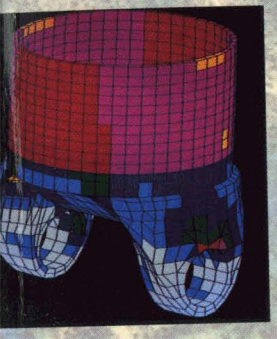
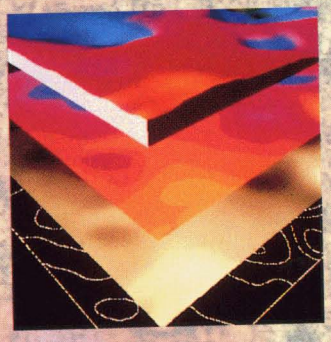
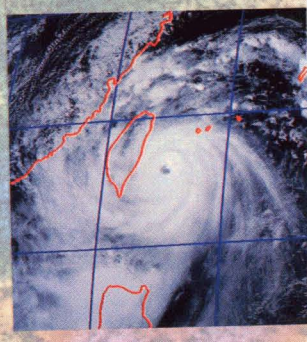
NASA

Spinoff

1991







NASA

Spinoff

1991

On the Cover:
The basic art is an image of Venus' surface acquired by NASA's Magellan spacecraft in 1990. The principal feature of the image is the meteor crater at lower right, surrounded by a collar of ejecta, material displaced and hurled great distances by the meteor's impact. The cover art symbolizes the technology transfer process: the photos superimposed on the Magellan image are spinoff products, representative of the tens of thousands of secondary applications that have been adapted from technology originally developed for NASA mainline programs, represented by the Magellan radar mapper. Additional Venus/ Magellan imagery leads each section of this volume.

National Aeronautics and Space Administration

Office of Commercial Programs

Technology Utilization Division

by James J. Haggerty

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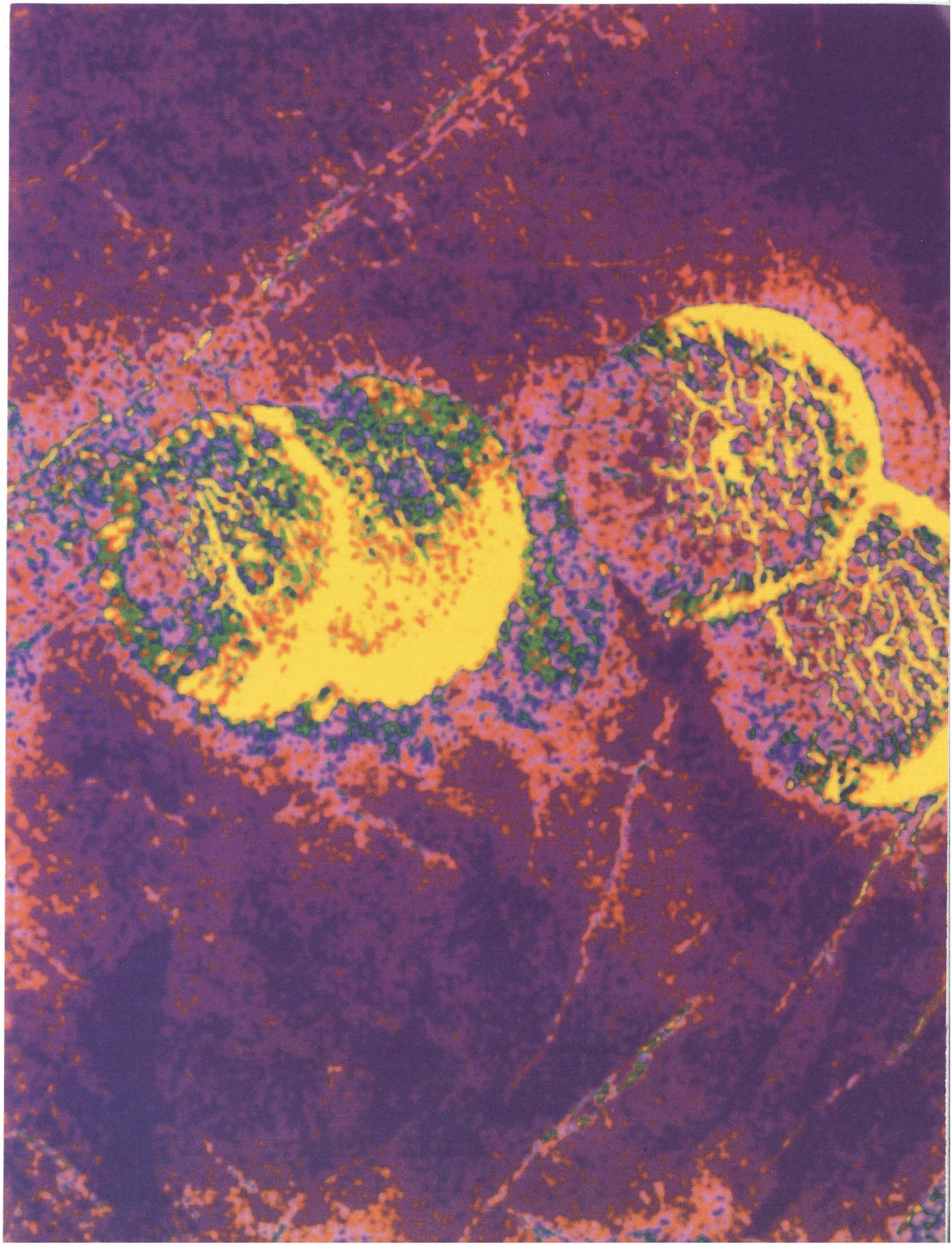
Contents



Foreword

The basic aim of the civil space program is the acquisition of scientific knowledge toward greater understanding of the universe and Earth's place in it. Successful accomplishment of that goal brings many corollary benefits. Probably the most important, from the pragmatic viewpoint, is the bank of technology developed to meet program requirements.

Although its total value can never be fully realized because of its far-reaching applications, this technology is, indeed, a significant national asset. It can be reapplied to the needs of the consumer marketplace, thus creating new products, new companies, and new jobs that provide a significant boost to the U.S. economy and to the nation's international competitiveness.

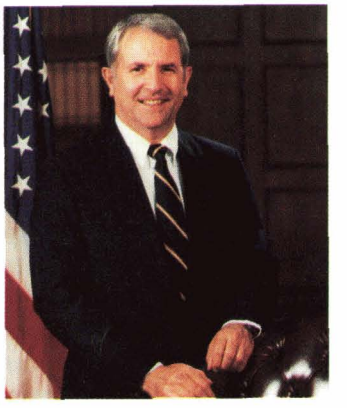
In 1992, NASA marks the 30th anniversary of the Technology Utilization Program, established under congressional mandate to promote the transfer of aerospace technology to other sectors of the economy. The program has been eminently successful; through NASA's efforts, buttressed by those of independent entrepreneurs, tens of thousands of "spinoff" products and processes have been derived from NASA-developed technology. Collectively, they represent an immense contribution to the nation's economy.

Impressive as they are, the spinoff benefits of past years pale in comparison with the benefits we can expect in coming years. Achievement of the challenging goals set forth by NASA and the Administration will demand a technological thrust of unprecedented order. The resulting technology advancement will solidify America's leadership in science and technology, significantly elevate the nation's competitive posture, and, inevitably, spawn an extraordinarily broad and diverse profusion of spinoff applications.

Consider, for example, Space Station *Freedom*, which provides a major opportunity to advance technology across a broad spectrum that embraces thermal control, power generation, life support and environmental control, guidance and navigation, structures and materials, robotics, and crew health care. In all these areas there is great potential for secondary Earth applications. To mention just a few, we anticipate advances in high reliability medical instrumentation and health care techniques; industrial robotics; environmental monitoring; and new, more efficient ways to extract and store energy from the Sun.

The Earth Observing System (EOS), centerpiece of NASA's Mission to Planet Earth, involves a comprehensive, long-term examination of Earth as a system leading to a capability for documenting and understanding global change. Aside from the direct benefit of addressing mankind's concerns about Earth's environment, EOS offers spinoff benefits from the broad array of sophisticated sensory devices the program demands. Additionally, the associated EOS data and information system will generate data processing and global dissemination technology with obvious Earth applicability.

The National Aero-Space Plane (NASP) program is an effort to develop the technology essential to easier, more flexible, more efficient access to space. The NASP program is already providing cutting-edge technology with broad potential for secondary application. Some examples: further advances in the competitively important technology of computational simulation; lightweight, high-temperature materials for autos, aircraft, and piping systems that need protection from heat and corrosion; and prosthetic devices for the handicapped that offer a doubling of useful life.



Finally, there is the Space Exploration Initiative (SEI), the national plan to extend human presence beyond Earth orbit. The technological demands of SEI are so extensive that they defy detailing. By the same token, the range of possible spinoff applications is so broad that it can be described only in general terms—for example, revolutionary advances in artificial intelligence, automation and robotics, materials, supercomputers, waste recycling, clean energy production, pollution reduction systems, and a wide variety of medical/health care devices and techniques. Additionally, SEI is expected to provide stimulus to the science and engineering elements of the national education system.

I have mentioned only a few out of scores of NASA programs that have potential for generating terrestrial applications. NASA is taking steps to assure that the potential is realized. We hope to expand the spinoff benefits by improving the whole technology transfer process and by making spinoff possibilities a consideration in designing new space systems. We seek to broaden spinoff benefits by developing mechanisms whereby aerospace technology is transferred earlier to the non-aerospace community for more timely, hence more competitive, development of spinoff products.

In the ongoing national debate about the direction and scope of the civil space program, it is important to remember that the funds expended represent an investment in tomorrow's national competitiveness, economy, and lifestyle. The past three decades have demonstrated that the payback is of impressive dimension. NASA technologists believe it will be significantly greater in the years to come.

Richard H. Truly
Administrator
National Aeronautics and Space Administration

Introduction

NASA contracted with a food manufacturer to develop a technique for preventing serious mishap in space by assuring that astronaut meals are free from bacteria and toxins; the resulting food safety system is now widely used by consumer food producers and food-regulating government agencies in the U.S. and abroad.

To avoid entanglement of free-floating cables in the Space Shuttle Orbiter, NASA developed a wireless voice communications system; the technology provided a development base for a commercial wireless signal transmission and data communications system with multiple advantages.

Originally developed to detect microscopic flaws, NASA ultrasound technology has found commercial application as the first clinically-tested ultrasound system that permits accurate measurement of human skin burn depth, an advancement with life-saving potential.

These are three of the 59 "spinoff" examples detailed in this volume. Spinoff, in this context, means products and processes developed as secondary applications of existing NASA technology. This secondary use of once-developed technology is important to the nation because it represents an extra dividend on the investment in aerospace research.

Because NASA mainline programs, by their challenging nature, are particularly demanding of technological advancement, the spinoffs they have generated are broad and diverse. There have been at least 30,000 of them, a number extrapolated from a survey of known and documented spinoffs. There have been a great many more, a number literally countless because it is impossible to track all the unknown cases, for example, a situation wherein a first generation spinoff provided a technology base for a company's development of whole families of second and third generation products whose technological lineage has been lost to passing time. The 30,000 estimate is an extremely conservative, tip-of-the-iceberg figure.

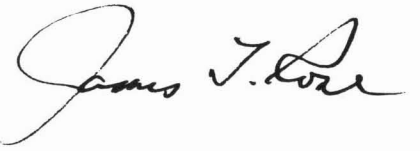
Over the 33 years of its existence, NASA has built a great storehouse of technology, a valuable national resource available for secondary application. Through its Technology Utilization Program, NASA seeks to promote wider use of this resource, in the interests of expanded industrial productivity, the lifestyle benefits of spinoff, and the boost to the economy generated by new products, processes, jobs and the attendant contribution to the Gross National Product.

This publication is an instrument of the Technology Utilization Program. It is designed to heighten awareness of the technology available for transfer and its potential for public benefit. Spinoff 1991 is organized in three main sections:

Section 1 summarizes NASA's mainline programs, whose objectives require development of new technology and therefore expand the bank of technology available for transfer in future years.

Section 2, the focal point of this volume, contains a representative sampling of spinoffs that resulted from secondary application of technology originally developed to meet mainline goals.

Section 3 describes the various mechanisms NASA employs to stimulate technology transfer and lists contact sources in an appendix for further information about the Technology Utilization Program.



James T. Rose
Assistant Administrator for Commercial Programs
National Aeronautics and Space Administration

Aerospace Aims

An Illustrated summary of NASA's major aeronautical and space programs, their goals and directions, their contributions to American scientific and technological growth, and their potential for practical benefit

Exploring the Universe

Magellan's close scrutiny of neighbor planet Venus highlights a résumé of NASA's broad space science and application program

On May 15, 1991, the Magellan radar-mapping spacecraft completed its first "day" of studying Earth's sister planet Venus —meaning one Venus day or 243 Earth days, the time it takes the planet's surface to pass beneath the gaze of Magellan's radar.

It was an extremely productive day's work, as Magellan mapped some 84 percent of the planet's surface with 10 times better detail than that of previous Venus images and 100 times the resolution of Magellan's predecessor, the Pioneer Venus spacecraft of 1978-79.

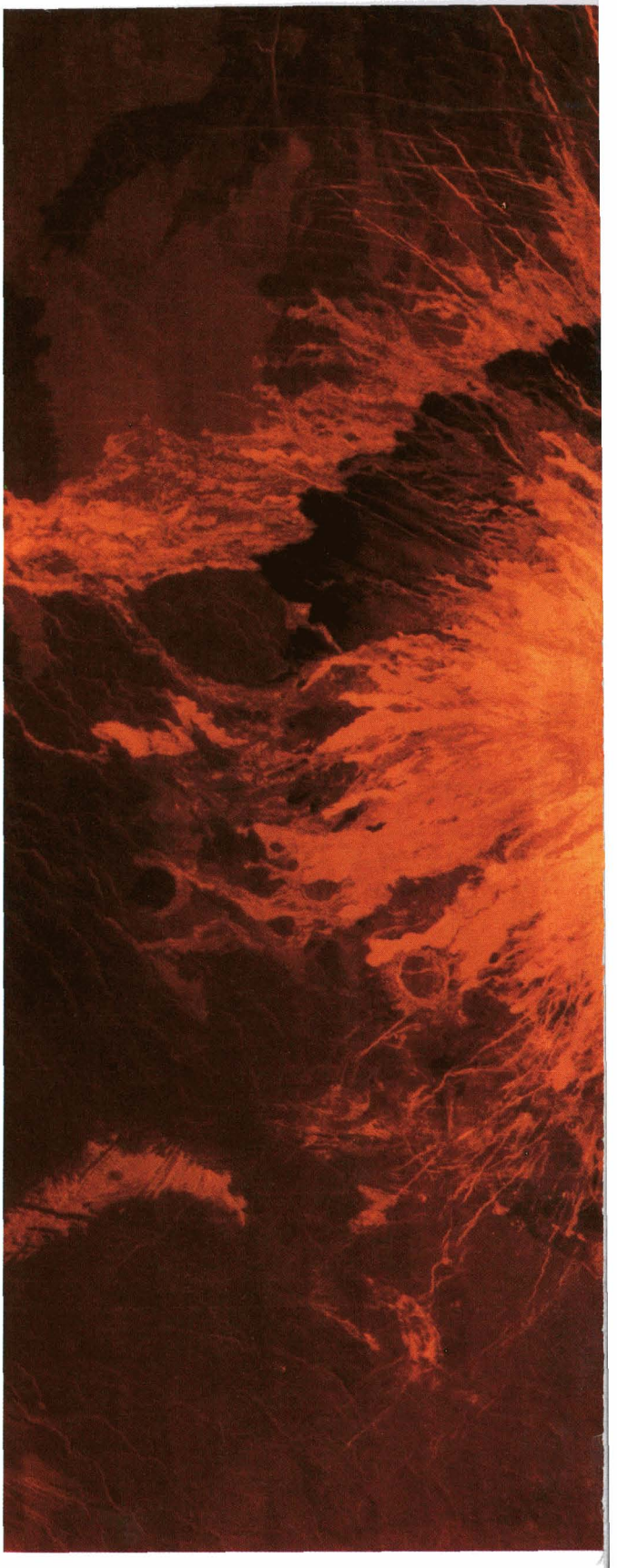
The topographic map Magellan produced on its first mapping cycle is of enormous importance to space scientists, who are looking for answers why two very similar planets approximately the same mean distance from the Sun —Earth and Venus — evolved in such a strikingly dissimilar fashion.

