as a mission trajectory engineer. "The rest is history."

Ranger 7 performed flawlessly, as did its successors, Ranger 8 and 9. They returned pictures that helped to pick the landing sites for the Apollo Moon program. The peanuts have shown up on informal countdown checklists for most every launch since then.

On a few occasions, the peanuts didn't make it for launch day. In one case, the spacecraft was lost soon after launch. In another, the launch was delayed for 40 days, and only took place after the lucky peanuts were delivered to the mission team.

Just in case,
flight team
members pass
the peanuts.

Up until the Voyager mission, the peanuts showed up only at launch.

Nowadays, they are often seen in mission control facilities during critical mission stages such as orbit insertions, flybys and landings, or any other event of high anxiety or risk.

Superstition? "I hope not," said Wallace. "Not in this bastion of logic and reason."



[The Great Galactic Ghoul

fabled monster, the Himalayas are supposedly prowled by the Abominable



Loch Ness has its fabled monster, the Himalayas are supposedly prowled by the Abominable Snowman. For interplanetary spacecraft, danger lurks in the vast expanses of the solar system in the form of the Great Galactic Ghoul.

Or so JPL's local culture would have you believe. For decades beginning in the 1960s, it was popular to suspect that "the Ghoul" was at work when malfunctions or even spacecraft losses befell missions.

Stories of the Ghoul were recounted in whimsical songs performed at parties at the time of major mission events. Engineers and scientists on one 1970s mission were so ecstatic at having evaded the Ghoul that they presented the project scientist with a mockup of the Ghoul's "heart" on a plaque.

(Not that it prevented the creature from occasionally striking later missions, however.) Although regarded as having a special appetite for Mars probes, the Ghoul can strike any mission at any time.

The Ghoul dates to the fall of 1964, when JPL was preparing to launch Mariner 4 to Mars. The launch attempt came on the heels of Soviet probes that had failed as they approached Mars. A magazine reporter asked JPL engineer John Casani in a press conference if there could be a dust belt or micrometeoroids near the planet that doomed the robot visitors.

Casani said he doubted it. "Maybe some space monster is gobbling them up," he joked. Applying poetic license, the reporter created "the Great Galactic Ghoul" for his story. Mariner 4, however, survived the mythic beast to execute the first successful Mars flyby, returning 21 photos of the red planet.

Getting Soaked

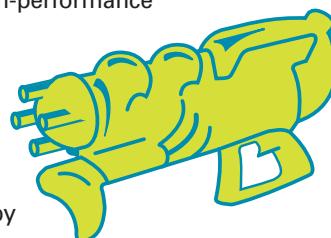
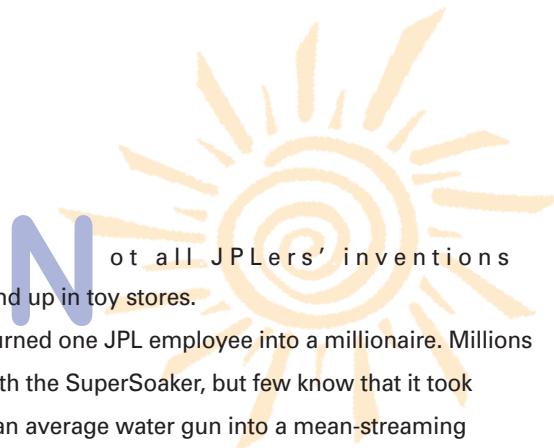
Not all JPLers' inventions end up in space. Some end up in toy stores.

A homemade gadget turned one JPL employee into a millionaire. Millions of people have played with the SuperSoaker, but few know that it took a rocket scientist to turn an average water gun into a mean-streaming machine.

Lonnie Johnson, a mechanical engineer, worked on thermodynamic and control systems for the Galileo and Mars Observer projects. While tinkering with a pump in his bathroom, Johnson put the pressure on some vinyl tubing and a homemade metal nozzle. The resulting blast of water sent his shower curtains flying. The idea was to create a new cooling device that used water instead of freon. But what he had just created — besides a mess in the bathroom — was the world's first high-performance squirt gun.

