



NASA

Steven J. Dick, Stephen J. Garber, and James I. Deutsch

Fifty Years and Beyond



Jeff Hamilton was born in 1958—the same year that the National Aeronautics and Space Administration (NASA) was created—and grew up on a small farm outside Huntsville, Alabama. Fifteen miles away was NASA’s Marshall Space Flight Center, where engines for the Saturn V rocket were being tested. When these tests took place, Hamilton recalled, “The ground would shake, the house would shake, the windows would rattle. I would run out into the yard, and you could feel it as a rumbling, you could feel it as a low-frequency thump in your chest, and you could see the smoke billowing up on the horizon. That was real cool, for a kid growing up on a chicken farm.” Listening to the thundering roar of those rockets in the mid-1960s, Hamilton dreamed that one day he might get to work on those engines himself. He studied electrical engineering at the University of Alabama in Huntsville and joined the University’s Cooperative Education Program in 1979. That allowed him to take classes one semester and work the following semester for NASA’s Marshall Center. As luck (or fate) would have it, Hamilton’s very first assignment was to work in the exact same place where the Saturn V engines had roared. “By then they had converted it for testing the Space Shuttle’s external fuel tank,” Hamilton explained. “But there I was, climbing around on the very same test stand that had called me to NASA as a young boy.” Thirty years after he started, Hamilton is still with NASA, having worked primarily as an aerospace engineer, but also in areas of administration and management.

The Saturn V rockets were the most powerful launch vehicles ever used by NASA and first saw service on November 9, 1967, when the unmanned *Apollo 4* lifted off from the Kennedy Space Center. All images in this article courtesy NASA, unless otherwise indicated.



The 2008 Smithsonian Folklife Festival program *NASA: Fifty Years and Beyond* presents these and other occupational traditions from the National Aeronautics and Space Administration, an organization now celebrating its first fifty years. Approximately 100 participants are on the National Mall to share their skills, experiences, and traditions with members of the public. They include administrators, aeronautical engineers, analysts, archaeologists, astrobiologists, astronauts, astronomers, astrophysicists, atmospheric scientists, and avionics technicians—not to mention the occupational groups from the remaining twenty-five letters of the alphabet.

NASA: Fifty Years and Beyond builds upon previous Folklife Festival programs that have examined occupational traditions, such as *American Trial Lawyers* in 1986, *White House Workers* in 1992, *Working at the Smithsonian* in 1996, *Masters of the Building Arts* in 2001, and *Forest Service, Culture, and Community* in 2005. Every occupational group—including actuaries, biologists, cowboys, dishwashers, engineers, firefighters, gaffers, and haberdashers—has its own set of skills, specialized

knowledge, and codes of behavior that not only distinguish it from other occupational groups, but also meet its needs as a community.

The engineers, scientists, and administrators who work at NASA may be surprised to find themselves regarded as bearers of tradition and thus the subject of study by folklorists. After all, NASA generally perceives itself as a paragon of progressive science, continually breaking new ground rather than conserving its culture. But another way of looking at occupational culture is to see it as distinctive to a particular agency, company, or organization. As sociologist James Q. Wilson has observed, “Every organization has a culture, that is, a persistent, patterned way of thinking about the central tasks of and human relationships within an organization. Culture is to an organization what personality is to an individual. Like human culture generally, it is passed on from one generation to the next. It changes slowly, if at all.” The fiftieth anniversary of NASA in 2008 provides a wonderful opportunity for understanding and appreciating its organizational and occupational cultures.



(Upper) The first Space Shuttle external fuel tank rolled off the assembly line on September 9, 1977, at the Michoud Assembly Facility in New Orleans, Louisiana. The tanks for the first two Shuttle missions were painted white but were thereafter left unpainted, reducing the weight by approximately 600 pounds.

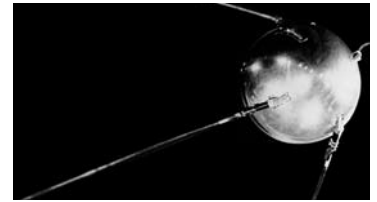
(Lower) Onboard the Space Shuttle *Endeavour* in September 1992, crew members representing NASA's diverse occupational culture pose for their traditional portrait in space. Pictured front row, left to right, are Payload Commander Mark Lee and Payload Specialist Mamoru Mohri (from Japan's National Space Development Agency); middle row are mission specialists Jan Davis, Jerome Apt, and Mae Jemison; and back row are Commander Robert Gibson and Pilot Curtis Brown.

NASA's Origins

Undoubtedly, NASA is one of the U.S. government agencies with the highest name recognition. Not many Americans know much about the General Services Administration or the Office of Government Ethics, but they are likely to know of and have strong opinions about the Internal Revenue Service, the Social Security Administration, and the National Aeronautics and Space Administration. What the public may know about NASA is that its astronauts have circled the world, walked on the moon, piloted the first winged spacecraft, and constructed the International Space Station. Less well known is that NASA's robotic spacecraft have studied the Earth's climate, oceans and land masses, visited all the planets (except for the dwarf planet Pluto, which will be visited by the New Horizons mission in 2015), captured images of the universe at many wavelengths, and peered back to the beginnings of time. Its scramjet aircraft have reached the aeronautical frontier, traveling 7,000 miles per hour, ten times the speed of sound to set a world record.