Their interest goes well beyond academic curiosity. Scientists feel that Magellan will contribute immensely valuable new volumes to the science of comparative planetology, or relating phenomena on one planet to conditions on another. Through this process, they hope to shed new light on the many factors that influence Earth's complex environment.

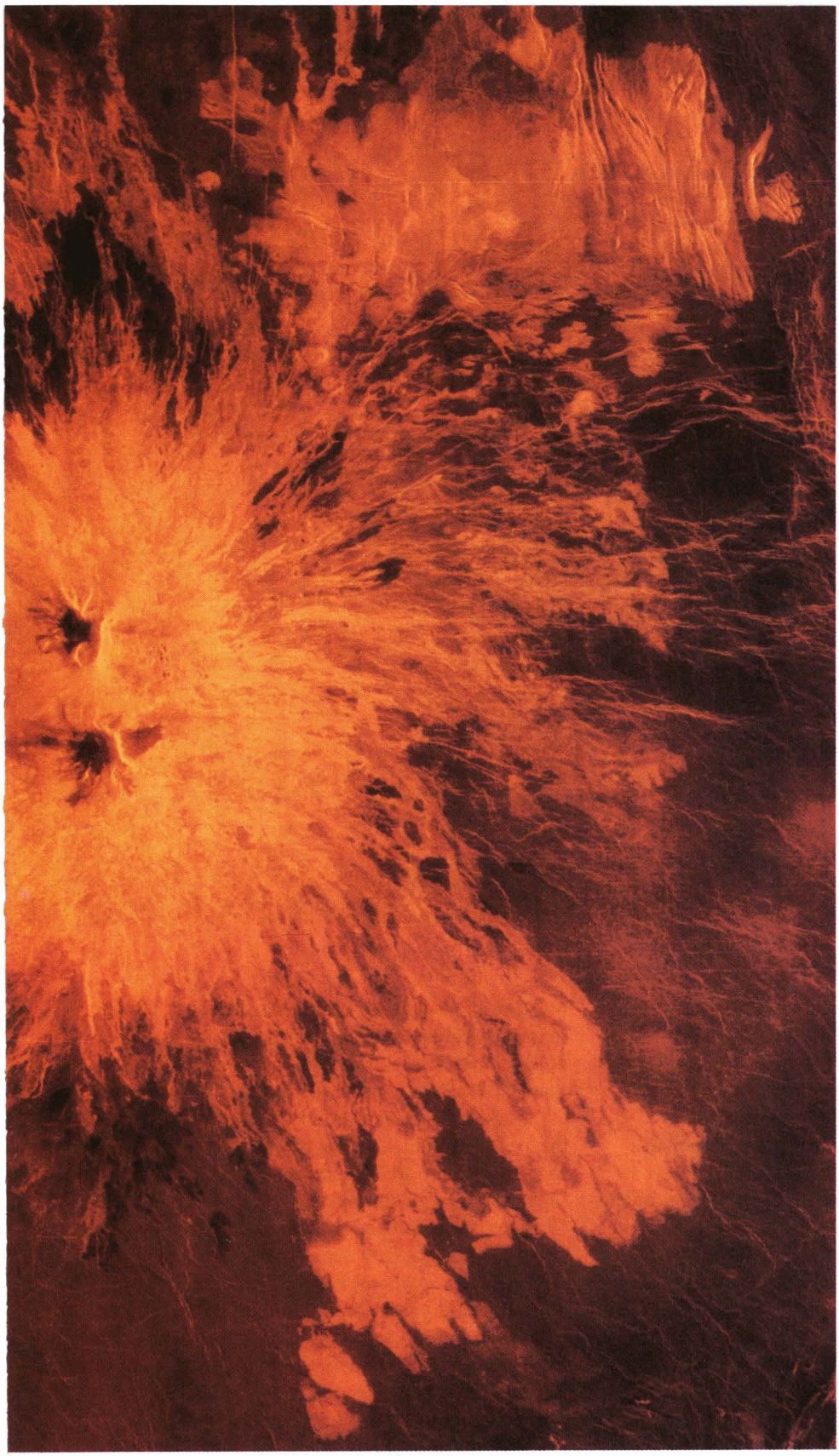
A matter of profound interest, for example, is the "greenhouse effect" on Venus, wherein the extremely dense atmosphere serves, like the glass roof of a greenhouse, to trap solar heat radiated from the surface. Unable to escape back into space, the heat has built up over millennia to create a surface temperature of about 900 degrees Fahrenheit.

There is concern that continuing buildup of carbon dioxide in Earth's atmosphere may create a greenhouse "roof" and cause hazardous global warming. Study of Venus' evolution may provide Earth benefit through greater understanding of the greenhouse phenomenon.

Previous U.S. and Soviet radar-mapping spacecraft produced a good deal of general information about Venus' surface, but their imagery lacked sufficient resolution —a measure of the smallest objects that can be seen on radar maps — to provide precise information about small-scale features. Magellan's advanced radar, however, has demonstrated ability to delineate sharp detail of features as small as a football field.



The Venus mapper's data offers scientists a new and vastly more detailed view of earlier-mapped features, including mountains, hills and valleys. Magellan also offers a look at some fascinating new features not earlier detected, such as the "pancake



This is an example of the Venus imagery supplied by radar mapping system aboard the Magellan spacecraft. The image shows the volcano Sapis Mons, located in Venus' equatorial belt, which measures 250 miles across and is almost one mile high.

domes" on the surface, described by one observer as "mile-high English muffins," and the enormous river-like lava flows, hundreds of miles long.

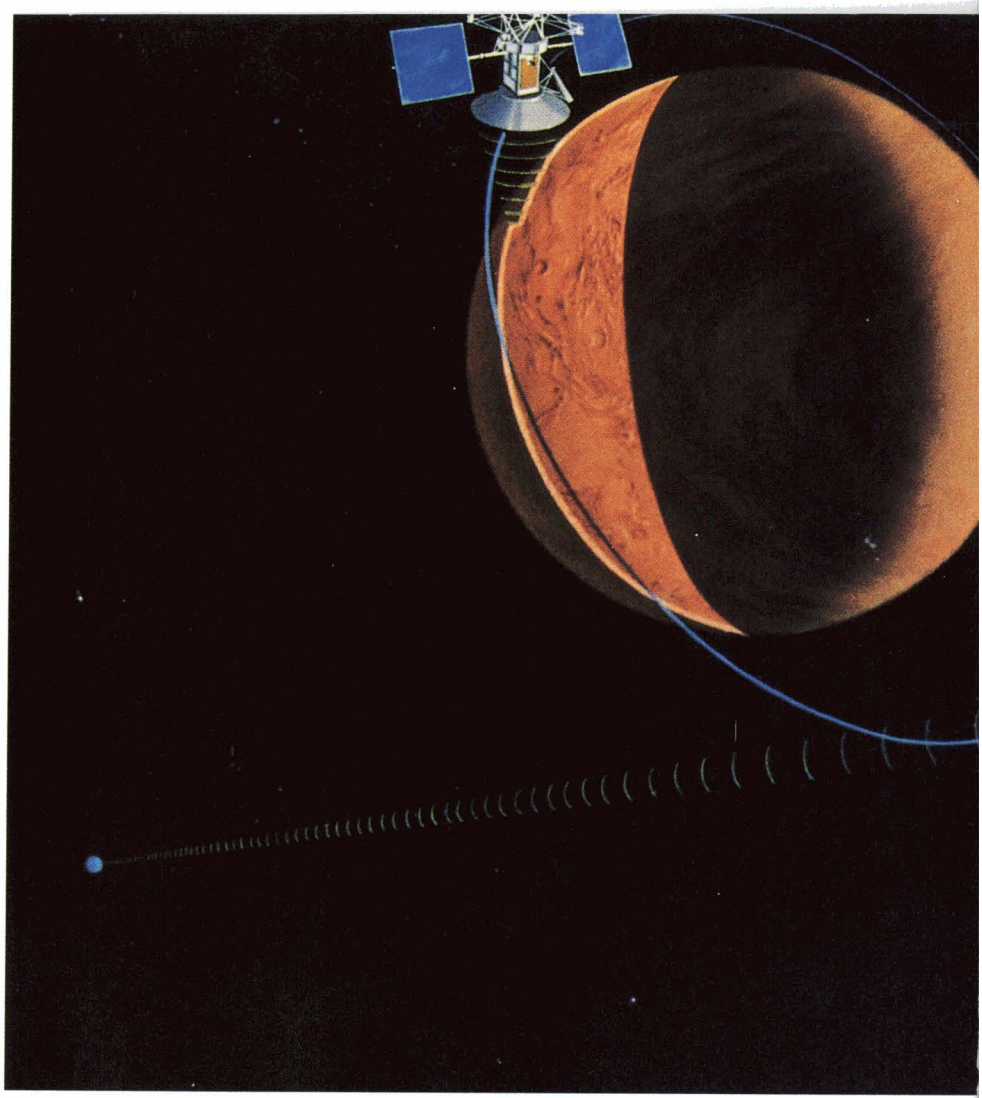
Magellan's imagery shows evidence of extensive and relatively recent volcanic activity. It also shows a large number of meteor impact craters, some up to 120 miles across. There were, however, no craters detected by Magellan with diameters of less than 2.5 miles, suggesting that smaller meteors could not survive the plunge through Venus' thick cover of sulphurous clouds and its carbon dioxide atmosphere. Magellan confirmed earlier knowledge that Venus is waterless today, but left open the question of whether water existed eons ago.

This wealth of information provides an exciting new model for scientists' study of the geologic history of Venus and the factors that shaped the face of the planet. It also provides an elevated plateau for continuing comparative planetology investigations of the Earth-Venus relationship.

The Magellan program is managed for NASA by Jet Propulsion Laboratory; Martin Marietta Astronautics is spacecraft prime contractor and Hughes Aircraft developed the radar-mapping system.

(Continued)

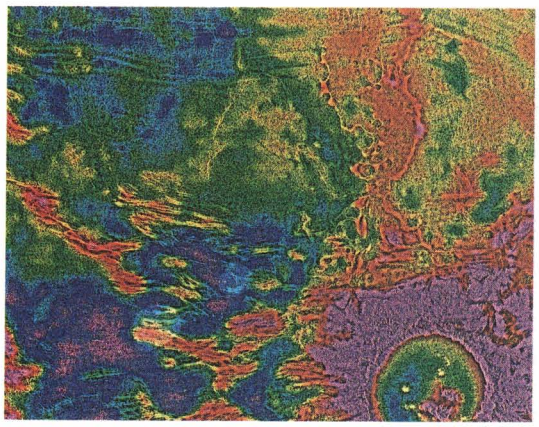
Exploring the Universe (Continued)



Because Venus is permanently cloud-shrouded, conventional cameras cannot penetrate the clouds. However, with the increased resolution of Magellan, detailed information about the solid "face" of the planet is now possible.

Since the early 1960s, scientists have used cloud-penetrating radar systems to provide data for images derived from computer processed radar reflections. Such images contributed valuable information about the planet, but the radars employed lacked the resolution needed to identify small-scale features.

This Magellan image, developed by a special process to enhance details, shows a large meteor impact crater at lower right. The streaks across the top of the image are believed to be streams of fine dust and sand particles formed by wind redistribution.

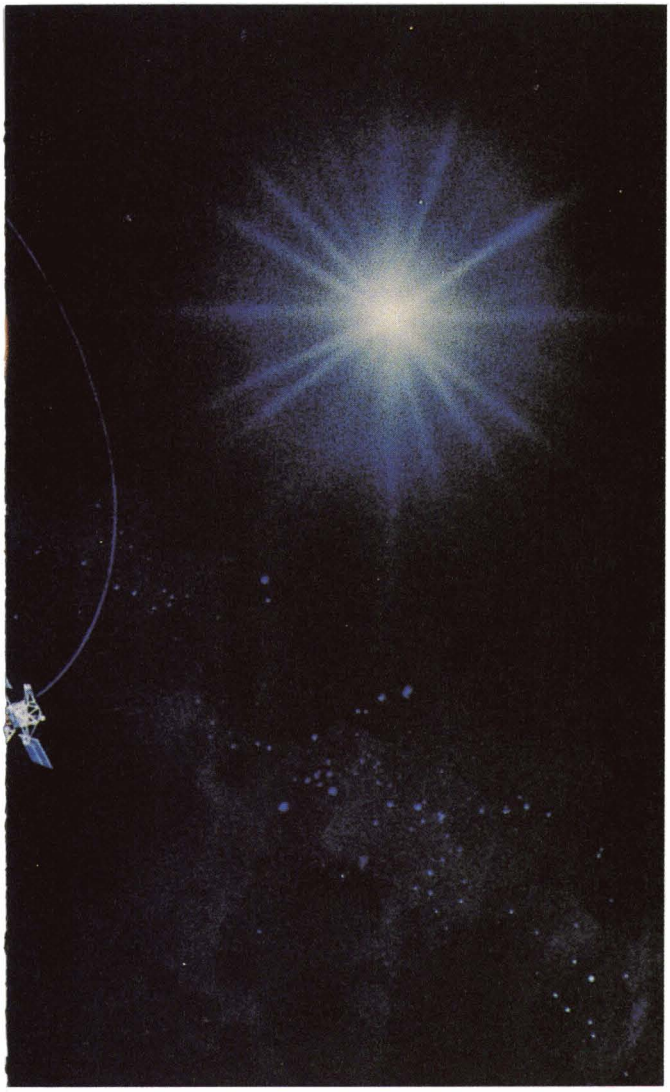


The Magellan radar system, known as a Synthetic Aperture Radar (SAR), provided the essential degree of resolution. The term "synthetic" refers to a technique for figuratively increasing the size of the antenna by an ingenious method of computer processing the SAR's signals; Magellan's 12-foot-diameter dish antenna becomes in effect an antenna several miles long , thus providing an extraordinary degree of resolution.

The radar performs three functions: collecting data for surface imaging; measuring surface height variations as small as 100 feet to construct a topographic profile of Venus; and measuring the natural thermal emissions from the planet to determine surface temperature variations. Additional information is provided by Earth-based tracking of Magellan's orbit around Venus, which detects slight changes in the planet's gravitational field and thereby offers clues to the makeup of the planet's interior.

Magellan operates in an elliptical orbit around the poles of Venus, taking three hours 15 minutes to complete an orbit. During each orbit, the SAR's highgain antenna illuminates a surface swath 10 to 17 miles wide and several thousand miles long, and acquires imaging data for a 37-minute mapping sequence; an altimeter antenna provides complementary data on the heights of mountains and hills and the depths of craters and gorges. Once each orbit, Magellan maneuvers to point its antennas Earthward and transmit the imaging/altimetry data.