Since 1990, more than 70 million SuperSoakers have generated over \$500 million in sales.

The SuperSoaker isn't the only work by JPLers to end up on store shelves. In the late 1970s, a JPL programmer named Wayne Ratliff developed a database program called Vulcan based on software that had been used at the Lab since the 1960s on old Univac computers. An outside entrepreneur found the program interesting, renamed it dBase II and it became one of the most popular database packages on personal computers in the 1980s.



The Clean-Room Flood

They don't call them webmasters for nothing. At 5:30 in the afternoon on Friday, January 19, 2001, Ron Baalke was checking images taken by a web camera that was trained on the Mars Odyssey spacecraft, undergoing final preparations for launch from NASA's Kennedy Space Center. As Baalke, a web engineer for the Mars program, compiled the stills into a movie, he noticed that a mysterious brown stain suddenly appeared in the pictures. It seemed to spurt out and then slowly spread under the tables on which Mars Odyssey and one of its instruments sat.

Baalke was galvanized. He called, paged and e-mailed the project's managers at JPL and at Lockheed Martin, the contractor company that built the spacecraft. In just 10 minutes, officials from Kennedy Space Center were on the scene. They identified the stain as rust-colored water from a burst tube in a cooling system underneath the instrument.

The room's humidity monitors would eventually have picked up on the water seeping through the room, but Baalke's dedication made the job even easier. The 2,200 liters (500 gallons) of water on the floor were easily cleaned up over the weekend. A few power cords got wet, but nothing was harmed.

Three months later, Mars Odyssey soared away to study the red planet.



Where the Gnatcatchers Play

So much of the action at JPL takes place on an interplanetary landscape that it's easy to forget that the Lab is perched on the edge of a national forest.

They may not wear lab coats or design spacecraft, but the wildlife that share JPL's 177-acre campus is also part of its culture along with the human inhabitants. The Lab was built from the arroyo, or dry creek, up into the side of the San Gabriel Mountains. Lab employees learn quickly that they are simply allowed the courtesy of sharing the land.



know the lively

It is not uncommon to leave JPL in the evening and see numerous deer nibbling on leaves. Occasionally a peregrine falcon is spotted hunting.

According to wildlife biologists who work for the Angeles National Forest and intimately grounds that surround the Lab, the population of animals — including mountain lions, red-tailed hawks, coyotes, opossum, raccoons, lizards and rattlesnakes — is typical of this region. They also note that sections of the Lab have been identified as critical habitats for the Arroyo Southwestern Toad as well as the Coastal California Gnatcatcher and Least Bell's Vireo, birds that are on the U.S. Fish & Wildlife Service's threatened and endangered species list.

One animal-loving employee was summoned by colleagues to a remote building where kittens had been found under a sewer grate. The "kittens" turned out to be infant bobcats. A grumpy female bobcat waited for her four babies to be plucked, one by one, from their stranded position. As a reward for her valiant effort, the good-hearted JPLer had an allergic reaction to the poison sumac that surrounded the grate.