Few people might have predicted all these achievements when NASA was first created. On July 29, 1958, President Dwight D. Eisenhower signed the National Aeronautics and Space Act to support research into the problems of flight, both within the Earth's atmosphere and in space. The act created NASA, which became operational on October 1, 1958. NASA's birth was directly related to the pressures of international political and military competition and in particular to the Soviet Union's launch of Sputnik. After World War II, the United States and the Soviet Union were engaged in the Cold War, a broad contest over the ideologies and allegiances of nonaligned nations. During this period, space exploration emerged as a major disputed area and became known as the "space race."

NASA began by absorbing the earlier National Advisory Committee for Aeronautics (NACA), including its 8,000 employees, an annual budget of \$100 million, and three major research laboratories—Langley Aeronautical Laboratory (Hampton, Virginia), Ames Aeronautical Laboratory (Moffett Field, California), and Lewis Flight Propulsion Laboratory (Cleveland, Ohio). These three facilities are now known as the Langley, Ames, and Glenn research centers.



(Upper) On the evening of October 4, 1957, a 183-pound beach ball-sized aluminum sphere, known as *Sputnik*, was launched from the Soviet Union's rocket test site near Tyuratam, Kazakhstan.

(Center) Test pilot Lawrence A. Clousing climbs into his Lockheed P-80 aircraft for a test flight at the Ames Aeronautical Laboratory, Moffett Field, California.

(Lower) Technicians at the Kennedy Space Center prepare the *Pioneer 10* spacecraft for operation prior to liftoff in March 1972. In December 1973, it became the first spacecraft to fly by Jupiter. Although researchers hoped for seven years of service, the *Pioneer 10* continued to send signals back to Earth for twenty-four years as it became the first human-built object to leave the solar system.

(Left) With its twin solid rocket boosters and three main engines churning at 7 million pounds of thrust, the Space Shuttle *Atlantis* thunders skyward from the Kennedy Space Center on March 24, 1992.

(Right) On its way to the moon in April 1970, the *Apollo 13* spacecraft was crippled by an explosion in one of its oxygen tanks. Shortly before that occurred, Astronaut Fred W. Haise Jr. (shown on the screen) spoke with the Mission Operations Control Room in Houston, Texas.



Today, NASA is run by personnel at its headquarters in Washington, D.C., and has ten major field centers spread around the country. Headquarters personnel broadly oversee the direction of NASA's programs at the field centers, where employees actually perform specific engineering tasks and conduct scientific research. In addition, NASA headquarters personnel liaise with other government personnel in Washington, such as White House and Congressional staff. NASA is an independent, civilian agency whose top official, the administrator, reports directly to the president. While NASA cooperates closely with the various military services, it was set up as and remains a civilian agency.

Over 18,000 civil servants and more than 43,000 on-site contractors work at headquarters, the ten field centers, and other smaller facilities. In general, civil servants oversee research, coordinate programs,

and handle inherently governmental tasks, while the contractors manufacture new hardware, perform operational tasks, and carry out a variety of other support functions. In addition, this workforce is backed up by the broad-based national aerospace industry.

Some of NASA's facilities—such as the Kennedy Space Center (KSC) near Cape Canaveral, Florida, and the Johnson Space Center (JSC) in Houston—are well known, due to their very visible roles in human spaceflight. Many Americans are aware that astronauts and rockets are launched into space from Florida's KSC and that astronauts talk directly to Mission Control at the JSC—as in “Houston, we’ve had a problem.” Astronauts are clearly the figurative and literal faces of NASA, which is the only U.S. government organization able to send people into space. The United States is one of only three nations able to do this; the others are Russia and China.

Another NASA facility is the Marshall Space Flight Center in Huntsville, Alabama. When it opened in 1960, Wernher von Braun (who had developed the V-2 rocket for Germany during World War II) became its first director. Von Braun's "German rocket team" was instrumental in developing the large Saturn rockets used in the Apollo missions to the moon. Engineers at Marshall have continued developing launch technologies such as the Space Shuttle main engine and its solid rocket boosters. In neighboring Mississippi, the Stennis Space Center is where engineers test rocket engines on gigantic stationary stands. Stennis employees also engage in other research such as Earth science (See page 46).



Mementos in Time: Crew Patches Help Piece Together NASA's Spaceflight History

by Catherine E. Borsché and Brad Thomas

The most highly identifiable symbol for each NASA mission is the crew patch, which adorns the crew's flight suits and personalizes the mission. Because each patch is designed by crew members themselves, it "tells a story about the mission and is often a peek into the personalities of the people onboard," according to Steve Robinson. Robinson should know because he designed the patch for STS-114, on which he served as mission specialist in July–August 2005. STS-114 was the first Space Shuttle mission to fly after the tragic *Columbia* accident in February 2003.

Robinson personally crafted the initial elements. "The initial concept took shape over two days in my home studio. I roughed out three to four different concepts using pencil, colored felt pens, and watercolor," he recalls. "I worked for years as a graphic designer as a side job, and I always wondered what it would be like to design a mission patch."

Once the crew members formulate a concept, they bring it, sometimes as a sketch, to a NASA graphic artist. Before the switch to computers, it took a graphic artist up to 300 hours to create a patch. Now that time has decreased to no more than twenty hours. The results become an indelible part of NASA history.

Five rocket pioneers pose in 1956 with models of missiles they created. Clockwise from center are Hermann Oberth, a German-born physicist who first used the term "space station" to describe a wheel-like facility for space travel; Ernst Stuhlinger, a German-born electrical scientist who designed a solar-powered spacecraft; Major General Holger Toftoy, who recommended that German scientists be sent to the United States to work in the rocket program after World War II; Wernher von Braun, one of Oberth's students in Germany and the first director of the Marshall Space Flight Center; and Robert Lusser, a German-born aircraft designer and engineer.