The spacecraft started a second 243-day mapping cycle on May 16, 1991, immediately after completing the first cycle. The priority during the second cycle is to acquire the remaining 16 percent of the planet's surface in radar imagery, including the planet's south pole, which has never been imaged by spacecraft. Magellan completed the first cycle in "good health," according to project officials and technically could continue to function for several more cycles.

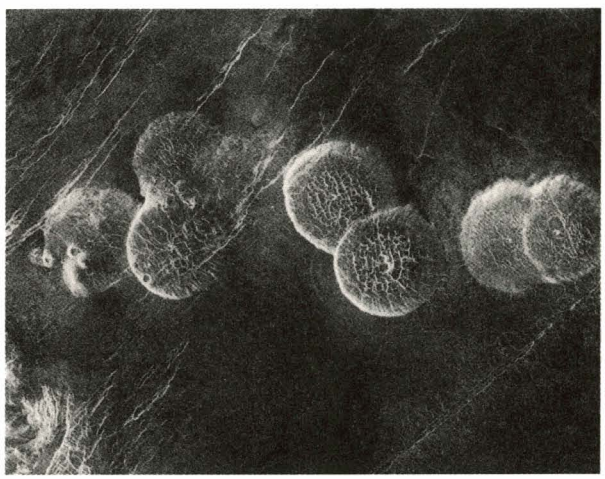


The artist's rendering shows Magellan in elliptical orbit around Venus and illustrates the mapping and data transmission phases of the mission. For 37 minutes on each orbit, the Synthetic Aperture Radar (SAR) maps a 10 by 17–mile-wide swath, then the spacecraft maneuvers to point its antennas to transmit its data back to Earth.

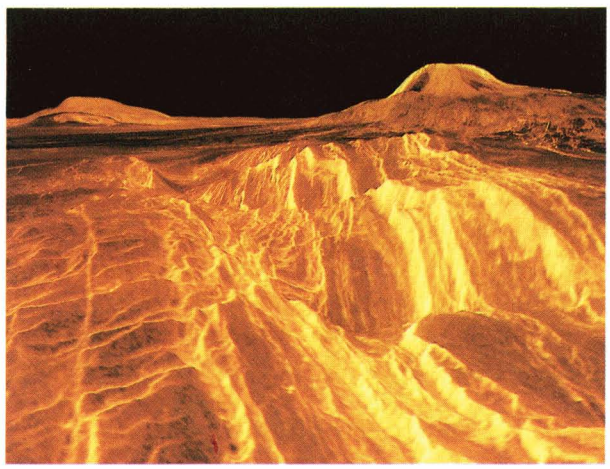
The Magellan project exemplifies one of six main science disciplines in NASA's broad space science and applications program. Magellan comes under the heading of solar system exploration, investigation of the planets, moons, comets and other bodies of the solar system.

The other major science divisions are:

- Astrophysics, the study of stars and galaxies toward an understanding of the origin and evolution of the universe;
- Space physics, which involves investigation of the origin, evolution and interactions of plasma, ionized gases originating in the solar system and beyond;
- Earth science and applications, which seeks understanding of the factors that influence Earth's environment and ways to use that knowledge to benefit humanity
- Life sciences, aimed at understanding the origin and distribution of life in the universe and at utilizing the space environment to improve knowledge of medicine and biology; and
- Microgravity science and applications, involving investigations directed toward greater understanding of the airless, weightless Earth-orbital environment and its effects on Earth-use materials.



Newly discovered Venus features are the mysterious "pancake domes," each about half a mile high and 15 miles across, believed to have been formed by volcanic eruptions.



This three- dimensional perspective of the surface of Venus was made by superimposing radar imaging data on altimetry data. The view shows the 9,800-foot-high volcano Gula Mons at top right in the image and the neighboring Sif Mons, a 6,300-foot volcano, at top left. In the foreground are lava flows that extend more than 70 miles down the flanks of the mountains.

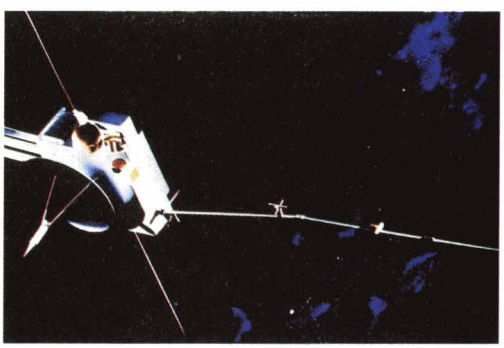
Solar System Exploration

The mission is expected to revolutionize man's knowledge of the Sun and the space around it

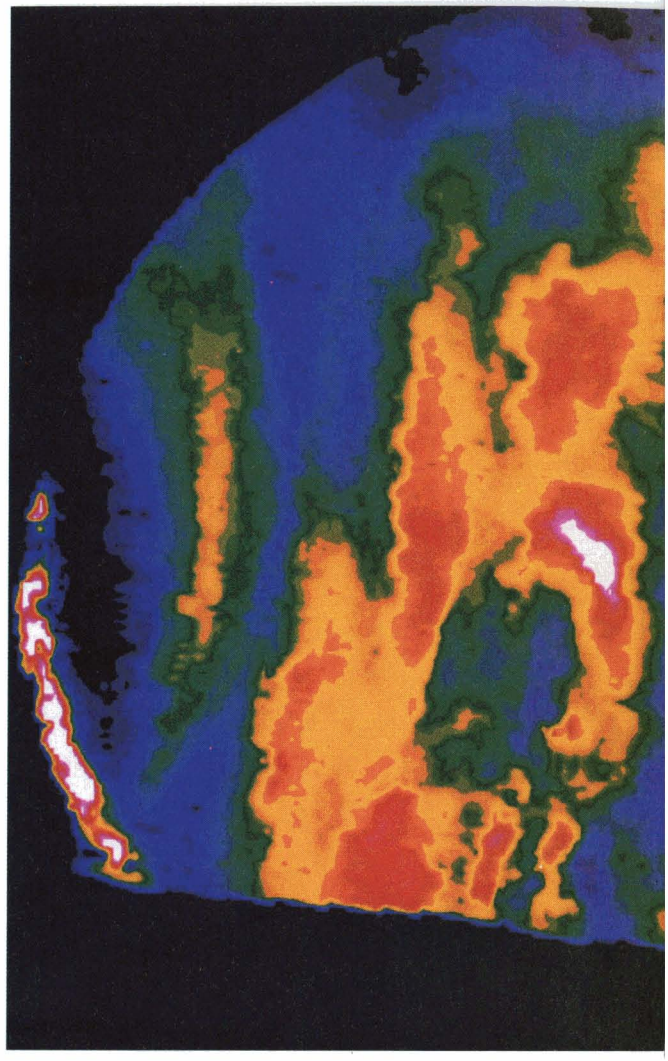
Launched October 6, 1990, the Ulysses spacecraft **(below)** is off on a "voyage of discovery," breaking new scientific ground with a study of the poles of the Sun, which cannot be observed from Earth. A joint project of NASA and the European Space Agency (ESA), the mission is expected to revolutionize man's knowledge of the Sun and the space around it. Ulysses carries nine instruments whose measurements will help scientists understand how the Sun creates and controls virtually all the major processes affecting the solar system.

At midyear 1991, Ulysses was en route to Jupiter, a way station on the journey to the Sun. The 809-pound spacecraft is due to reach Jupiter on February 8, 1992 and, during a two-week sweep past the planet, make measurements of the Jovian magnetosphere. Ulysses' closest approach will be about 280,000 miles from Jupiter's center.

After this encounter, Ulysses will take advantage of the gravity assist technique — in which planet's gravity is used as a "slingshot" to accelerate a spacecraft and alter its trajectory — to swing itself out of the plane of the ecliptic, an imaginary plane that approximates the plane in which all the planets orbit the Sun. Ulysses' altered course will take the spacecraft on a path toward the Sun's southern pole. In June 1994, Ulysses will begin its primary mission of exploring the polar regions of the Sun and the space above the poles; closest approach to the Sun will be about 130 million miles. Tracking and data collection is provided by the Deep Space Network, managed for NASA by Jet Propulsion Laboratory (JPL).



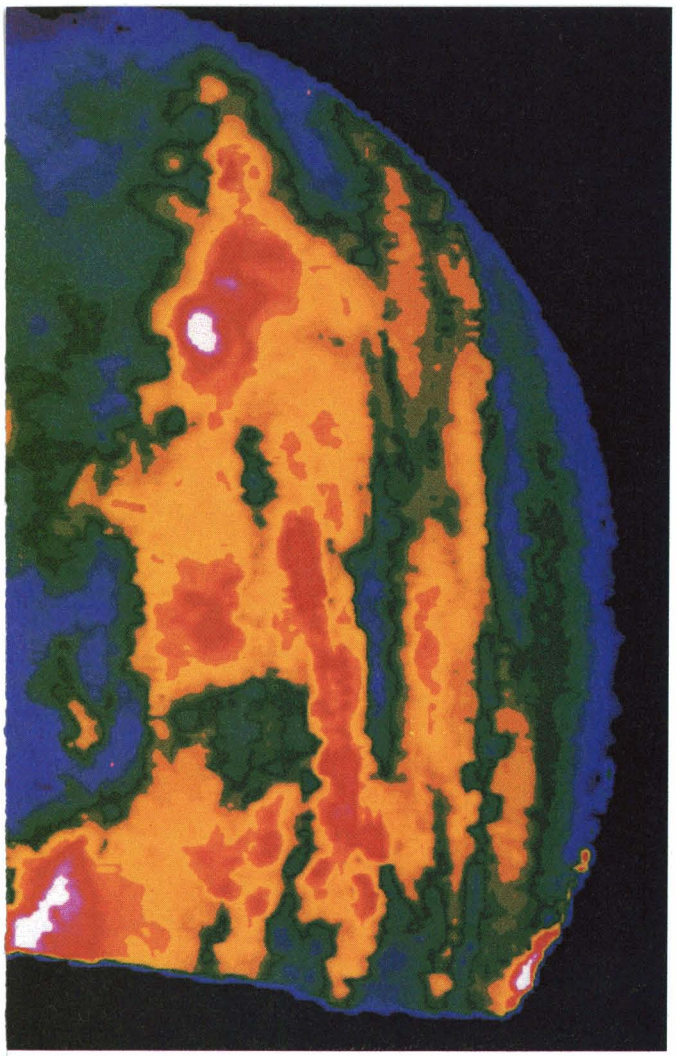
Also en route to Jupiter for an extensive study of the planet and its moons is the Galileo spacecraft, a cooperative U.S./German project managed for NASA by JPL. In December 1995, the Galileo main spacecraft will swing into orbit around Jupiter, imaging the planet and its moons with resolutions far better than any imagery yet acquired of Jupiter. The Galileo system also includes an instrumented probe that will separate from the main spacecraft in July 1995 during the initial approach to the planet, descend into the Jovian atmosphere and review data on its composition. JPL designed and built the main spacecraft, or orbiter; Ames Research Center has responsibility for the probe, which was developed by Hughes Aircraft.



Galileo is flying a complicated path to Jupiter to take advantage of multiple planetary gravity assists. Launched October 18, 1989, it flew past Venus early in 1990 for its first gravity assist, then made a 10-month trip back to Earth for another assist in December 1990. It is now on a two-year loop that will bring it back to Earth for a final gravity assist and a push into Jupiter trajectory in December 1992.

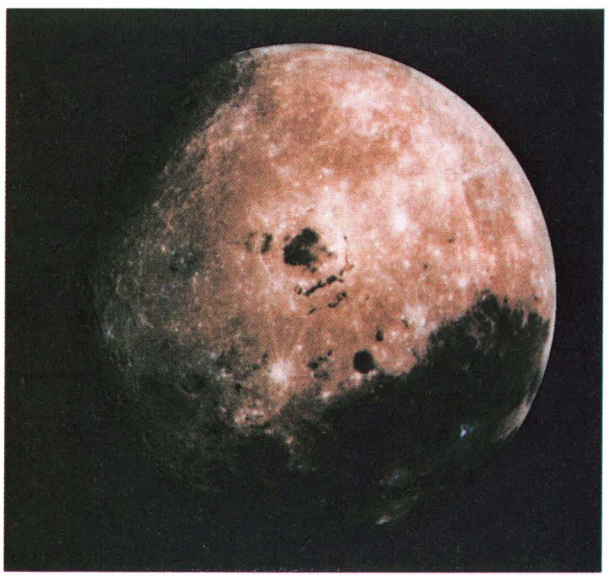
During that loop — in October 1991 — Galileo will fly within 1,000 miles of an 8-mile-diameter asteroid known as Gaspra, photographing and collecting a wide variety of scientific data on the asteroid. This will mark the first encounter of a spacecraft with an asteroid. Galileo will have an opportunity for a second encounter with a larger asteroid, Ida, in 1993 while en route to Jupiter.

Galileo's unusual flight path will stretch the journey to Jupiter to six years, but much of the en route time will be productive; the spacecraft is "working" during the gravity assist phases, for example, making scientific measurements of Earth and Venus. **Shown above** is a near-infrared cloud map of the "night side" of Venus, acquired by a Galileo instrument from a distance of 60,000 miles.

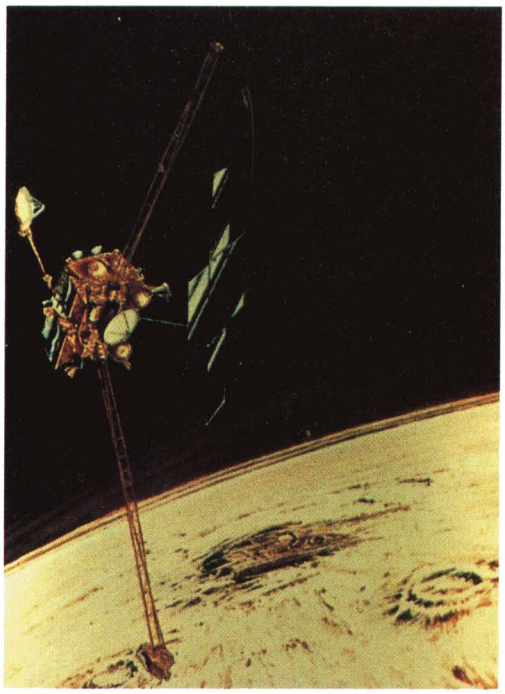


The image shows radiant heat (about 400 degrees Fahrenheit) from the lower atmosphere shining through the sulfuric acid clouds. The colors indicate relative cloud-cover transparency; white and red show thin clouds, black and blue thick clouds.

Pictured below is a view of Earth's Moon acquired by Galileo in December 1990. The dark patch near the center of the image is Mare Orientale and at upper right is the large, dark Oceanus Procellarum. These "seas" are actually basaltic lava flows formed more than three billion years ago.



Planned for launch in 1992 is the Mars Observer **(right)**, which will make a two-year global survey of the planet from orbit, providing data on Mars' surface and atmosphere with the highest resolutions yet obtained and collecting new information in two general areas: Mars geoscience and climatology. JPL manages the Mars Observer program; General Electric Astro Space is developing the spacecraft. The project includes participation by the United Kingdom, France, Germany and the Soviet Union.



NASA's plans include two additional authorized solar system explorations beginning in the late 1990s and extending into the 21st century. The Comet Rendezvous Asteroid Flyby (CRAF) mission will take close looks at a comet and an asteroid on a multiyear mission. CRAF will study, during a close flyby, the 53-mile-diameter asteroid Hamburga. Then the spacecraft will rendezvous with and "fly formation" with Comet Kopff, shadowing the comet for two and a half years, making high resolution images of the comet's nucleus and studying its chemical and mineral composition. CRAF will also collect comet dust and samples of the comet's nucleus for on-site analysis.