[The Dress Code

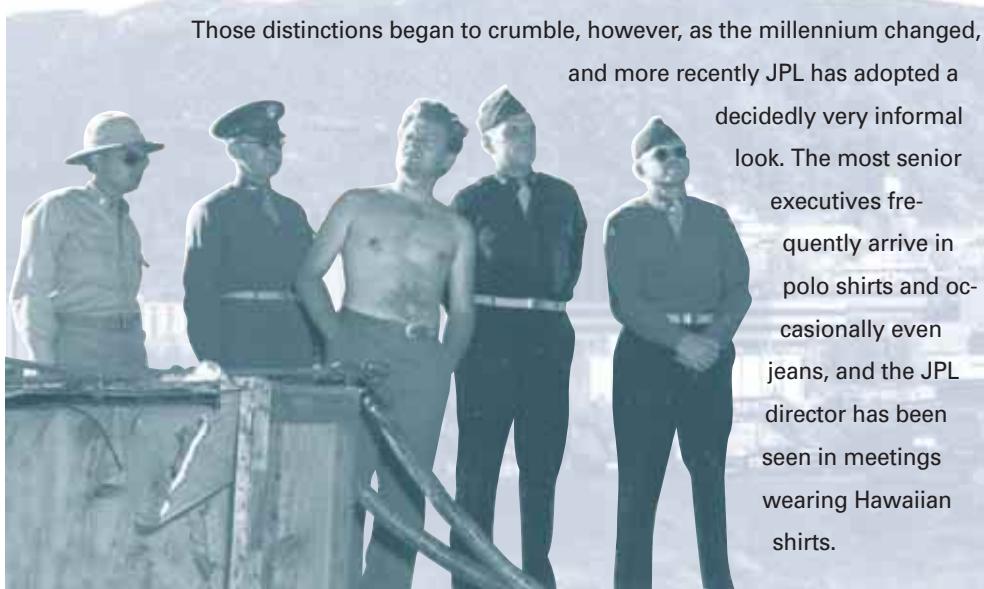
New York in the Fifties may have had its Man in the Gray Flannel Suit, but no one ever accused JPLers of overdressing. Here, the saga would be The Project Scientist in the Hawaiian Shirt and Sandals.

The Lab's propensity for informality apparently is longstanding. A memorable 1940s-era picture of a missile test shows several crisply attired Army officers surrounding a shirtless JPLer who looks as though he could have walked off the cover of a gothic romance. Chalk it up to the Lab's roots in the more free-ranging culture of academia.

Pictures from such 1970s missions as Voyager and Viking reflect the fashion fads of the times, with Q-Tip haircuts, sideburns on steroids and shirt prints that put paisleys to shame.

In recent decades, dress served to differentiate job groups at JPL. A necktie was the badge of the supervisor or manager. If you came to work in shorts and sandals, chances are that "scientist" was somewhere in your job title.

Those distinctions began to crumble, however, as the millennium changed, and more recently JPL has adopted a decidedly very informal look. The most senior executives frequently arrive in polo shirts and occasionally even jeans, and the JPL director has been seen in meetings wearing Hawaiian shirts.



Day of the Gales



newcomers to Southern

California's San Gabriel Valley in the early 1900s entertained their former neighbors back in the Midwest with stories of the gentle, Mediterranean-like climate that allowed flowers to blossom and oranges to grow in winter. Indeed, the benign climate was one of the main draws for many who settled here in those days. Benign, yes, but not always.

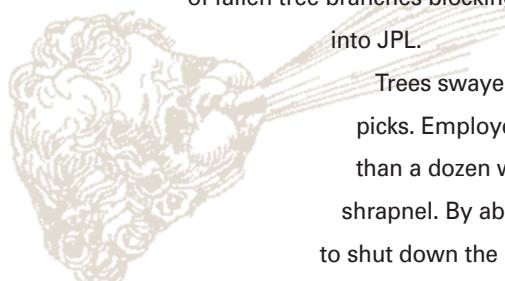
In January 1949, as JPL technicians were working on missile projects

shortly after World War II, they awoke one morning to find the Laboratory blanketed in snow. The weather was short-lived, though it made for a memorable picture.

**Gale-force winds
caused the
Laboratory to
close for the day.**

Nearly half a century later, on another morning just after New Years, a mighty wind visited the Lab. On January 6, 1997, winds roared through the San Gabriel Valley at 70 to 80 miles per hour, with gusts of 127 miles per hour. Every JPL employee arriving at work had a story to tell. One woman barely managed to avoid a flying camper shell on the freeway just a couple of miles away. Others encountered an obstacle course of fallen tree branches blocking Oak Grove Drive, the main road