Human Spaceflight

More NASA personnel work on human spaceflight efforts—such as the Space Shuttle, International Space Station, and the planned Constellation program—than on robotic spacecraft missions, such as the well-known Mars Rovers and Earth science satellites. By its nature, human spaceflight is more risky and complex than sending robotic craft into space. While some space scientists decry the greater funding given human spaceflight, there is no doubt that human spaceflight captivates the public’s attention and imagination and that without this intangible support, NASA would likely not even exist. As a result, human spaceflight dominates the agency’s organizational culture.

NASA’s human spaceflight initiatives began with project Mercury, a single astronaut program (flights during 1961–1963) to ascertain if a human could survive in space. Project Gemini (flights during 1965–1966) proceeded with two astronauts to practice space operations, especially docking of spacecraft and extravehicular activity (or spacewalks).

These early missions culminated in project Apollo (flights during 1968–1972) to explore the moon. Apollo became a NASA priority on May 25, 1961, when President John F. Kennedy announced the goal of landing a man on the moon and returning him safely to Earth by the end of the decade. Despite a deadly fire in 1967, which took the lives of three astronauts, the Apollo program recovered and on a memorable Christmas Eve in 1968, the Apollo 8 crew went into orbit around the moon and broadcast live images of the moon’s forbidding surface to



a worldwide audience on Earth. On July 20, 1969, the Apollo 11 mission fulfilled Kennedy’s challenge by successfully landing Neil Armstrong and Edwin E. “Buzz” Aldrin Jr. on the lunar landscape known as the Sea of Tranquility. Five more successful lunar-landing missions followed, leading to a total of twelve Apollo astronauts conducting brief (up to three days) exploratory missions on the lunar surface. The final three missions (Apollo 15, 16, and 17) undertook more extensive activities, aided by lunar rovers that could travel at speeds up to eight miles an hour.



(Upper) Alan Shepard was the first American and the second human (after Yuri Gagarin) to fly in space. Here he is being inserted into the tight confines of the Mercury capsule for a flight simulation test in early 1961.

(Left) The imprint of Buzz Aldrin’s boot—left when he and Neil Armstrong became the first humans to walk on the moon in July 1969—has become one of the iconic images of human exploration in space.



On June 3, 1965, Edward H. White II became the first American to step outside his spacecraft and let go, effectively setting himself adrift in the zero gravity of space—though attached to the spacecraft by a 25-foot umbilical line and a 23-foot tether line.

The Apollo program continued in a different form with the Skylab “orbital workshop” missions (1973–1974). As an indicator of or perhaps a contributing factor to the superpower détente of the time, NASA worked with Soviet counterparts on the Apollo–Soyuz Test Project of 1975, with its famous handshake in space between astronauts and cosmonauts.

After a break of six years, NASA returned to human spaceflight in 1981 with the advent of the Space Shuttle program. The Shuttle’s first mission, which was launched on April 12, 1981, demonstrated that it could take off vertically and glide to an unpowered airplane-like landing. During its early missions, the Shuttle proved useful for placing communications and other satellites in Earth orbit, for launching robotic missions toward their planetary targets, and for conducting microgravity research. On January 28, 1986, however, a leak in the joints of one of two solid rocket boosters attached to the Shuttle orbiter *Challenger* caused the main liquid fuel tank to explode seventy-three seconds after launch, killing all seven crew members. In 1988, the Shuttle successfully returned to flight, and NASA then flew eighty-seven successful missions before

tragedy struck again on February 1, 2003, with the loss of the orbiter *Columbia* and its seven astronauts during reentry. Three Shuttle orbiters remain in NASA’s fleet: *Atlantis*, *Discovery*, and *Endeavour*.

In 1984, Congress approved President Ronald Reagan’s proposal for NASA to build a space station as a base for further exploration of space. After many revised plans, the International Space Station finally emerged. Permanent habitation of the ISS began when the Expedition One crew arrived in 2000.

In 2004, President George W. Bush announced a Vision for Space Exploration that entailed sending humans back to the moon and on to Mars by retiring the Shuttle in 2010 and developing the Constellation program. The latter includes a new, multipurpose Orion crew exploration vehicle, as well as new crew and cargo launchers, known as Ares I and Ares V. Robotic scientific exploration and technology development were also integrated into the Vision, as was the completion of the ISS in 2010.

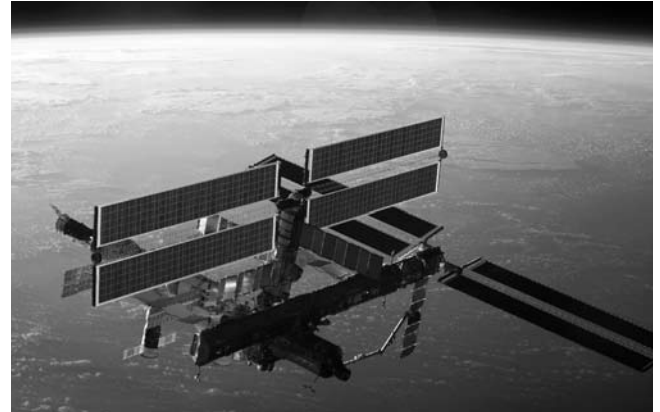
This fish-eye view of the Space Shuttle *Atlantis* was taken from the Russian *Mir* Space Station in 1995. The *Mir* station was operational from 1986 to 2001.