A companion Cassini spacecraft is being developed to fly past an asteroid in the late years of the century, make a flyby of Jupiter, then proceed to Saturn and go into orbit around the ringed planet for a comprehensive, four-year study of Saturn, its rings, its moons and its magnetosphere.

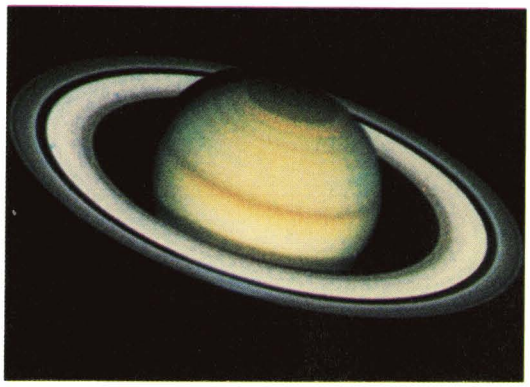
JPL is project manager for both CRAF and Cassini. ESA and Germany are participants in both missions.

NASA's plans include two additional authorized solar system explorations

Great Observatories

Below and at right are two dramatic images of Saturn acquired by the Hubble Space Telescope (HST) in Fall 1990. The full-planet view was taken by HST's Wide Field/Planetary Camera from a distance of 860 million miles, but the imagery's high resolution shows Saturn as it would appear to the naked eye if the planet were only twice as far away from Earth as the Moon.

The HST image reveals to analysts unprecedented detail of atmospheric features at the northern polar hood, a region not extensively imaged by the Voyager space probes. The image also shows the classic features of Saturn's ring system with extraordinary clarity.



The closer view of Saturn, also taken by the Wide Field/ Planetary Camera, was part of a special study undertaken in November 1990 after ground-based astronomers discovered a "Great White Spot" measuring more than 10,000 miles across near Saturn's equator. Within a few weeks, the spot (just above the ring system had grown to more than 50,000 miles and spread from Saturn's equator to higher latitudes. HST acquired several images per orbit for two orbits a day on three successive days, providing a record of the motion of the storm across the face of Saturn.

The telescope will literally look back in time some 14 billion years to the early days of the universe

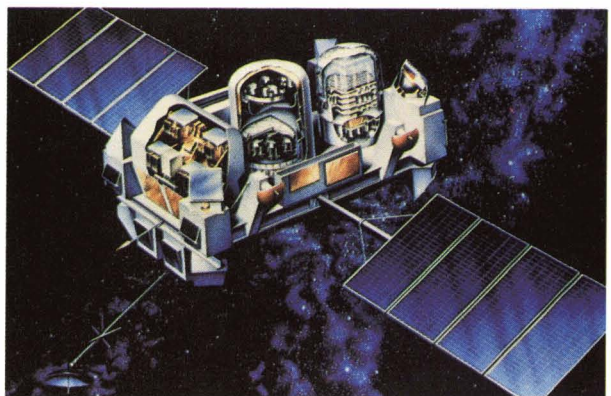
Another image **(top)** shows the HST's capability for acquiring clear imagery from very distant objects. This is a raw image, not computer-reconstructed, of the remnants of the exploded star Supernova 1987A some 160,000 light years from Earth. This image provides, with unprecedented sharpness and clarity, an intriguing view of the supernova and its surrounding shell of stellar material.

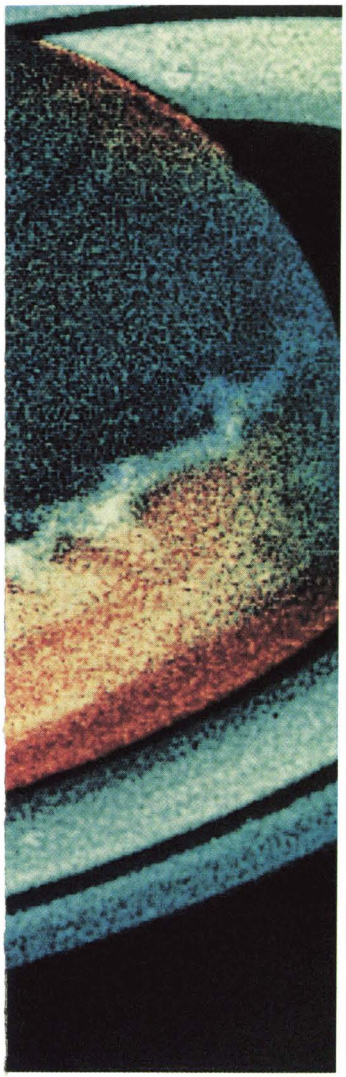
The visible light image shows an elliptical, luminescent ring of gas about 1.3 light years across surrounding the still glowing center of the 1987 explosion. The imagery is expected to provide important insight into the evolution of massive stars and their deaths as supernova explosions.

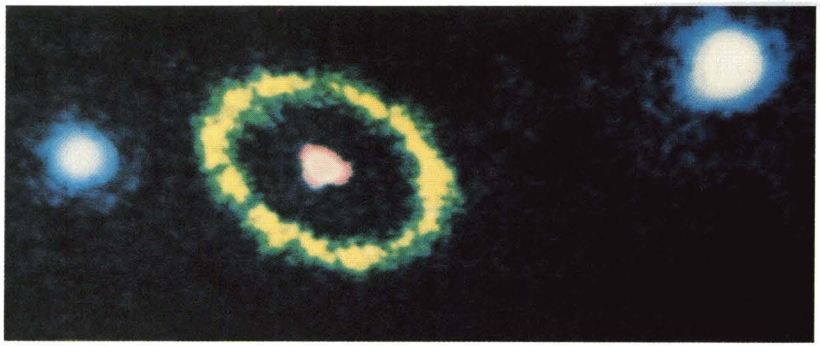
In addition, combining data from the International Ultraviolet Explorer (IUE) with HST

images and spectra has permitted astronomers to measure the distance to the Large Magellanic Cloud with unprecedented accuracy. Measuring the distance to this nearby object is the first step in determining the distance scale of the universe, one of HST's core programs. Originally, astronomers thought that work in this area would have to be deferred until after the HST servicing mission in 1993; now we know that some work can be done with HST in its current configuration.

These images constitute a very small fraction of the growing collection of incredible HST images and spectra accumulated to date. These images are representative of what HST can accomplish today, even with the effects of the mirror anomaly discovered in June 1990. Innovative techniques, including image reconstruction programs and enhanced control software, have helped to alleviate







some of the effects of the optical system problem and the solar-array induced "jitter." A more complete solution to these problems is planned for the servicing mission scheduled for late 1993.

The HST spacecraft was developed by Lockheed Missiles & Space Company and the Optical Telescope Assembly was designed and built by Perkin-Elmer Corporation (now Hughes Danbury Optical Systems, Inc.). Marshall Space Flight Center was manager for the development effort and orbital verification; after verification, Goddard Space Flight Center took over responsibility for controlling the telescope and processing its data. The center for collection and distribution of HST data is the Space Telescope Science Institute in Baltimore, Maryland, operated for NASA by the 17-member Association of Universities for Research in Astronomy, Inc. The HST's power-generating solar arrays and one of the telescope's five science instruments were furnished by the European Space Agency (ESA).

HST is the first in orbit of four planned "Great Observatories," large astronomical satellites each operating in a different portion of the electromagnetic spectrum, that collectively will examine the full range of phenomena in the universe. Together they will cover the visible light, ultraviolet, infrared, x-ray and gamma ray bands of the spectrum, a capability of enormous importance to astronomical science, because each band of the spectrum offers a different set of clues to the origin and evolution of the universe.

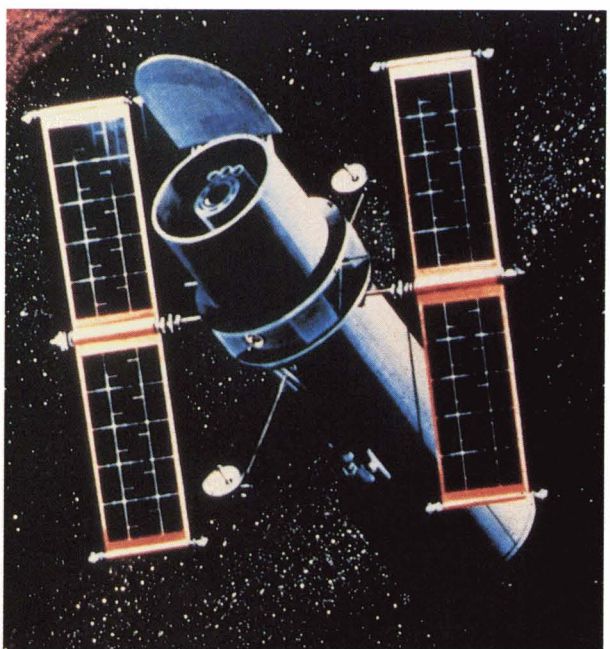
The second of the Great Observatories, the Gamma Ray Observatory (GRO) was launched aboard the Space Shuttle Atlantis on April 5, 1991, and deployed two days later. GRO **(bottom left)** is investigating gamma radiation, the most energetic form of radiation known, and its exotic and violent sources–pulsars, quasars and possibly black holes. After completing its on-orbit checkout activities, GRO commenced its 15-month all-sky survey on May 16, the first such survey ever undertaken. GRO is also designed to take advantage of unusual occurrences, interrupting its scheduled operations to focus its four science instruments on "targets of opportunity." GRO has already encountered two such targets: our Sun during a period of unusual flare activity, and a recently discovered supernova explosion (Supernova 1991T). After completion of its all-sky survey, GRO will begin a series of scheduled observations of specific celestial targets for individual examinations lasting up to two weeks each.

Managed by Goddard Space Flight Center, GRO is a cooperative development of the U.S., ESA, Germany, the Netherlands and the United Kingdom. TRW Space and Technology Group is NASA's prime contractor.

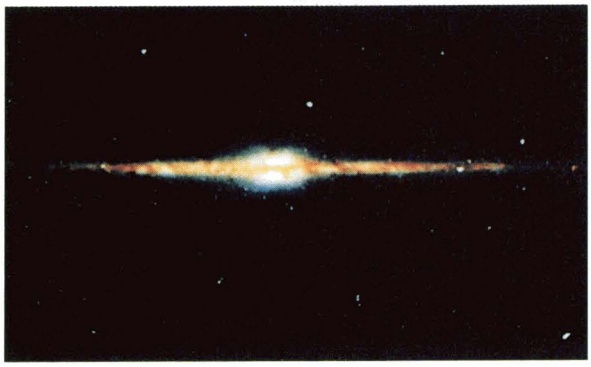
Planned for service beginning in the late years of this decade is the third Great Observatory, the Advanced X-ray Astrophysics Facility (AXAF), which will carry instruments 100 times more sensitive than the best prior x-ray **(below)** observatories. AXAF is being developed by TRW Space and Technology Group under the management of Marshall Space Flight Center. Foreign participation includes Germany, the Netherlands and the United Kingdom.

The contemplated fourth Great Observatory is the Space Infrared Telescope Facility, managed by The Jet Propulsion Laboratory, which is intended to conduct advanced investigations of prime interest targets identified by earlier infrared observatories.

The Hubble Observatory was the first in orbit of four planned "Great Observatories"



Astronomy and Astrophysics



To bridge gaps and complement the measurements of the Great Observatories *(see previous page)*, NASA is employing — and developing for future employment —a number of other astronomy/ astrophysics systems, including Shuttle-based instruments, orbital satellites, and instruments for suborbital observations from sounding rockets, aircraft and balloons.

Three important systems made their orbital debuts in 1989-90:

• Launched on November 18, 1989, the Cosmic Background Explorer (COBE) is studying the origin and dynamics of the universe and seeking evidence to support the Big Bang theory that the universe began with a cataclysmic explosion.

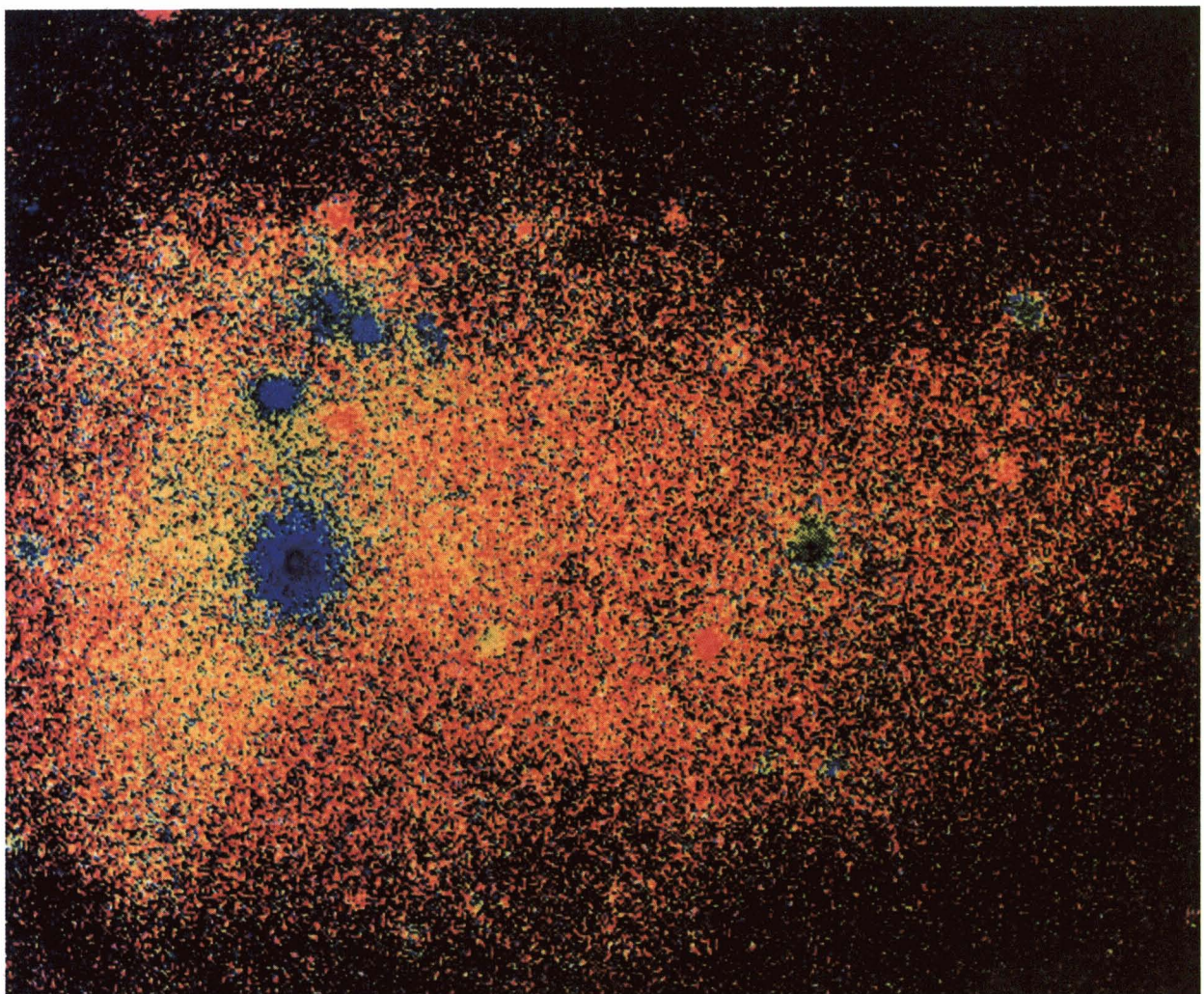
• Roentgen Satellite (ROSAT), launched June 1, 1990, is conducting a sweeping survey of x-ray sources and making dedicated observations of certain specific sources.