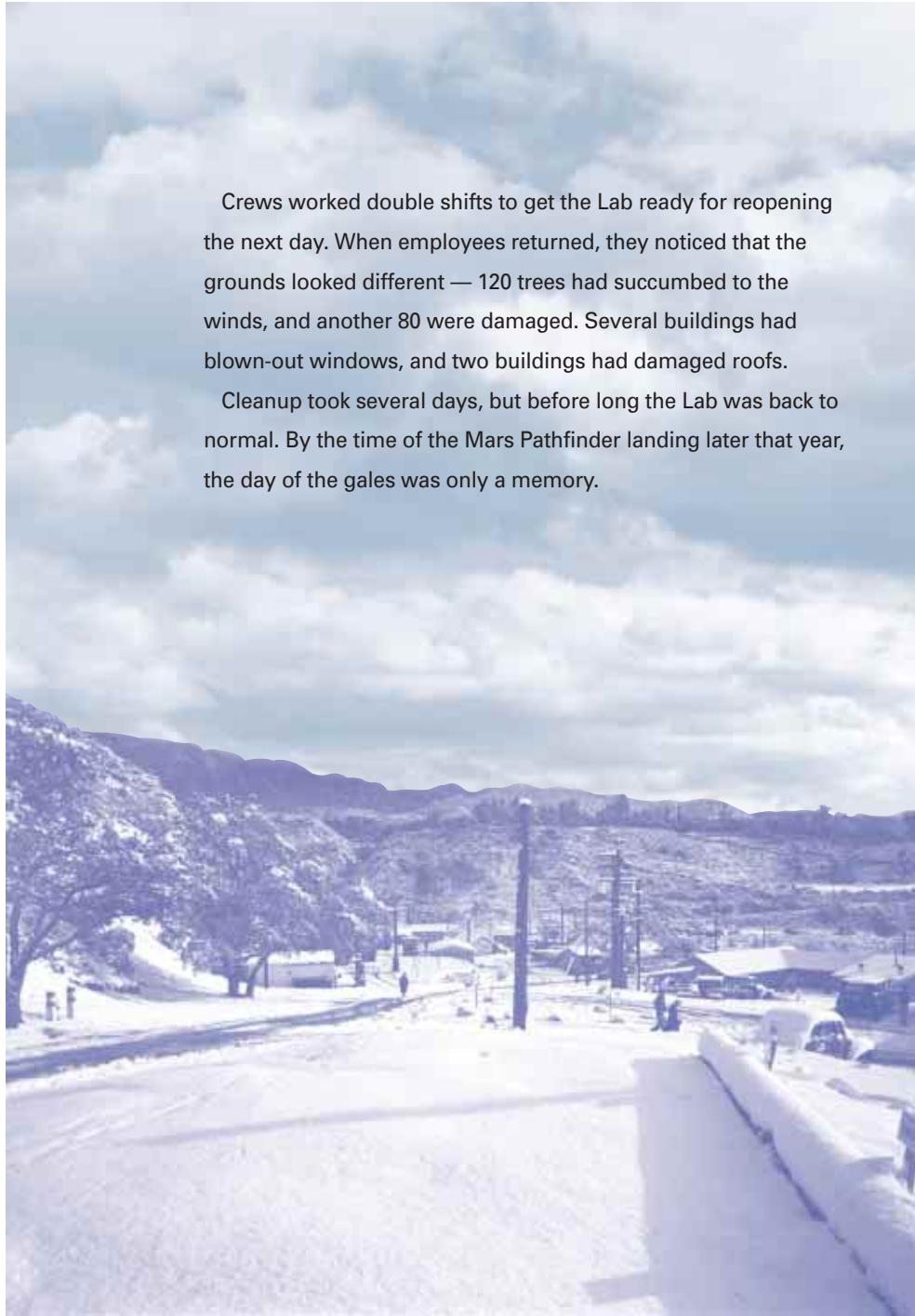
into JPL.



Trees swayed violently and snapped like toothpicks. Employees dodged flying debris, and more than a dozen were actually hit by this nature-made shrapnel. By about 9 a.m., the decision was made to shut down the Laboratory for the day. Employees were sent home, and those who had not yet arrived were turned away at the gate.

Crews worked double shifts to get the Lab ready for reopening the next day. When employees returned, they noticed that the grounds looked different — 120 trees had succumbed to the winds, and another 80 were damaged. Several buildings had blown-out windows, and two buildings had damaged roofs.

Cleanup took several days, but before long the Lab was back to normal. By the time of the Mars Pathfinder landing later that year, the day of the gales was only a memory.