(Upper) Astronauts Leland Melvin (left) and Stanley Love, both in space for the first time, float from the Space Shuttle *Atlantis* to the International Space Station in February 2008.

(Center right) Continuously inhabited since November 2000, the International Space Station orbits the Earth every ninety-one minutes at an altitude of 250 miles.

(Center left) This conceptual image shows the Ares I crew launch vehicle during ascent. The Ares I will carry crews of up to six astronauts in the Orion capsule (seen here with flag decal) into Earth orbit. Photo courtesy NASA Marshall Space Flight Center



Jennifer Heldmann: In the Footsteps of Galileo

by Ruth Dasso Marlaire

In 1609, Galileo Galilei made his first major discovery with the telescope when he observed that the moon was mountainous and pitted, much like the Earth. Almost four hundred years later, the same discovery was made by ten-year-old Jennifer Heldmann.

"I had a small telescope at home," recalls Heldmann. "One night, my mom and I pointed it at the moon, and I couldn't believe I could see craters and mountains! Right there, so close to us, was a whole other world."

Today, Heldmann is a research scientist at NASA's Ames Research Center, where she works on the Lunar Crater Observation and Sensing Satellite (LCROSS) project, an

important precursor mission to humans returning to the moon. The LCROSS mission objective is to search for water on the moon to prepare for a future lunar outpost. In early 2009, LCROSS will crash two vehicles on the moon's surface to kick up a plume of dust. A sensing satellite will then pass through the plume, trying to detect water. Heldmann enjoys "studying the world and universe because there are so many mysteries to unravel. It helps us understand our context in the grand scheme of the cosmos."

Space Exploration

The robotic exploration of space has also long been a significant part of NASA's mission, particularly with scientific probes that explored the moon, the planets, and other areas of Earth's solar system. The 1970s, in particular, heralded the advent of a new generation of scientific spacecraft. For example, *Pioneer 10* and *Pioneer 11* were launched in 1972 and 1973 to study the composition of interplanetary space and thus became the first human-built objects to leave the solar system. Several years later, *Voyager 1* and *Voyager 2* began to explore the outer reaches of the solar system and beyond; they are both still providing scientific data and have established new records for distance from Earth. In 1976, NASA landed two Viking spacecraft on Mars where they searched for evidence of life, but neither mission found convincing evidence for past or present biological activity. However, shortly after the *Spirit* and *Opportunity* rovers landed separately on different parts of Mars in January 2004, they analyzed rocks and were able to demonstrate, to much scientific and popular acclaim, that liquid water had existed on Mars. Other NASA missions—such as Magellan, Galileo, and Cassini—have sent robots to explore Venus, Jupiter, and Saturn, respectively.

The Goddard Space Flight Center in Greenbelt, Maryland, is the nexus for much of NASA's robotic space work. In concert with personnel in Baltimore, Goddard scientists and technicians control the Hubble Space Telescope and also operate Earth science and remote sensing satellites such as Landsat. Delivered into Earth orbit in 1990, the Hubble Space Telescope has provided a wealth of scientific data, made possible by four shuttle servicing missions. Hubble is the first of NASA's "Great Observatories" (or powerful telescopes based in space) and operates in the optical portion of the spectrum, i.e., that which can be seen by the human eye. It was followed by the Compton Gamma Ray Observatory (launched in 1991), the Chandra X-ray Observatory (1999), and the Spitzer Space (infrared) Telescope (2003).

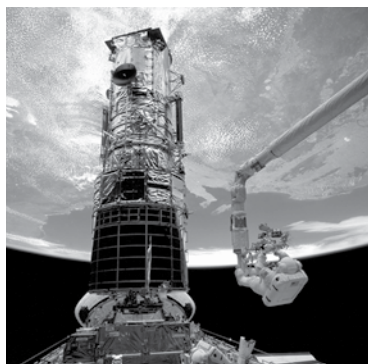
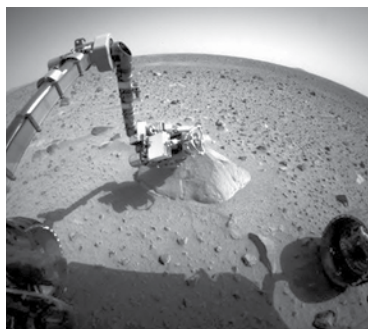
Holding even more promise is the James Webb Space Telescope (JWST), which is scheduled to launch in 2013. Like the Spitzer telescope, the JWST will make observations in the infrared portion of the spectrum, utilizing a mirror that is 21.3 feet in diameter (by comparison, Hubble's mirror is only 7.8 feet in



This composite image—taken by two of Hubble's telescopes—shows pillar-like structures that are actually columns of cool interstellar hydrogen gas and dust, which serve as incubators for new stars. Photo courtesy NASA, European Space Agency, Space Telescope Science Institute, and Arizona State University

Dave Redding: Telescope Optical System Designer

by Franklin O'Donnell



(Upper) Taken by NASA's Exploration Rover *Spirit* on Mars, this photograph shows its robotic arm extended to the rock called Adirondack in January 2004, with a spectrometer used for identifying possible minerals. Photo courtesy NASA Jet Propulsion Laboratory

(Lower) Astronaut F. Story Musgrave, anchored on the end of the Space Shuttle *Endeavour's* mechanical arm, is about to install protective covers on the Hubble Space Telescope's magnetometers as part of the first servicing mission in December 1993.

diameter). The JWST will reside in an orbit roughly one million miles from Earth (versus the Hubble's position only 366 miles away). NASA scientists are hoping that the JWST will be able to locate the very first galaxies that formed in the Universe, thereby connecting the Big Bang to our own Milky Way.