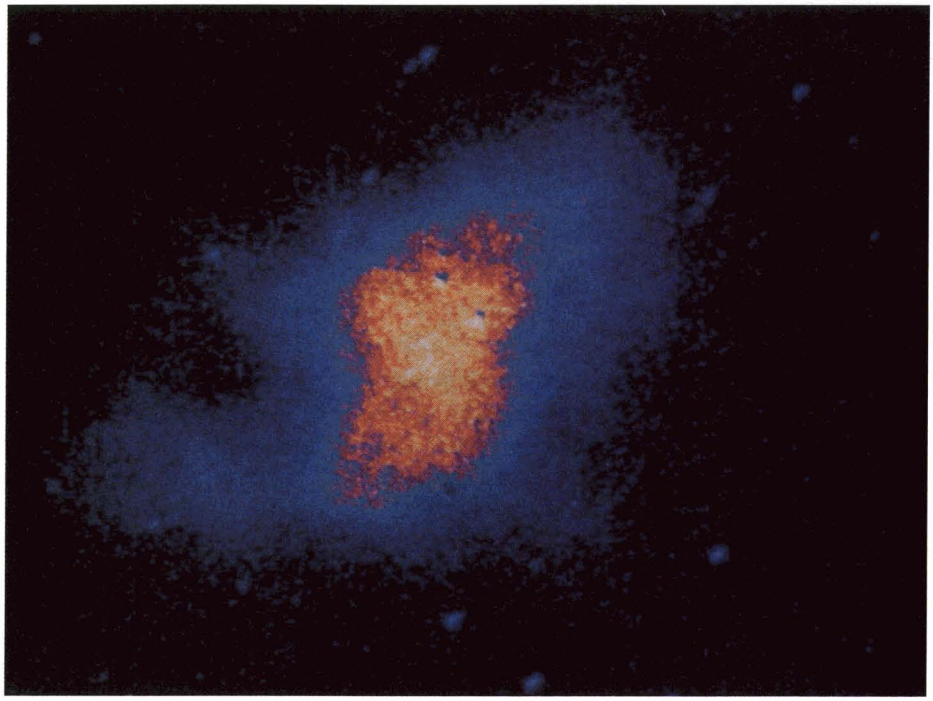
• The Astro Observatory, a Shuttle-based astronomical payload designed to complement findings of the Hubble Space Telescope, is studying quasars, galaxies and active galactic nuclei in the ultraviolet range. Astro-l made an initial 10-day flight aboard the Shuttle Orbiter *Columbia* December 2-11, 1990; an Astro-2 mission has been approved for an undetermined date.

At **upper left** is a sample image taken by COBE, a view of the plane of the Milky Way galaxy. The image shows the thin disc of the outer galaxy and the "central bulge" population of stars closer to the Galactic Center than our Sun (which lies in the disc at a distance of 28,000 light years from the center).

Operating in a polar orbit 560 miles high, COBE

The Cosmic Background Explorer is studying the origin and dynamics of the universe





is mapping the diffuse infrared radiation — called the cosmic background — that bombards Earth from every direction, determining the detailed spectrum of the background radiation, and searching for the earliest-formed galaxies. COBE data has enabled astronomers to create the first map of the distribution of nitrogen throughout the Milky Way galaxy. COBE's all-sky nitrogen survey, along with additional maps of carbon and dust distributions, provides information that may help scientists understand better the heating and cooling processes that take place in the universe. It is expected that COBE data will help clarify such matters as the nature of the primeval explosion believed to have created the universe, and the processes leading to the formation of galaxies. Goddard Space Flight Center is COBE project manager.

The ROSAT sample image **(at left)** is a view of the Large Magellanic Cloud, the Milky Way's nearest neighboring galaxy, approximately 170,000 light years from Earth. The false color image shows the temperature range of the gases emitted by x-ray sources. Red indicates temperatures of about half a million degrees Kelvin; the orange, yellow, green, and blue colors indicate progressively greater temperatures up to 10 million degrees Kelvin.

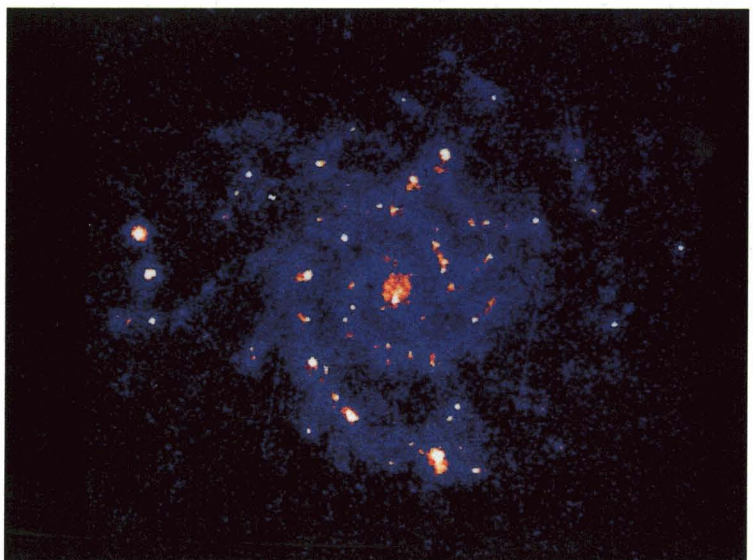
ROSAT is a cooperative U.S./Germany/United Kingdom project in which NASA provided the high resolution x-ray imaging system, Germany the spacecraft and main telescope, and the United Kingdom a wide field camera.

Two samples of the images acquired on the Shuttleborne Astro-1 mission are pictured; both were taken by Astro's Ultraviolet Imaging Telescope (UIT). The image at top, made in ultraviolet light not visible to Earth telescopes, shows the Crab Nebula, the remains of a supernova (exploded star) whose detonation was observed by medieval astronomers in 1054 A.D. The eerie blue glow is produced by energetic electrons rushing out from the nebula at close to the speed of light.

In the **photo below** is an Astro image of the spiral galaxy M74, which is some 55 million light years from Earth. The image shows "stellar nurseries," regions of intense star formation; the false color coding represents the varying intensities of ultraviolet light emissions. Studies of young star populations are intended to foster greater understanding of how stars are formed.

In addition to the UIT, the complete Astro system includes two other ultraviolet instruments and an x-ray telescope. Goddard Space Flight Center designed and built the UIT and the x-ray telescope; the other ultraviolet instruments were developed by the Johns Hopkins University Center for Astrophysical Sciences and the University of Wisconsin. Marshall Space Flight Center is the Astro Observatory program manager.

Studies of young stars improve understanding of how stars are formed



Space Physics

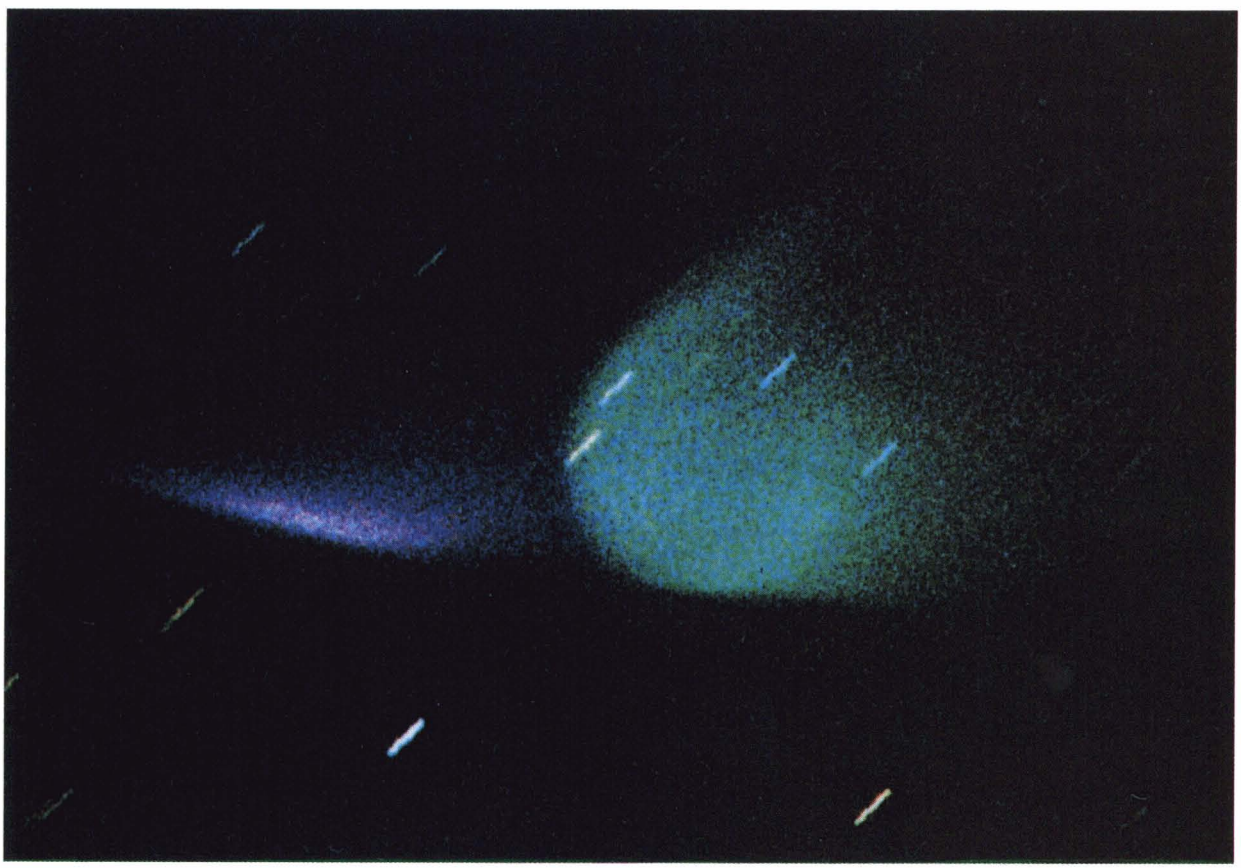
A new satellite studies ionization of gases

NASA's space physics program seeks expanded knowledge of magnetic and electric fields, radiation and plasmas (streams of electrified particles), and other phenomena of the Earth/Sun relationship. In 1990-91, a new satellite program called CRRES (Combined Release and Radiation Effects Satellite) provided significant advances in this area.

A joint NASA/Air Force mission, the CRRES project has dual objectives: to increase scientific knowledge of Earth's ionosphere and magnetosphere, and to gain practical benefit through monitoring the effects of space radiation on electronic equipment (the sophisticated electronics of modern spacecraft are subject to radiation damage).

A special feature of the CRRES mission is a series of chemical release experiments designed to aid scientists studying the processes by which fast-moving neutral gases become ionized, or electrically charged. Canisters ejected from the CRRES spacecraft release chemical vapors that briefly "paint" the invisible magnetic field lines with luminous particles, creating, in effect, an artificial aurora. The chemical clouds created are observed by instruments aboard CRRES, aboard aircraft and at ground installations.

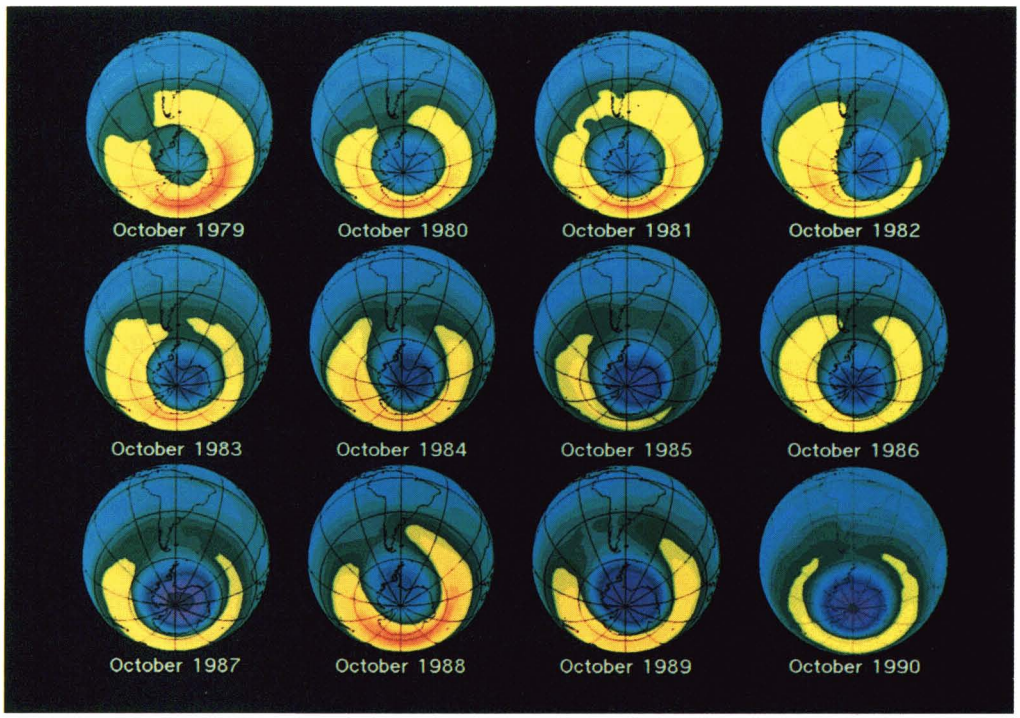
An example of the results is shown in the **photo below**. This is not a spacecraft image but a time-exposure photograph taken on January 12, 1991 by Naval Research Laboratory scientists at White Sands, New Mexico. The green sphere is a cloud of electrically-neutral barium, shown 90 seconds after its release from the spacecraft, during which time it has grown at the rate of about half a mile per second. (The CRRES spacecraft is in the center of the cloud, but not visible.) The purple streak to the right of the cloud was formed by ionized barium, created as the cloud interacted with Earth's magnetic field. The barium cloud was "grown" by release of approximately three pounds of barium at an altitude of 3,600 miles.



In addition to the chemical payload, CRRES carries four instrument payloads for studies of ionospheric structure and chemistry, for an investigation of how radiation affects electronic devices, and for experiments in high-efficiency solar cells. CRRES is managed for NASA by Marshall Space Flight Center and for the USAF by the Air Force Space Test and Transportation Program. The satellite was built by the Space Systems Division of Ball Corporation.

Ozone Monitoring

Ozone, a molecule made up of three atoms of oxygen, comprises a thin but important layer of the upper atmosphere — important because the layer absorbs ultraviolet radiation from the Sun and protects Earth from its potentially harmful effects. In the presence of sunlight, atoms of chlorine and other chemicals can strip an oxygen atom from an ozone molecule and nullify ozone's radiation-blocking ability. Because of the catalytic nature of such reactions, one chlorine atom can destroy thousands of ozone molecules.



The possibility of serious ozone depletion, with adverse effects on human health, Earth's climate and agriculture, is a matter of world concern and scientists of many nations are keeping a watchful eye on the ozone layer. An important but little known aid to the world ozone watch is a NASA-developed ozone monitoring instrument called TOMS (Total Ozone Mapping Spectrometer). Since it was launched aboard NASA's Nimbus-7 polar-orbiting satellite in 1978, TOMS has provided reliable, high resolution mapping of global total ozone on a daily basis.