Murmurs and Other Sounds from Earth

Call it a personal ad for the human race — when NASA's Voyager spacecraft leave the solar system, out beyond the bounds of our Sun's influence, they will carry a message to any intelligent alien life. The manager of the Voyager project at JPL asked astronomer Carl Sagan to design a message for Voyager to take to the stars. On a golden record the size of a dinner plate are inscribed everything from rock 'n' roll to aboriginal chants. Of course, instructions to build a record player are included.

Eighty-seven images were carefully chosen to represent humanity: our bodies, our ways of life and our interaction with our home planet. The pictures depict childbirth, computers, art, human musculature, friendship, snowflakes, sports and more — everything an alien species would want to know about the people that sent the message. Delegates to the United Nations recorded greetings to the aliens in almost every known language:

"Please come to visit when you have time," "Have you eaten yet?" and "May the honors of the morning be upon your heads."

Lastly, the record holds music, from a chorus of crickets and frogs to one of Zairean pygmy girls, from Beethoven to Chuck Berry to the sound of a kiss.



JPL's Diverse Roots

A How do you say spacecraft in German? B Or galaxy in Farsi?

C Asteroid in Greek?

D Rocket in Navajo?

E How about comet in Tamil?

A: Raumschiff

B: Kah-ke-shon

C: Asteroids

D: chidi bitoo' aszoligii' yee nidzit'ii (runs by gas that runs out)

Odds
are you can

find someone at JPL to translate each of those words for you.

The Laboratory is a veritable United Nations of science and engineering, attracting the brightest minds from all corners of the globe.

Although everyone at JPL speaks English on the job, individuals represent native tongues from dozens of countries, including France, India, Korea, Russia, Egypt, Argentina, Israel, Poland and Norway. Since most languages existed long before the era of space exploration, some words are relatively recent additions, reflecting modern technologies and knowledge.

JPL employees are well aware that the pursuit of science and technical excellence knows no borders. At JPL, Earth is truly a small world.

E: Val Natchathiram (star with tail)

From "Miss Guided Missile" to Project Manager

Like most of the aerospace world, JPL's roots were in an era when engineers and scientists were largely crew-cutted, black-necktied men. In those days, the women in the office were usually the ones answering the phones, taking dictation or typing.

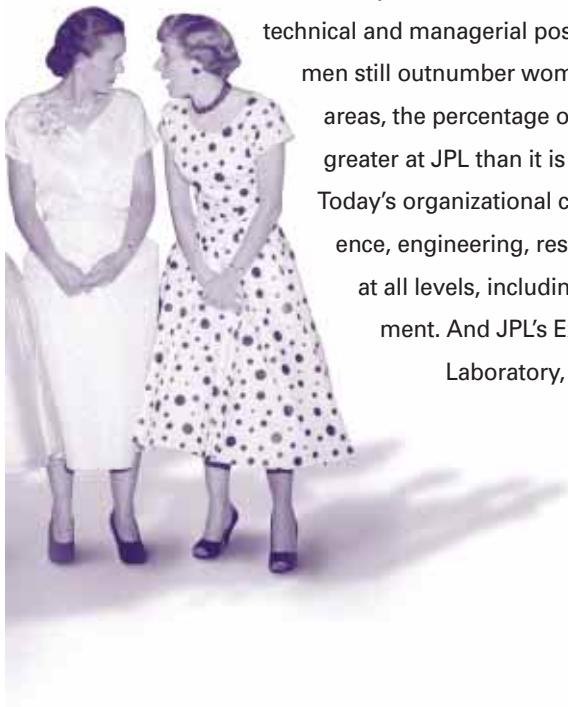
Or running for the honor of being crowned "Miss Guided Missile." In 1952, the Lab initiated a tradition of holding a spring dance that climaxed with the announcement of a queen. Contestants, who were sometimes secretaries or clerks, but occasionally in jobs such as technical artist, were listed with their hobbies and, sometimes, their measurements. The contest became so well-known that it was spoofed



on radio's "My Little Margie" show in 1955. In 1959, the title was changed to "Queen of Outer Space," reflecting JPL's transition from missiles to spacecraft.