The Jet Propulsion Laboratory (JPL) in Pasadena, California, is a unique NASA Field Center because it is operated by the California Institute of Technology. Before it was part of NASA, JPL personnel contributed to the first successful launch of a U.S. orbital spacecraft, *Explorer 1*, which discovered the Earth's Van Allen radiation belts. JPL is widely recognized for its key roles on major robotic scientific spacecraft that go beyond Earth orbit, such as the Viking, Spirit, and Opportunity missions to Mars.

You might call Dave Redding the Jet Propulsion Laboratory's optician to the stars, literally. When NASA's Hubble Space Telescope proved to have a defective mirror after its launch in 1990, Redding was part of the JPL team brought in to create a fix. The optics they devised for Hubble were successful, enabling the space telescope to make a comeback and proceed to a mission that dazzled the world with scores of magazine cover images.

Since then, Redding has gone on to shape and deploy ever more sophisticated technologies for optical systems, both in space and on Earth. He was one of the original architects of the optical system for NASA's planned James Webb Space Telescope, which will launch in 2013 to study star-forming regions in the distant universe.

What excites Redding today are futuristic space telescopes using precision-made composite mirrors that actively control the surface to adapt to observing conditions. "These can be made quickly and relatively inexpensively and can be assembled in segments to create a telescope on orbit that wouldn't fit in a launch vehicle," he notes.

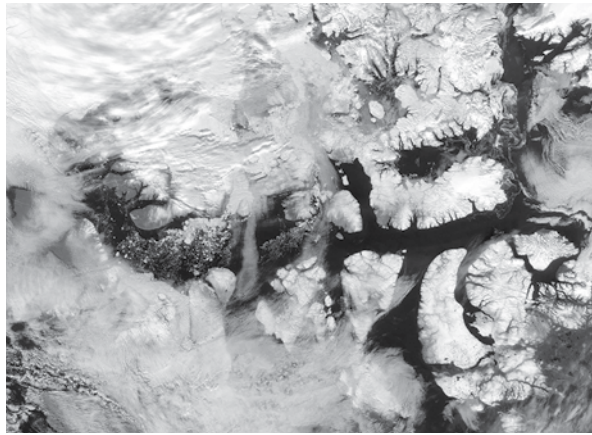
Redding not only has his eyes on the stars but, clearly, on new ways of seeing them.



Earth Science

Not all of NASA's ventures are out of this world. For example, in the 1970s, NASA's Landsat program literally changed the way humans looked at our own planet. Landsat data became used in a variety of practical commercial applications, including crop management and fault line detection. They were also helpful in tracking many kinds of weather and phenomena such as droughts, forest fires, and ice floes. Since then, NASA has engaged in a variety of other Earth science efforts, notably the Earth Observing System (EOS) of spacecraft and data processing that have yielded important scientific results in such areas as tropical deforestation, global warming, and climate change.

Over the coming years, NASA and its research partners will be analyzing EOS data to better understand the complex, dynamic system that is our Earth. As far as we know, Earth is the only planet that is capable of sustaining life. Given that the world's population doubled from 3 to 6 billion in just thirty-eight



NASA's Terra satellite captured this image of the Arctic Sea in September 2007. It shows the Northwest Passage free of ice for the first time since satellite records began in 1979.

years (from 1961 to 1999), and is expected to reach 7 billion by 2011, it is vital that Earth scientists—at NASA and elsewhere—help us understand whether the Earth can continue to sustain this type of growth in the future, as well as what effect a changing climate may have on the inhabitants and surface of the Earth.



"Antarctica is Earth's largest reservoir of fresh water. Understanding the behavior of the ice sheets has important societal and economic impacts."

Isabella Velicogna: From Italy to Ice Sheets

by Franklin O'Donnell

When Isabella Velicogna was growing up in northern Italy, physics didn't sound like a promising career to her mother. "She tried to get me to do something else," Velicogna recalls of the time her interest in math and physics was blossoming in high school. "She didn't think I could get a job."

Fortunately, her mother's fears proved to be unfounded. Several college degrees later, including a doctorate in applied geophysics from the University of Trieste, Velicogna has recently joined NASA's Jet Propulsion Laboratory and has plenty of work. Her specialty: studying the loss of ice in polar regions as Earth's climate warms, with the aid of the Gravity Recovery and Climate Experiment, or GRACE—two satellites that make extremely accurate measurements of Earth's gravity as they circle the planet.

In the future, Velicogna—who paints abstract art in her spare time—hopes to combine data from more satellites and ground studies to create a more complete portrait of ice around the planet, or Earth's cryosphere.

Aeronautics

Although NASA may now be known primarily as a “space agency,” the first “A” in NASA stands for aeronautics. Indeed, the agency’s roots go back to 1915, when its predecessor the National Advisory Committee for Aeronautics (NACA) was formed. Moreover, during NASA’s earliest years, most of its engineers and scientists had only aeronautics training because astronautics had not yet been established as a discipline.

Building on these roots, NASA has continually conducted research on aerodynamics, wind shear, and other important topics using wind tunnels, flight testing, and computer simulations. In the 1960s, NASA’s X-15 program involved flying a rocket-powered airplane above the atmosphere and gliding it back unpowered to Earth. The X-15 pilots helped researchers gain useful information about supersonic aeronautics, and the program provided data for development of the Space Shuttle.