An example of TOMS' utility is its discovery of the now-well-known "ozone hole" over Antarctica, a large area of intense ozone depletion that typically occurs in August-October and breaks up in mid-November. The results are shown in the accompanying illustration, which shows the annual October average ozone levels in Dobson units (named for a pioneer in ozone studies). Red and yellow indicate high levels of ozone, blue and green medium levels and purple an extremely low level. The development of the Antarctic hole is evident with the appearance of the purple color in 1983 and subsequent expansion of the purple area. Scientists at Goddard Space Flight Center reported that the 1990 hole matched the previous record (1987) Antarctic ozone depletion in depth, duration and area, and that during the formation of the hole in August 1990 total ozone values were the lowest ever recorded.

TOMS has measured and mapped the distribution of ozone over the whole globe and also indicated a general decrease in global ozone levels. Researchers are now trying to determine how much of the change is due to man-made causes and how much is attributable to natural atmospheric processes. To find answers, they need a data record spanning a long period. Therefore NASA plans to extend ozone observations by TOMS and other systems through the l990s.

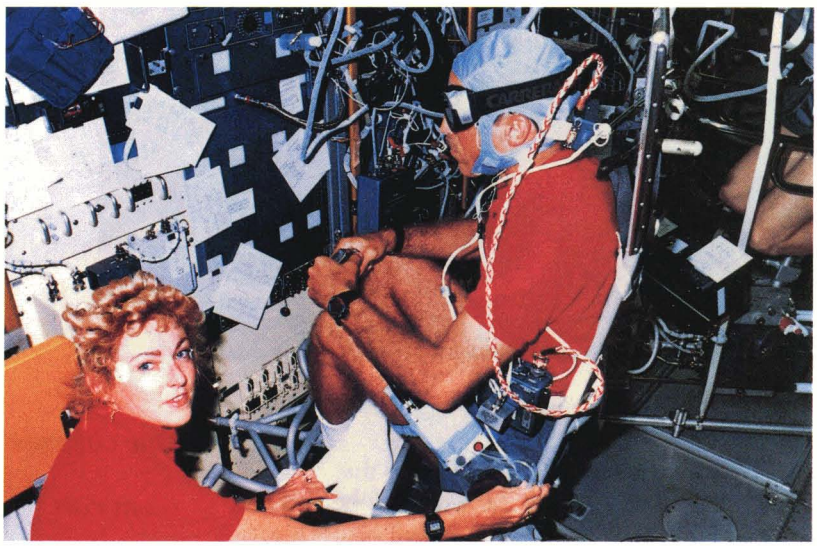
Late in 1991, NASA will launch the Upper Atmosphere Research Satellite, which will investigate the chemistry, dynamics and energy of the upper atmosphere with particular regard to ozone depletion. A Shuttle-based ATLAS-1 mission scheduled for April 1992 will complement TOMS global measurements by studying the distribution of ozone at various altitudes. In addition, NASA plans to launch TOMS instruments aboard a Soviet Meteor satellite in 1991, a new NASA TOMS/Earth Probe satellite in 1993, and the Japanese Advanced Earth Observations satellite in 1995.

Instruments to better understand the dynamics of the upper atmosphere, and of ozone in particular, will also be part of NASA's Earth Observing System (EOS) spacecraft series later in the decade.

One chlorine atom can destroy thousands of ozone molecules

Life Sciences

As NASA prepares to extend human presence beyond Earth orbit in the 21st century, there is increased need for expanded knowledge about the role of gravity — or the lack of it — on living systems in space. NASA is therefore expanding its life sciences research program, which combines Earth-based research in NASA and university laboratories with orbital research involving study of the effects of microgravity on the basic processes of human, animal and plant life.

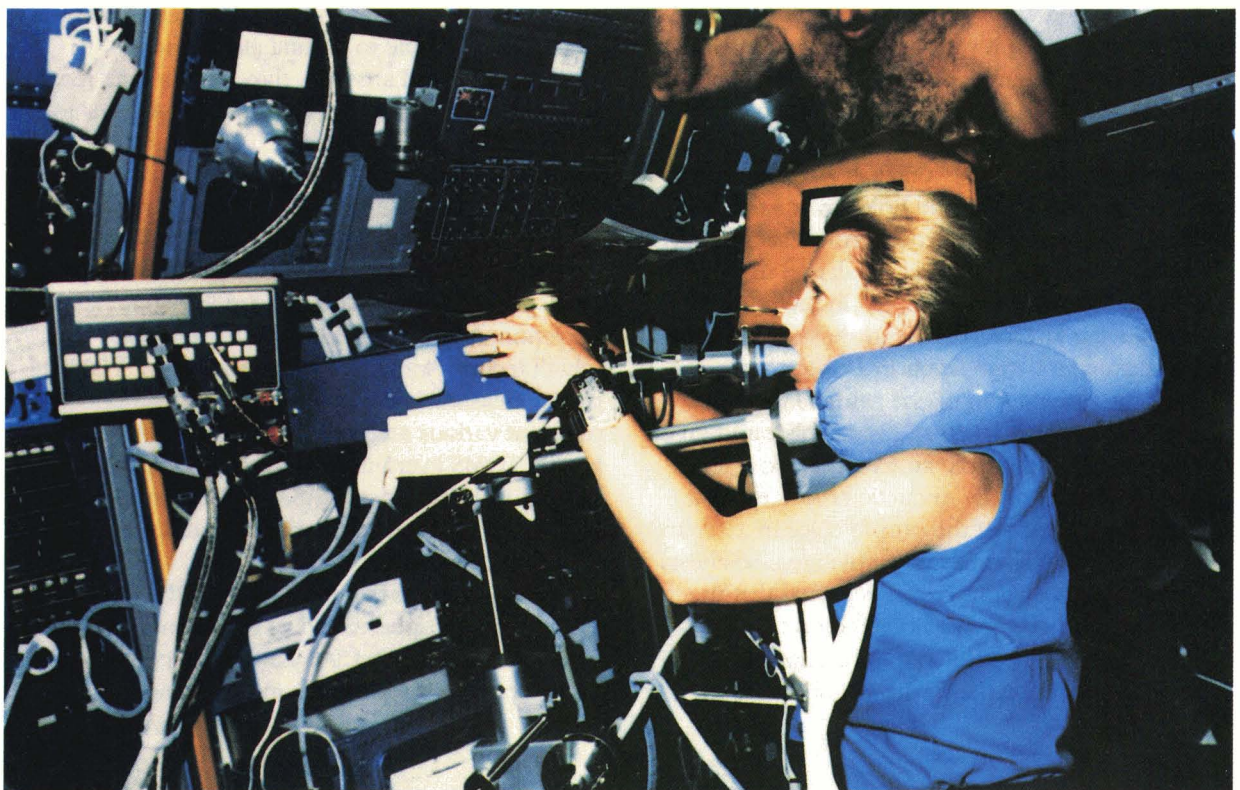


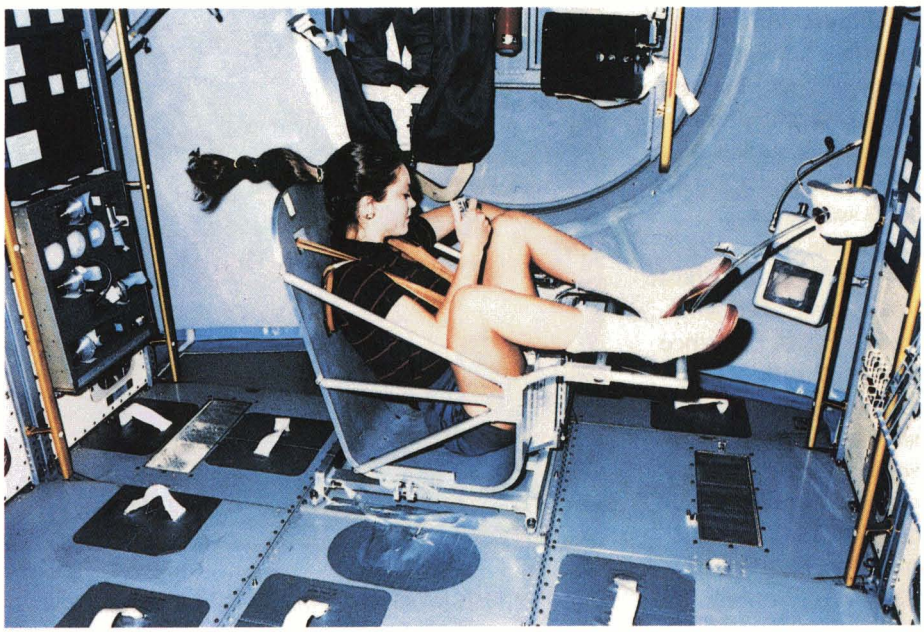
The centerpiece of the program is a series of Spacelab Life Sciences (SLS) missions to be flown aboard the Space Shuttle. Spacelab, developed by the European Space Agency with U.S. coordination by Marshall Space Flight Center, is a unique orbital laboratory carried in the payload bay of the Shuttle Orbiter. The flexible Spacelab can be configured as a manned "long" (two-segment) or a "short" (one-segment) pressurized module, used in combination with one to three non-pressurized pallets in the open bay, or as an unmanned system with up to five pallets.

The SLS program began on a high note with a successful initial mission in which the seven-member crew exceeded the planned agenda of experiments by some 40 percent. SLS-1 was a 10-day mission flown aboard the Orbiter *Columbia* June 5-14, 1991. For this mission, the Spacelab was configured as a two-segment long pressurized module, which provided a cylindrical laboratory about the length of a medium size bus for the SLS-1 science crew of four, three physicians and a research biochemist.

The science team — Dr. James P. Bagian, Dr. M. Rhea Seddon, Dr. Francis (Drew) Gaffney and Dr. Millie Hughes-Fulford — served multiple roles as investigators, lab technicians and experiment subjects. They conducted 20 investigations devoted to comprehensive study of six body systems: heart,

The centerpiece of the program is a series of Spacelab Life Sciences missions





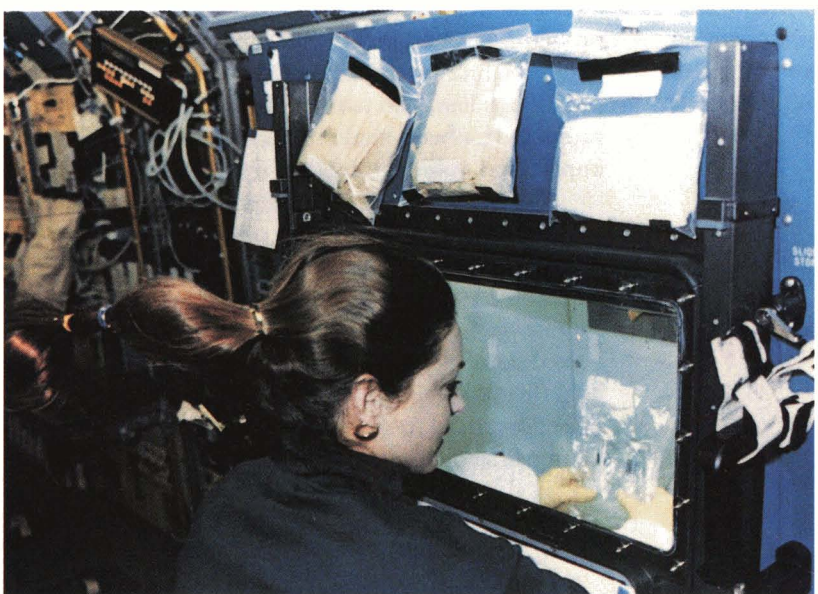
Orbital research involves study of the effects of microgravity on human, animal and plant life

lungs and blood vessels; kidneys and hormone secreting organs; the blood system; the immune system; muscles and bones; and the vestibular system, which embraces the brain, nerves, eyes and inner ear. Mission Specialist Tamara Jernigan also participated in the tests.

At far left, Hughes-Fulford assists in a test wherein James Bagian, seated in a rotating chair, is wearing an accelerometer and electrodes to record head motion and horizontal/vertical eye movements during rotations. **At lower left**, Rhea Seddon is using a baroreflex neck pressure chamber, a collar that stimulates the baroreceptors in the carotid artery, which adjust heart rate and blood pressure. **At left**, Tamara Jernigan is weighing herself in weightless space, using a body mass measurement device scientists developed to determine mass in orbit. **At bottom**, Rhea Seddon is breathing into a cardiovascular rebreathing unit while exercising (pedaling a bicycle ergometer), the experiment focused on the deconditioning of the heart in space and the changes in cardio-pulmonary function that occur after return to Earth.

Other subjects included 29 white rats and 2,478 jellyfish. The rats were subjected to such studies as the microgravity effects on muscle atrophy rates, bone development and on the inner ear gravity receptors. The jellyfish studies focused on how microgravity influences the development of invertebrates (some of which completed their entire development cycles while in microgravity) and the ability of invertebrates to maintain their correct orientation to water while in weightless condition.

Upon landing at Edwards Air Force Base, California, the astronaut subjects spent a week in confinement undergoing the same types of tests they had performed in orbit, allowing comparison studies and observations of their readaptation to Earth gravity.



Toward Future Flight

NASA Aeronautical research is providing technology for tomorrow's safer, more efficient, more environmentally acceptable aircraft

In Europe, the United Kingdom's British Aerospace and France's Aerospatiale are jointly conducting studies of a supersonic transport successor to the Concorde.

Similarly, the British Rolls Royce Company and SNECMA of France are working together on new engine concepts for tomorrow's advanced supersonic transport. Japan, through its Ministry of International Trade and Industry, has started a supersonic/hypersonic technology program, initially focused on a high speed aircraft propulsion system.

These examples of investment in high speed transport research underline the interest among aircraft manufacturers of foreign nations in getting an early jump on what will be the next plateau for international aviation competition: the long range, economical, environmentally acceptable supersonic passenger transport. Aviation experts feel that — with sufficient technology development — high speed transports can become competitive with subsonic jetliners and capture a significant portion of the growing long haul intercontinental market, especially in transpacific service, where passenger traffic is expected to quadruple by the start of the new century.

In the interest of maintaining U.S. world leadership in commercial aviation, and in recognition of the economic potential of the multibillion dollar transport market, NASA is conducting a High Speed Research (HSR) program. Designed to help U.S. manufacturers prepare for the coming competition, the HSR program addresses the key technologies essential to resolving environmental and economic barriers to supersonic flight.

The HSR program is a follow-on to a two-year, first phase effort that involved high speed civil transport studies conducted for NASA by Boeing Commercial Airplane Company and Douglas Aircraft Company, the nation's two leading jetliner producers. The companies identified technological advances that should be possible by the early 21st century, developments that could make supersonic airliners more efficient and permit lowering fare levels to the point where they would be competitive with subsonic fares. However, the studies cautioned, demand for an advanced supersonic transport will materialize only if — in addition to being operationally efficient — the airplane can meet allowable noise standards and demonstrate that it will have no harmful effects on the atmosphere.

These environmental/economic challenges are the focus of the NASA/Boeing/Douglas HSR program, initiated in late 1989 and expected to continue through the mid-1990s. Although the program is less than two years old, significant progress has been made in both the atmospheric impact and noise elements of the research.

NASA is conducting atmospheric modeling research to evaluate potential ozone depletion due to the effects of high speed transport engine exhaust emissions. Laboratory simulations of near-cruise supersonic transport flight have indicated considerable promise of meeting the emission index goal (less than six grams equivilant nitrogen dioxide per kilogram of fuel); one combustion concept tested demonstrated between two and three grams.