The contest continued for another decade as a popular Lab event that included extensive campaigning with a manager team promoting each candidate, a parade around the Lab in decorated convertibles and a campaign luncheon. It was eventually discontinued around 1970, due to a combination of changing times and because managers and supervisors complained that it took too much time away from productive work.

Over the past few decades, the representation of women in technical and managerial positions has steadily increased. While men still outnumber women in engineering and scientific areas, the percentage of women in most of these fields is greater at JPL than it is in the available outside job pool. Today's organizational climate fosters opportunities in science, engineering, research, education, and management at all levels, including project and program management. And JPL's Executive Council, which guides the Laboratory, now includes two female members.



The Best of Several Worlds

Hardly a week goes by that someone or another on the outside doesn't ask exactly what JPL is. Is it a branch of the government? Part of a university? A private company? All, or some, or none of the above?

**The people at JPL
are as diverse
as the skills
required to run
the Laboratory.**

JPL is most decidedly a unique institution with an identity that is, in some ways, complex. In many respects, the Laboratory enjoys the best of several worlds.

JPL as a physical place is a federal facility. As a human organization, it exists as a division of Caltech, which manages the Lab for NASA under a contract renegotiated every five years. Whereas most NASA centers are run by a core staff of government employees with support from on-site contractors, JPL's management and staff are employees of Caltech. Another 10 percent of the workforce are on-site



contractors who work for private companies, somewhat like other NASA centers. In addition, there is a small group of on-site government employees who act as NASA's liaison to the Lab.

In formal talk, JPL is a "federally funded research and development center," putting it among a small cadre of similar institutions around the country. The closest comparable organizations might be the Lawrence Livermore or Los Alamos national laboratories, both of which the University of California manages for the Department of Energy.

Although the Lab's dual identity can be challenging, it has its definite upsides. Caltech has prided itself on its stewardship of JPL over the decades, believing that the intellectual cross-fertilization with the campus has made both communities stronger.



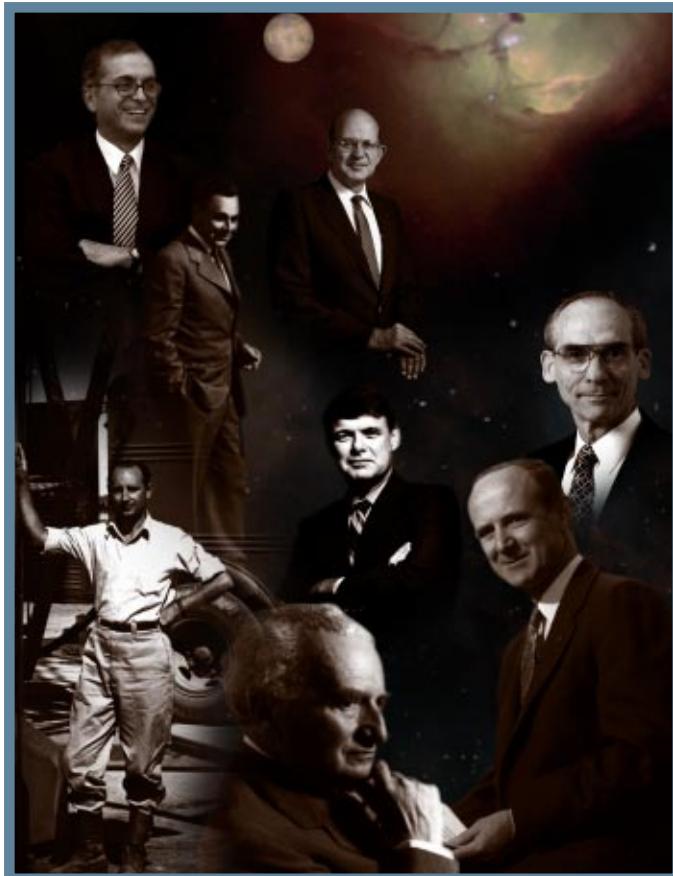
The Makings of a JPL Director

[What does it take to become a director of JPL? Some eight individuals have held that job title over the past six decades. Most have come from within JPL or the Caltech community, although in one case recruiters reached outside to find a leader for the Lab. All of them have had Ph.D.'s. Most have intermingled interests in science and engineering.