NASA has also conducted significant research on high-speed aircraft flight maneuverability that was often applicable to lower-speed airplanes. NASA scientist Richard Whitcomb invented the “super-critical wing,” which was specially shaped to delay and lessen the impact of shock waves on transonic military aircraft and had a significant impact on civil aircraft design. From 1963 to 1975, NASA conducted a research program on “lifting bodies” (aircraft without wings). This paved the way for the Space Shuttle to

glide to a safe unpowered landing, for the later X-33 project, and for a crew return-vehicle prototype for the International Space Station. In 2004, the X-43A airplane used innovative scramjet technology to fly at ten times the speed of sound, setting a world record for air-breathing aircraft (i.e., those that require the intake of air for fuel combustion).

NASA’s aeronautical research heritage continues at some of its lesser-known facilities. For instance, the Langley Research Center (1915) in Hampton, Virginia, is the original “mother center.” Its staff is not only still a leader in aeronautical wind tunnel research, but also includes scientists in atmospheric science research and engineers who tackle other problems of spaceflight.

Another early NASA center for aeronautics was what is known today as the Dryden Flight Research Center in California’s Mojave Desert. The center traces its origins to 1946, when NACA researchers came to the Muroc Army Air Base, now the Edwards Air Force Base, to test the first supersonic flights by the X-1 rocket plane. The facility was ideally suited for this type of research because it contains the Rogers Dry Lake—at forty-four square miles, the largest dry lakebed in the world. Here, the test pilots demonstrated that they had “the right stuff,” what Tom Wolfe described in his best-selling book by that title. As he observed, the world of the test pilots “was divided into those who had it and those who did not.”



(Left) Future astronaut Neil Armstrong stands next to the X-15 rocket-powered aircraft, which set unofficial records for speed and altitude. Before entering astronaut service, Armstrong worked as a test pilot at what later became the Dryden Flight Research Center.

(Right) The Dryden Flight Research Center has served as the testing grounds for a variety of innovative aircraft. The smallest aircraft at center is the radio-controlled Mothership; from there clockwise are the X-36, X-31, F-15, SR-71, F-106, F-16XL, and X-38.

Today, Dryden's flight engineers continue to enjoy the sunny, clear weather and vast expanses of dry lakebed there to test fly unusual and high-speed aircraft.

Several hundred miles further north, on the south end of San Francisco Bay, employees at NASA's Ames Research Center are also involved in aeronautics and space efforts. Building on pioneering aerodynamic work in the 1950s, researchers at Ames developed the blunt body shape for the Mercury, Gemini, and Apollo capsules. More recently, they have tackled such diverse space research areas as advanced spacesuit development and astrobiology, the search for life beyond Earth. In addition to cutting-edge work on air traffic control, aircraft simulators, and tiltrotor aircraft (i.e., those with propellers that tilt for both lift and propulsion), Ames personnel also take advantage of their location in Silicon Valley to cooperate with computer companies and "push the envelope" in supercomputing.

Engineers and scientists at the Glenn Research Center outside Cleveland also conduct aeronautics and space research. Experts at its unique Icing Research Tunnel analyze the historically persistent and potentially catastrophic problem of airline travel in cold weather. Scientists at Glenn also conduct research in the behavior of materials and fire in the microgravity of space. Glenn engineers are also known for their work on spacecraft and launch vehicle propulsion, especially for testing and developing propulsion systems using liquid hydrogen and liquid oxygen.



(Upper) A refrigerated wind tunnel at NASA's Glenn Research Center creates realistic icing conditions for models and airfoils on the ground. Photo courtesy NASA Glenn Research Center

(Lower) NASA's Future Flight Central, the world's first full-scale virtual airport control tower, opened in December 1999 at the Ames Research Center in California. The facility is designed to test ways to solve potential air and ground traffic problems at commercial airports under realistic airport conditions.



Kim Hambuchen: A Passion for Robotics

by Amiko Nevills

Robots like R2D2 of *Star Wars* and the obedient female replicas of *The Stepford Wives* have long intrigued us. Fascination in these non-human but intelligent forms brought Kim Hambuchen to the Johnson Space Center, where robots are born, or rather built, to help us in space.

Hambuchen first came to NASA by way of a research fellowship award to work with Robonaut, the humanoid designed at the Johnson Space Center to demonstrate a robotic system that could function as a spacewalker. "I chose NASA because there is literally no other place on Earth where I could be doing what I do now," Hambuchen explains. Today, she works for the Robotics Systems and Technologies branch in Engineering, where as a robotics engineer, she develops software in the area of Human-Robot Interaction. Robots are created to do one of two jobs: jobs that a robot could do better than a human or jobs that a human could do better than a robot, but are too dangerous. Working side by side with humans or going where the risks are too great for people, the robots Hambuchen helps develop will expand our ability to explore in space.

NASA's Organizational Culture

While many people think correctly of NASA as a technical organization, its organizational culture is primarily one of engineers, although scientists have important roles at the agency. In general, engineers are practical-minded people who develop tools and technologies to build specific structures and to solve specific technical problems. Scientists, on the other hand, tend to focus on gaining fundamental knowledge to help them understand how the natural universe works and how specific systems within it are structured.

Because NASA's culture has been dominated by human spaceflight, more engineers than scientists have been needed to design and oversee construction of safe, reliable, "human-rated" rockets and spacecraft. Accordingly, many observers point out that NASA's best-known human spaceflight programs, such as Apollo, the Space Shuttle, and the ISS, have been engineering, rather than scientific, achievements.