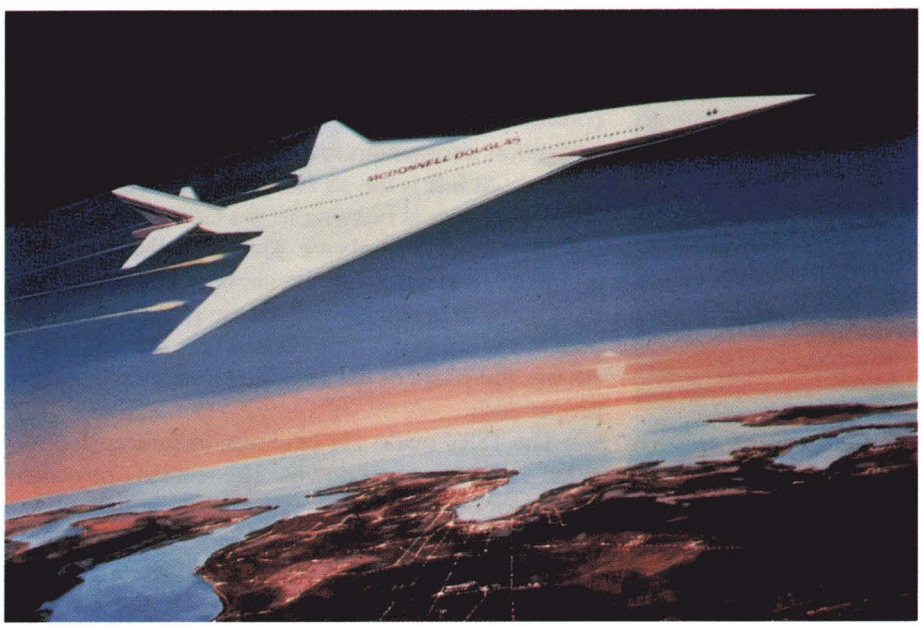
In the area of engine noise reduction, acoustic testing of model mixer-ejector nozzles demonstrated noise suppression capabilities of a degree that suggested considerable potential for achieving noise levels comparable to those currently required for new subsonic transports.

A big factor in the efficiency and operating economy of the advanced high speed civil transport is the ability to operate over land at supersonic speed, unlike the Concorde, which is restricted by sonic boom considerations to subsonic flight over land areas. NASA research is focused on two key areas. One is to determine the feasibility of minimizing the pressure wave that induces the sonic boom, without compromising aerodynamic performance, by reshaping parts of the airplane; small scale model wind tunnel tests are underway to quantify this possibility.

The other key area is establishing human acceptance criteria, which means determining just how much the sonic boom must be reduced to reach a level that is generally considered not objectionable to the public. NASA recently received approval to employ a sonic boom simulator for developing the needed database in these areas.

Materials present another research challenge. The candidate low-emission combustor concepts preclude the use of internal cooling now applied extensively, so there will be greater thermal stress on materials for the supersonic transport. In addition, the types of engine exhaust nozzles necessary for low noise levels will require much lighter-weight, higher-temperature materials. Both these requirements demand material properties that cannot be met with today's technology.

Therefore, NASA is accelerating development of a new class of ceramic-based composite materials capable of operating uncooled at 3000 degrees Fahrenheit in the combustor, and advanced high-temperature, high-strength intermetallic composites to reduce jet exhaust nozzle structural weight. Historically, development and introduction of new materials takes 10-12 years, so development of these new materials must start now to ensure their availability by the projected 2005 service-entry date for the advanced supersonic transport.



These artists' concepts show two possible designs for a second generation supersonic passenger transport. They were developed in a NASA research program by Boeing Commercial Airplane Company (top) and Douglas Aircraft Company (bottom). A new phase of this effort, known as the High Speed Research program, focuses on reducing noise and atmospheric impact to make the advanced supersonic transport an "environmental good neighbor."

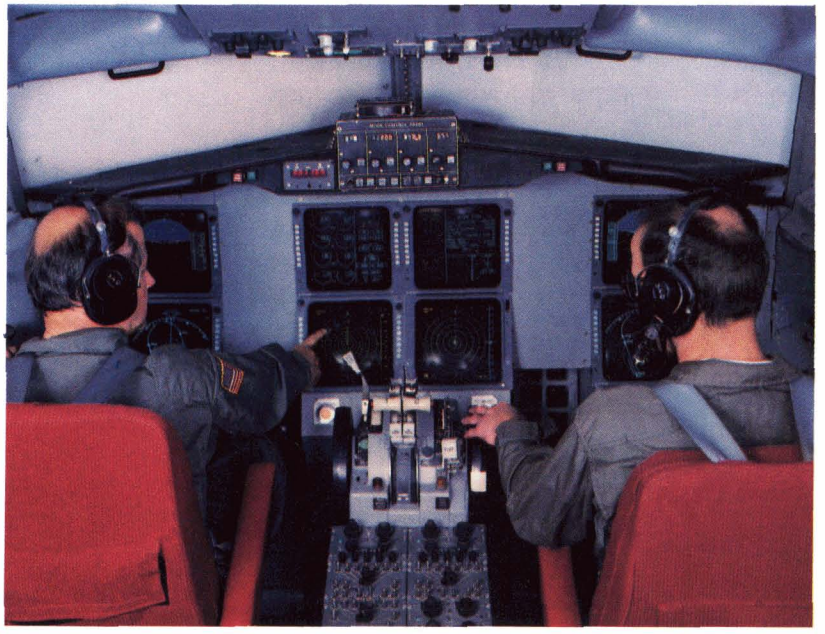
Subsonic Transport Aircraft Research

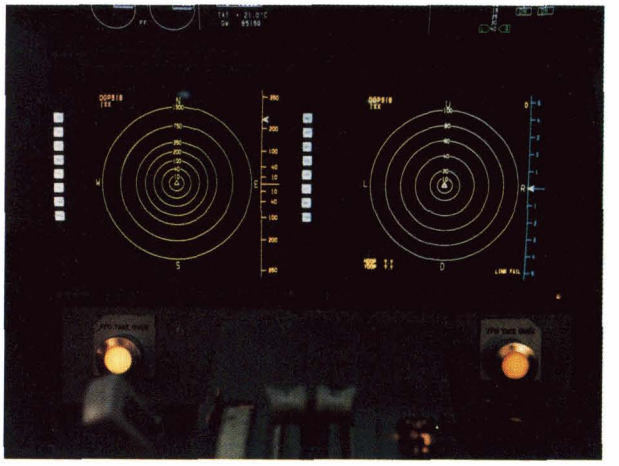
NASA seeks enhanced safety and improved U.S. competitiveness in transport development

A key facet of NASA's aeronautical research program involves development of new technology for subsonic transport aircraft. This effort has two main thrusts: finding ways to enhance the safety and productivity of the National Aviation System, and developing high leverage technologies that will assure the future competitiveness of U.S.-built transports.

Among safety-related programs, NASA and the Federal Aviation Administration (FAA) are jointly developing technologies for avoiding the consequences of hazardous windshear in aircraft landings and takeoffs. Windshear is a sudden shift in wind velocity and direction; its most violent characteristic is the microburst, an intense downdraft that can cause an aircraft accident. NASA and the FAA are investigating the physics of windshear and developing improved models for assessing the requirements and performance of windshear sensors.

A major part of the effort involves development of in-flight sensors by Langley Research Center. Three types of sensors are being evaluated: a Doppler radar system, a LIDAR (light detection and ranging) system, and an infrared system that detects microbursts by measuring temperature differential. In flight tests at Orlando (Florida) International Airport, the latter system achieved — for the first time — realtime airborne remote detection of microbursts. The goal of the research is to provide pilots sufficient warning of windshear danger to enable them to compensate.





Addressing advanced structural inspection and lifetime prediction for aging transport aircraft, NASA is developing NDE (non-destructive evaluation) techniques to detect fatique cracks, disbonds and corrosion during routine aircraft service inspections. Langley Research Center has developed and demonstrated a new thermal imaging method for detecting structural disbonds. To complement NDE research, NASA is developing fracture analysis methodology for multi-site fatigue crack damage analysis.

Langley and Honeywell, Inc. researchers concluded a flight research project that may contribute to improved automated landing capabilities for aircraft and spacecraft. Langley's Boeing 737 Transport Systems Research Vehicle (TSRV) was fitted with a Honeywell integrated differential navigation system linked to the Global Positioning System (GPS), an Air Force-operated constellation of satellites that provides precise navigation information to aircraft, ships and surface vehicles. **At left** is the aft (research) cockpit of the TSRV. The pilot is pointing to the GPS display, which is shown in closeup **above**. The left bullseye serves as a map centered about the airplane's location. The right bullseye is centered about the plane's approach path to the runway. An indicator (not shown) advises the pilots of the airplane's deviation from the proper path.

The TSRV made 111 landings, including 36 GPS-aided automatic touchdowns. The test data provides a basis for designing future aircraft/spacecraft automated systems and it will help researchers assess how risk can be reduced in automatic landings. In commercial aviation, an automated system based on

GPS-aided position determination offers potential for complete guidance, including approaches for a variety of air traffic patterns, landing rollout and taxiing to the gate in poor visibility conditions.

Langley also conducted, jointly with Boeing Commercial Airplane Company, a 1990 flight test program exploring a new way to keep the airflow over an aircraft wing "laminar," or smooth. Current aircraft wings have turbulent airflow over a large portion of their upper surfaces. Friction between the turbulent air and the airplane skin causes aerodynamic drag that reduces aircraft fuel efficiency. Looking for ways to reduce fuel consumption, NASA has investigated natural laminar flow, in which smooth airflow is achieved by wing shaping, and the suction mode of laminar flow control, in which a suction system pulls air through a porous wing skin, smoothing the turbulent air and establishing laminar flow. The natural method works only under restricted conditions; the suction mode suffers from a tendency to become clogged by insects or dirt in the suction holes or slots.

The Langley/Boeing research employed a new technique known as Hybrid Laminar Flow Control (HLFC) that combined the best of both techniques. To minimize clogging, the air suction system was limited to the wing leading edge. Boeing modified a 22-foot wing section of a Boeing 757 transport (the section with the blue lined surface in the photo **below**) to provide a surface with 19 million tiny, laser-drilled suction holes; part of the wing was shaped for natural laminar flow. During a five month test period, laminar flow control was achieved on all flights over a 65 percent segment of the modified wing section. Had the entire span of both wings been similarly modified, the HLFC system could have reduced total airplane drag by 10 percent or more, it was estimated. Gains of that order could cut the U.S. airline industry's fuel bill by $100 million annually.

In other subsonic research,

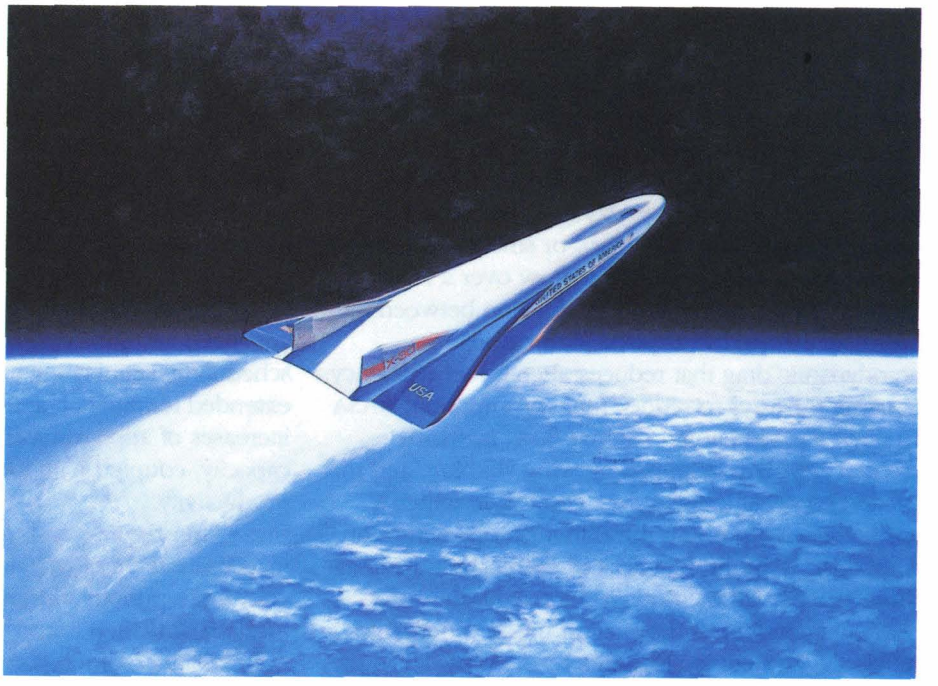
- Ames Research Center has developed an advanced air traffic control automation system for scheduling, sequencing and controlling traffic in an extended terminal area; the system has demonstrated increases of approximately 15 percent in traffic capacity, coupled with increased air traffic controller productivity.
- In materials and structures, NASA continues to investigate technologies for cost-effective advanced composite primary airframe structures, such as fuselage structural frames, window belts and sub-floor designs. A multi-axis filament winding concept shows potential for a 40-50 percent weight reduction and 30 percent cost savings over conventional metal construction.
- In subsonic propulsion systems research, NASA is investigating high efficiency core technology with the objective of providing enabling technologies for achieving cycle pressure ratios of 100:1 and peak cycle temperatures of 3000 degrees Fahrenheit in advanced ultra-high bypass ratio turboprop engines. The potential benefits are a 25 percent improvement in fuel consumption and a 10 percent improvement in direct operating costs. In other subsonic propulsion research, NASA has designed an advanced wing to eliminate interference caused by the engine's pylon; experiments have confirmed the absence of pylon interference.

A test program explored a new way to keep the airflow over an aircraft wing "laminar," or smooth

Hypersonic Research

The aero-space plane concept offers access to space with airplane-like flexibility, high responsiveness and reduced cost

At right is an artist's concept of the planned X-30, an experimental hypersonic flight research vehicle targeted for flight tests in the latter years of the century. The X-30 is the focal point of a joint NASA/Department of Defense (DoD)/National Contractor Team National Aero-Space Plane (NASP) program.



The program is aimed at eventual development of a revolutionary class of spaceplanes capable of taking off and landing horizontally like an airplane, operating in the upper atmosphere at hypersonic speed (more than 3000 miles per hour) or flying directly into Earth orbit. Such craft would offer on-demand access to space with airplane-like flexibility and high responsiveness and, because they would not require the extensive facilities needed for vertical space launches, they promise substantial reduction in launch costs.

The National Contractor Team is a group of five major aircraft/engine firms who are sharing development costs with NASA and DoD. The team includes three airframe companies — General Dynamics, McDonnell Douglas Corporation and Rockwell International — and two engine manufacturers — Pratt & Whitney Division of United Technologies and Rocketdyne Division of Rockwell International.

In mid-1991, NASP researchers concluded the first of five planned design cycles, during which the initial working configuration of the X-30 was selected; "slush" hydrogen was selected as the propellant to reduce fuel weight; and agreement was reached on the type of propulsion system. It will be a three-segment system with three different modes of propulsion: a low-speed module for takeoff to Mach 3, a high-speed ramjet module, and a hypersonic scramjet module. A substantial data base has been developed through ground tests of subscale engines in wind tunnels; a large scale engine in final configuration will be tested to Mach 7 by 1993.

The basic material of the X-30 airframe will be a metal composite made of high-strength silicon fibers embedded in an advanced titanium alloy; it is called TMC, for titanium matrix composite. NASP researchers are building and ground testing several large-scale TMC structures.