Theodore von Kármán was considered by at least some to be a mathematician at heart, by others as an academician with a gift for engineer-

ing topics. His specialty was fluid mechanics.

Frank Malina, who served as acting director of JPL in the Lab's infancy, focused on rockets in his work as a student at Caltech. Later in life he turned to a career in art.



At the helm: JPL directors (clockwise from upper left)
Charles Elachi,
Louis Dunn, Lew Allen,
Edward Stone,
William Pickering,
Bruce Murray,
Theodore von Kármán
and **Frank Malina.**

Louis Dunn had Caltech degrees in mechanical and aeronautical engineering. He presided over the JPL rocketry program that led to the Corporal and Sergeant missiles.

The New Zealand-born William Pickering took degrees in electrical engineering before earning a doctorate in physics. After teaching at Caltech, he joined JPL in the 1940s with a special interest in telemetry, or how ground stations communicate with spacecraft.

Bruce Murray was the first true planetary scientist to head JPL. A geologist by training, he worked in oil exploration before joining the Caltech faculty, where his interests turned extraterrestrial in the form of the rocky surfaces of Mars and other planets.

Lew Allen was the outside recruit among the JPL director crowd. A former chief of staff of the Air Force and former director of the National Security Agency, he was a physicist who spent most of his adult life working with heavily classified intelligence information.

Ed Stone was well-known throughout JPL when he became director in 1991. A physicist with a specialty in the study of charged particles, he is most remembered for serving as project scientist for the Voyager project for more than three decades.

Charles Elachi was likewise no stranger to JPL when he assumed the Lab's top spot. Born in Lebanon, he earned an eclectic mixture of degrees in physics, engineering, electrical sciences, geology and business administration. As a scientist he specialized in imaging radar carried by such spacecraft as the space shuttle and the Cassini mission to Saturn.

Regardless of their specialty — or whether they canted toward the scientific or engineering end of the scale — all of those who became JPL's director reached that position because of their qualities of leadership. Each in his own way had a vision of what the Lab could become in leading the nation and the world out among the stars.

SO WHERE ARE THE JETS?

In the 1930s, when JPL's founders were setting off rockets in the Arroyo Seco, to most of America they may as well have been tinkering with time machines or matter transporters.

In those days, most people's exposure to rockets was limited to the Saturday matinee, where Flash Gordon roared from planet to planet in a spaceship adorned with elaborate drapes.

Theodore von Kármán recalled that the director of a U.S. government science office once said bluntly, "I don't understand how a serious scientist or engineer can play around with rockets."

"Interestingly," von Kármán said in his autobiography, "the word 'rocket' was in such bad repute that for practical reasons we decided to drop it from our early reports and even our vocabulary."

The code for rockets, therefore, became "jets." The rocket boosters designed to help airplanes during takeoff were to go by the name of "jet-assisted takeoff," or "JATO." The Caltech facility where the project was conducted adopted the moniker "Jet Propulsion Laboratory."

Von Kármán and others at JPL became interested in the technologies of ram-jet engines, but they abandoned research by 1950. By 1959 the Lab got almost wholly out of the propulsion business when it discontinued missile work in favor of creating robotic probes for NASA.

JPL does maintain a propulsion department, however. Today its focus is on thrusters used to steer and brake planetary spacecraft, and on more exotic technologies such as ion propulsion.



C r e d i t s

Editor and lead author: Franklin O'Donnell

Research and writing: Carolina Carnalla-Martinez,
Mary Hardin, Martha Heil, Jane Platt, Christi Schuler,
Colleen Sharkey, Rosemary Sullivant, Guy Webster

Copyediting and captions: Marilyn Morgan,
Veronica McGregor

Designer: Audrey Steffan

Additional designers: Elsa King, Adriane Jach

Production: David Hinkle

Photo research: Russell Castonguay, Xaviant Ford

Additional photography: Carol Lachata

Coordination of additional photography: Susan Watanabe