Thus, although the job title of "rocket scientist" has entered the popular lexicon—as in "you don't need to be a rocket scientist" to understand such-and-such—the term is really a misnomer. NASA does not employ any "rocket scientists" per se. NASA engineers design rockets; technicians build them; and scientists learn about our universe from the spacecraft that rockets launch into space.

NASA engineers and scientists have been responsible for cutting-edge research achievements in virtually every major technical discipline; some of them seem only peripherally related to space. Going beyond fields such as astrophysics, rocket propulsion, and aerodynamics, NASA personnel have had a significant hand in such wide-ranging fields as archaeology, biology, chemistry, computer science, information technology, materials science, physics, and planetary geology. There are at least two reasons for this success: NASA attracts exceptional scientists and engineers, and like some other government agencies, such as the National Science Foundation, it does a good job of planting research seeds by providing grants and contracts to leading scientists and engineers around the country and the world.

Engineers make up by far the largest single professional cadre at NASA, with approximately ten times more engineers than scientists working as NASA civil servants and about twice as many engineers as people with business backgrounds. Nevertheless, many people

without technical backgrounds do work for NASA as budget analysts, educators, historians, legislative affairs liaisons, procurement specialists, public affairs officers, and in many other administrative and professional pursuits. Moreover, because NASA employs so many engineers, many of them work as administrators rather than in their fields. Some NASA administrators, like the current agency head Michael Griffin, have had technical backgrounds and some, like James Webb (administrator during the Apollo effort) have had non-technical, policy backgrounds. In other



Technician Pat Klose leans over an edge in order to repair one of the protective thermal tiles on the Space Shuttle *Columbia*, prior to its fourth launch in 1982.

words, you don't need to be an engineer to work at NASA, but having had some kind of technical background will help open doors to employment.

Even though NASA is often regarded as a large bureaucratic and hierarchical organization, it has an intellectually nimble and flexible workforce. Several factors may explain this. One is that NASA's civil servants and contractors tend to be highly educated. Moreover, because NASA cooperates on space and aeronautics projects with many other nations and international organizations, its staff is exposed to different ways of doing research. Likewise, NASA's cooperation with many other U.S. government agencies, as well as with for-profit companies, nonprofit organizations, and academic institutions—all with very different goals—fosters creative problem-solving by NASA personnel.

Michele Perchonok: Why Isn't Pizza Served on the Space Shuttle?

Food is essential to today's astronauts, providing them with both nutrition and a comfort from home. It's important also to Michele Perchonok. As the shuttle food system manager, she is responsible for making space food taste good and be good for the crews.

Seven months prior to spaceflight, Perchonok works with NASA astronauts to develop personalized food menus. She conducts taste tests with shuttle crews in the Space Food Systems Laboratory, located at the Johnson Space Center in Houston.

While in space, astronauts eat many of the same foods they enjoy on Earth, with a few exceptions—such as pizza. "Pizza is difficult," Perchonok explains. "Foods in space have to be stored at room temperature. It's difficult when you have too many components, like a pizza—where you have the crust and sauce and the cheese. Each component requires different processing conditions."

Perchonok said some of the more common items astronauts choose are shrimp cocktail and barbecued beef brisket.



"Each person is different, so we really don't have a lot of favorites," she observes. To add variety, NASA food scientists develop two to three new products each year. Some of the newest space foods are chocolate pudding cake and apricot cobbler with pieces of crust.

Tracy Drain: The Play-by-Play Voice of Mars Exploration

by Franklin O'Donnell



Since joining NASA's Jet Propulsion Laboratory in 2000, Tracy Drain has worn many hats in the Mars Reconnaissance Orbiter project, from building command sequences to supporting readiness tests to serving as the voice of mission control for major spacecraft events. During the spacecraft's insertion into orbit around the red planet, Drain appeared on television screens as the mission's spokesperson, explaining the orbiter's play-by-play maneuvers to the viewing public. Many mission events later, the orbiter has now settled into routine science operations, and Drain likewise has shifted hats. She has joined an on-the-job training program for systems engineers that will pair her with senior mentors such as Viking veteran Gentry Lee.

Which of her roles has been the most memorable? "The one with the most immediate cool factor was serving as an 'ace' because I got to actually send commands to the spacecraft," she observes. "It's an important function, and it taught me a lot about the Deep Space Network (NASA's tracking network for planetary spacecraft). But a lot of people don't like to do it because it involves strange hours. It's the kind of job you either hate or you love."

A Diverse Workforce

NASA's efforts to increase the diversity of its workforce started as early as 1961 under Administrator James Webb. Indeed, Webb fought to enable African Americans to work at the Marshall Space Flight Center in the 1960s at a time when racial tensions were high. In 1983, Sally Ride became the first U.S. woman and Guion Bluford became the first African American astronaut to fly into space. Since that time NASA has made considerable strides in achieving diversity, especially in its upper-level management; by 1993, women and minorities made up half the incoming class of NASA Senior Executive Service leaders. Overall, NASA now employs about 12,000 men and 6,500 women as civil servants, and at headquarters, the ratio is roughly even. Of those 18,500 civil servants, approximately 14,000 are white; 2,100 are African American; 1,000 are Hispanics; 1,100 are Asian or Pacific Islanders; and 150 are Native Americans. The percentage of African Americans at NASA is 11.4 percent, compared to 12.3 percent of the U.S. population (according to the 2000 census). Asian/Pacific Islanders repre-

sent 5.9 percent of NASA's workforce, compared to the national 3.7 percent. The percentage of Hispanics is 5.4 percent, well below the 12.5 percent recorded in the 2000 census. And the percentage of Native Americans at NASA is 0.8 percent, which is just below the census count of 0.9 percent.

When asked to assess NASA's efforts at achieving greater diversity, Julian M. Earls, the grandson of a sharecropper and former director of the Glenn Research Center, observed, "I think we've made considerable progress. . . . Put it this way: We're making progress; we have a long way to go, but the intent is there, and people are not being promoted because they are [people] of color [or] because they are female. Everyone that has been chosen for those positions has paid his or her dues and is extremely competent."

NASA's diversity also extends to geography. Its ten field centers draw employees from all fifty states and the District of Columbia. In virtually every congressional district of the country, there are aerospace workers at NASA-contracted firms.

(Left) In 1983, astronaut Sally K. Ride became the first American woman to reach outer space. As a mission specialist on the Space Shuttle *Challenger*, she monitored control panels from the pilot's chair on the flight deck. Floating in front of her is a flight procedures notebook.

(Right) In space, there is no up or down and there is no gravity. As a result, astronauts are weightless and can sleep in any orientation. Seen sleeping here on *Challenger's* mid-deck in September 1983 are astronauts Guion Bluford (left) and Richard Truly.



Whither NASA?

American popular culture is very much fascinated with technology and in particular with NASA, which has a strong reputation as a high-tech organization. However, some critics have observed that NASA engineers have a predilection for overly complex technologies, rather than scientific goals. For example, the Space Shuttle, while relatively graceful, is a very complicated means of transportation. The fact that it does not fly very often reflects its complexity and delicacy (or its creators' unrealistic expectations). The Russian/Soviet approach to space was generally more rugged and utilitarian, as well as somewhat less elegant.

Hundreds of technologies developed by NASA have already benefited U.S. industry and society. Among the technology spin-offs from the Space Shuttle alone are a miniaturized heart pump (based on the shuttle's fuel pumps), a handheld infrared camera used to find forest fires (based on the camera that observes the blazing plumes from the shuttle), and a new material for making prostheses (derived from the foam insulation used to protect the shuttle's external fuel tank).

As NASA leads the United States, if not the world, into the future of space and aeronautics, its workforce will continue to serve a world-class



Molds for prosthetic devices were formerly made from plaster, which was heavy and fragile. However, the foam insulation used by NASA to protect fuel tanks from excessive heat has proven to be an excellent material for molding prostheses; it is lighter, less expensive, and stronger at high temperatures.

organization that attracts talented individuals from a wide range of professional backgrounds. Indeed, it may become even more diverse professionally, especially across the broad spectrum of scientific and engineering fields. For example, NASA may well hire more biologists as the hunt for extraterrestrial life intensifies. In addition, NASA will need the skills of psychologists and other “human factors” specialists as it develops plans for the difficult, long human flight to Mars.

Should NASA continue to explore the outer limits of aeronautics and the furthest reaches of outer space? Admittedly, there are many reasons not to explore, and the vast scope of NASA's work inevitably raises questions about motivation, sustainability,



Jen Keyes: Planning for Humans on the Moon and Mars

by Rachel Samples

More than fifty years separate their ages, but fifty-year NASA employee Bill Scallion and Jen Keyes have one thing in common—they like to solve problems.

Scallion worked with each of the original Mercury 7 astronauts on simulations and practice runs before the first U.S. trips into space. “We simulated a four-orbit mission in real time. It takes four and a half hours to do that,” recalls Scallion. “It’s like producing a television show. You have to write scripts and send them out.”

Keyes, an aerospace leader working at NASA's Langley Research Center, is building upon the achievements of Scallion and his colleagues. One assignment is to explore upcoming opportunities for human spaceflight, including what to do on the moon once humans return there. “It will be great to see someone land on the moon again, even if it cannot be me right away,” Keyes notes. She has also worked on the objectives that address the goal of preparing for long-term, sustained human exploration of Mars. Keyes and Scallion both agree that although the past is important, it is more useful to prepare for the future. Keyes is a good example of what young minds and ingenuity are bringing to NASA.

and financial costs in a world fraught with many problems. Americans tend to think of space as a “new frontier,” but whether the Space Age will actually usher in a new Age of Exploration remains to be seen.

Perhaps the question should be seen in its larger historical context, rather than in that of passing politics or cultural whims. If so, we should remember what the British writer H.G. Wells said many years ago, “Human history becomes more and more a race between education and catastrophe.” We are still in that race today. And space exploration may express one of humanity’s loftiest aspirations.



Steven J. Dick is the chief historian for NASA. He worked as an astronomer and historian of science at the U.S. Naval Observatory in Washington, D.C., for twenty-four years before coming to NASA headquarters in 2003. Among his books are Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant (1982), The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science (1996), Life on Other Worlds (1998), and The Living Universe: NASA and the Development of Astrobiology (2004).

Stephen J. Garber also works in the NASA History Division. He has written on a wide variety of aerospace topics, including President Kennedy’s Apollo decision, the Congressional cancellation of NASA’s Search for Extraterrestrial Intelligence Program, the design of the Space Shuttle, and the Soviet Buran Space Shuttle.

James I. Deutsch is the curator of the 2008 Folklife Festival program NASA: Fifty Years and Beyond. He previously curated the National World War II Reunion in 2004 and Festival programs on the Forest Service in 2005 and (as co-curator) the Mekong River in 2007. He is also an adjunct faculty member in George Washington University’s American Studies Department.

Hoping to send humans back to the moon by 2020, NASA is also designing concepts for a permanent base for scientific research at one of the lunar poles. Photo courtesy NASA Glenn Research Center

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