The current phase of the NASP program involves additional design phases and complementary research in aerodynamics, aerothermodynamics, propulsion, high temperature materials and structures, computational fluid dynamics and other key technologies. This technology development phase will continue until early 1993, when a decision is due as to whether to proceed with construction of two X-30 prototypes.

The technical program is managed by the NASP Joint Program Office, located at Wright-Patterson Air Force Base, Ohio, and staffed by Air Force, Navy and NASA personnel. Government research facilities participating include NASA's Ames, Langley and Lewis Research Centers; the USAF's Aeronautical Systems Division, Air Force Weapons Laboratory and Arnold Engineering and Development Center; the Naval Surface Weapons Center; and the Department of Energy's Los Alamos Laboratory.

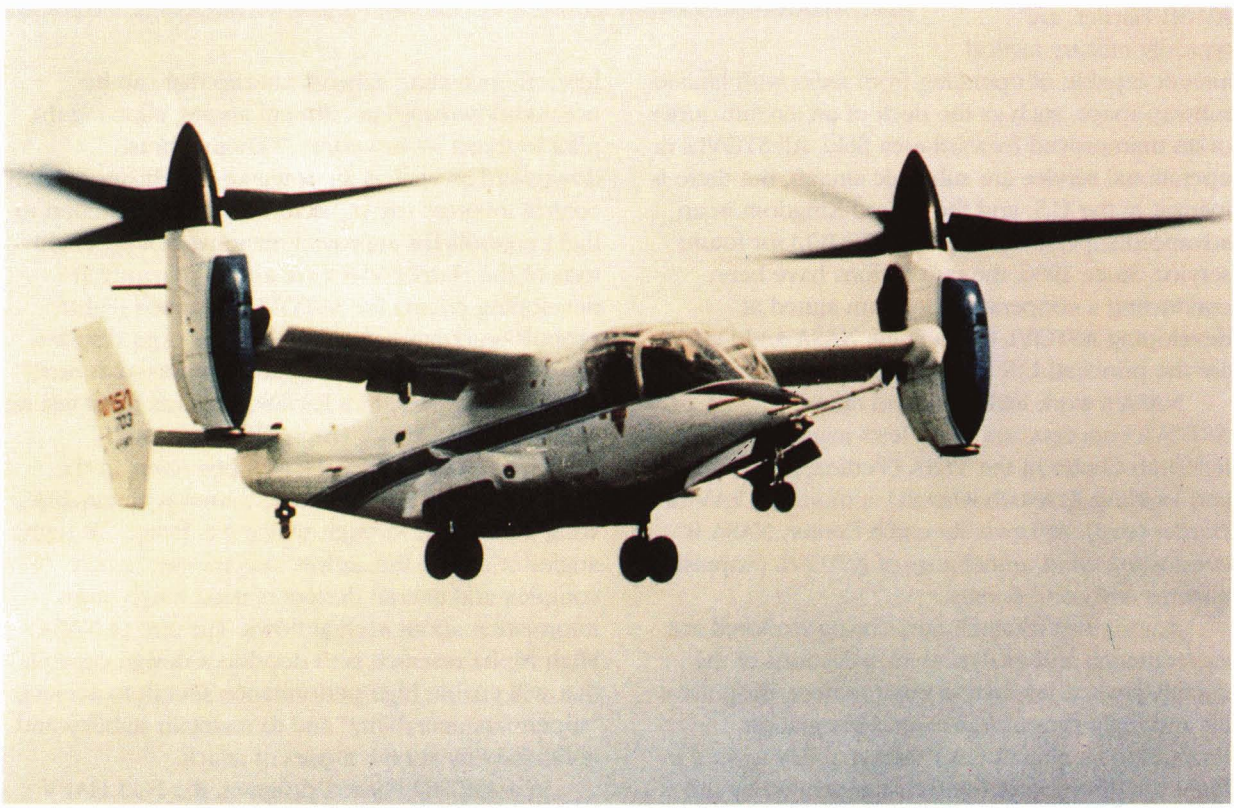
Tiltrotor Research

The XV-15 research aircraft pictured is undergoing tests — conducted jointly by Ames Research Center and Langley Research Center — to help determine the potential of advanced tiltrotor vehicles as future commercial transports. The XV-15 is a convertible rotorcraft that combines the unique flight capabilities of the helicopter with the greater forward speed of a fixed-wing airplane. It has helicopter-like rotors for vertical takeoff, hovering and landing; for cruise flight, its rotors tilt forward to become propellers.

Current flight research involves testing advanced technology rotor blades made of composite materials. The blades have demonstrated better cruise efficiency and significantly reduced noise in comparison with the rotor system on the two original XV-15s built by Bell Helicopter Textron for a joint NASA/Army research program. Those craft, tested in the 1970s and 1980s, led to development by the Department of Defense (DoD) of a larger, more advanced tiltrotor, the Bell/Boeing V-22 Osprey. In April 1991, the Osprey passed a developmental milestone when it passed 500 flight research hours.

NASA's XV-15 testing is part of a broader NASA/DoD/Federal Aviation Administration (FAA) effort that addresses the national need for further civil/military tiltrotor development; the economic viability of this type of aircraft as a 30-40 passenger transport in high-density, short haul, city-to-city markets; and whether such transports could make a significant contribution to the nation's airport congestion problem. In addition to accumulating flight data from XV-15 and V-22 tests, the program has included a series of studies concerning the tiltrotor market potential, the economics of tiltrotor operation, the problems of integrating tiltrotor transports with the U.S. civil aviation infrastructure, and the technological improvements required to make the tiltrotor a viable commercial transport.

The most recent study, conducted by Boeing Commercial Airplane Company for NASA/DoD/FAA and concluded at the end of 1990, indicated a worldwide demand for more than 2,600 40-passenger tiltrotor transports by the year 2000. The report stated that diversion of passengers to tiltrotor services in the high-density Washington-New York-Boston corridor could increase capacity at the corridor's major airports by one-third.



The tiltrotor is a convertible rotorcraft that combines the unique flight capabilities of the helicopter with the greater forward speed of a fixed-wing airplane

High Performance Aircraft

Among key research areas being explored are aircraft and ground interaction, propulsive lift and flight propulsion/ control integration

NASA's High Performance Aircraft research program is concentrated on exploration of concepts and technologies applicable to future military aircraft. Most of these activities are cooperative projects with industry and agencies of the Department of Defense, such as the Air Force, Navy and the Defense Advanced Research Projects Agency (DARPA).

One current effort seeks to expand the technology base for supersonic STOVL (Short TakeOff and Vertical Landing) aircraft. STOVLs, exemplified by the Navy/Marine Corps AV-8B Harrier, are typically military tactical aircraft capable of operating from areas with limited runway space, such as the deck of an aircraft carrier or an unimproved forward-area field. All STOVLs in operational service are subsonic aircraft, but there is interest in the U.S. and the United Kingdom in an advanced supersonic STOVL (ASTOVL) for future service. Since 1986, the two nations have been conducting a cooperative program aimed at developing ASTOVL technology; NASA and DARPA are the principal U.S. agencies involved.

NASA's work includes wind tunnel tests of ASTOVL concepts and flight tests managed by Ames Research Center of the VSRA (Vertical/Short TakeOff and Landing Research Aircraft), a modified YAV-8B Harrier (**top**). At Lewis Research Center, NASA is conducting wind tunnel tests of ASTOVL propulsion systems and components.

Among key research areas being explored are experimental and analytical investigations of the aircraft/ground interaction environment, propulsive lift and flight propulsion/control integration. Propulsive lift aircraft have the capability to vary in flight the direction of the thrust generated by the propulsion system; the Harrier VSRA, for example, has four swiveling exhaust nozzles that can be pointed downward at different angles, allowing the pilot to direct — or vector — engine thrust downward as well as aft. Integrated flight/propulsion control involves use of vectored thrust in addition to flight controls for improved maneuverability. Flight tests of the Harrier VSRA are aimed primarily at developing criteria for ASTOVL integrated flight/ propulsion controls and advanced cockpit displays.

A related research program, conducted at Ames-Dryden Flight Research Facility, involves flight testing of NASA's F-18 HARV (High Alpha Research Vehicle), shown **above**. High Alpha refers to the high angle of attack, the angle between an airplane's wing and the air through which it is flying. At high angles of attack, the airflow becomes extremely complex and aircraft designers need much more information about such airflows. The aim of NASA's High Alpha research is to develop a design capability that will enable high performance aircraft to achieve "supermaneuverability" and to maintain stability and controllability at high angles of attack.

In a 1987-89 Phase I program, the F-18 HARV was flown at angles of attack up to 50 degrees. To

allow flight at higher angles, the aircraft was returned to the plant of its builder — McDonnell Douglas Corporation — for installation of a thrust vectoring system. The F-18 HARV resumed flight tests in January 1991; the Phase II program will explore maneuverability at angles of attack up to 70 degrees.

High Alpha is being investigated in another Ames-Dryden program jointly conducted by NASA, DARPA and the Air Force. The test vehicle is the X-29A research aircraft, two of which were built by Grumman Aerospace Corporation to demonstrate a variety of advanced technologies that collectively offer promise of designing smaller, lighter and more efficient military aircraft without sacrificing performance. Among the technologies are a unique forward-swept wing made of composite materials; rotating canards that replace conventional horizontal tail surfaces to control pitch; and an advanced digital flight control system that stabilizes the aircraft by adjusting the wing trailing edges, canards and other control surfaces up to 40 times a second.

Following completion of a 242-flight concept demonstration program in 1984-88 with the Number One aircraft, the Number Two X-29A (**top**) began an advanced series of tests in 1989. These tests involve investigation of High Alpha maneuverability at angles of attack up to 70 degrees. This effort is complementary to the F-18 HARV tests, but not duplicatory. It offers a different research view because the X-29A's forward swept wing flows inward rather that outward as it does on the HARV, which substantially changes airflow and controllability characteristics. NASA, Air Force and Grumman project pilots report that the X-29A offers excellent control response up to an angle of attack of 45 degrees and it still has limited capability at 66 degrees.

Integrated flight/propulsion control is being demonstrated and evaluated at Ames-Dryden in a cooperative NASA/Air Force/industry program known as HIDEC (for Highly Integrated Digital Electronic Control); industry participants include McDonnell Douglas, builder of the F-15 fighter now used as the HIDEC research aircraft (**above right**) and the engine builder, Pratt & Whitney division of United Technologies.

In the HIDEC program, NASA has demonstrated that it is possible to realize significant gains in engine thrust and fuel efficiency through employment of an advanced engine control system together with engine/flight control integration. This technology could make it possible to extend the service lives of existing military aircraft and engines and defer costly development of new types.

Integrated flight and propulsion control is being demonstrated and evaluated in a cooperative program

A highlight of this program was a series of successful flight tests marking the first demonstration of a Self-Repairing Flight Control System, one capable of identifying a component failure, isolating the failure, and reconfiguring other control elements (ailerons, rudders, elevators, flaps) to allow continuance of the aircraft's mission or a safe landing. In mid-1990, the HIDEC F-15 began research flights in a project called Performance Seeking Control (PSC). Employing digital flight control, inlet control and engine control systems, PSC uses advanced techniques to identify the condition of the engine components and optimize the overall system for best efficiency. Among PSC functions are reduction of fuel consumption at cruise speed; maximizing excess thrust during acceleration, climb and dash; and extending engine life by reducing fan inlet turbine temperature. When fully developed, PSC engines are expected to display thrust increases up to 15 percent and fuel consumption reductions up to 20 percent.

Commercial Use of Space

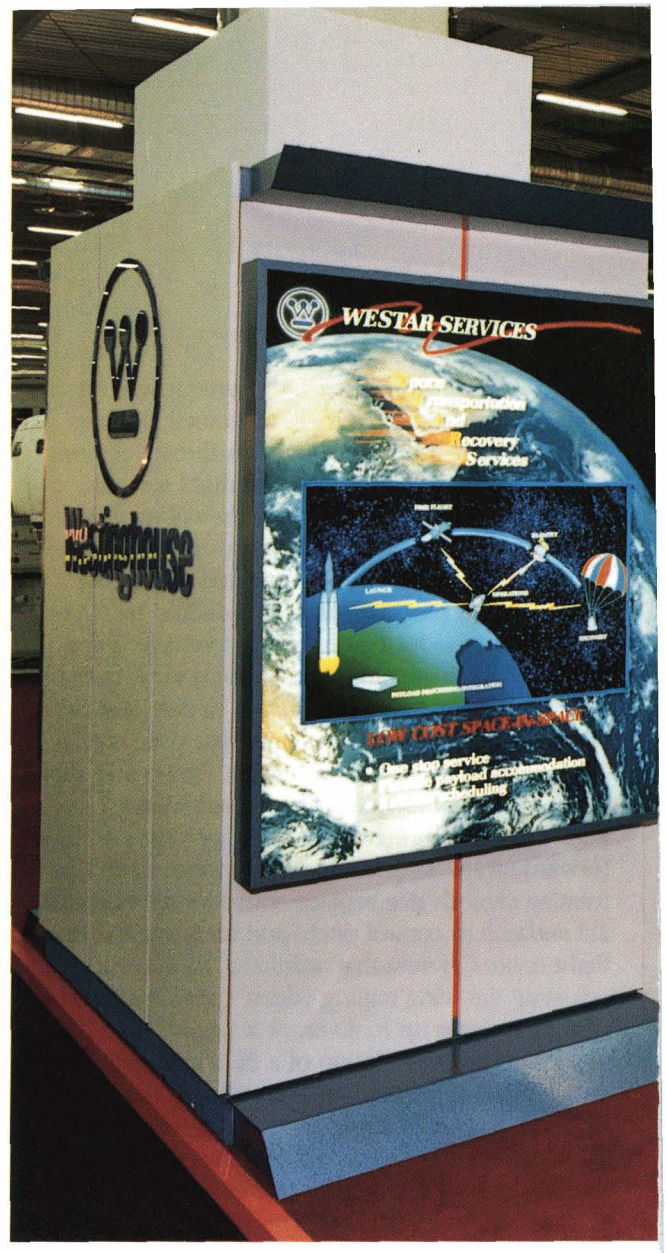
Commercial Use of Space

A new means of access to orbit exemplifies NASA's efforts to stimulate industry interest and investment in commercial space ventures

In 1992, NASA's Centers for the Commercial Development of Space (CCDS) will introduce to orbital service an innovative space system that will significantly enhance the U.S. capability for commercial experimentation in space. Known as COMET — a compression of Commercial Experiment Transporter — the unmanned system will enable recovery of some experiment payloads for analysis on Earth, and permit long-duration operation of payloads that do not need to be recovered.

Boosted by an expendable launch vehicle, an 1,800-pound "freeflyer" spacecraft will provide six cubic feet of payload volume in the non-recoverable service module and nine cubic feet in the recoverable reentry system. The freeflyer will operate in a 300-mile-high orbit for about a month, at which time the recovery system will separate for retrieval at a U.S. location, while the service module will remain in orbit to support non-recoverable experiments for 100 days or more.

System components are being designed and developed by an industry team selected in January 1991 after a procurement competition. Space Industries, Inc. (SII), Webster, Texas has responsibility for recovery system development, payload integration and orbital operations. Space Services, Inc. (SSI), Houston, Texas will provide launch services. Westinghouse Electric Company, Millersville, Maryland is charged with systems engineering and development of the service module.



The COMET program is managed by the University of Tennessee-Calspan's Center for Advanced Space Propulsion (CASP), one of 16 NASA-sponsored CCDS. The CCDS are competitively selected consortia of industrial firms, universities and government organizations, established to expedite development of a technology base on which to build new commercial space industries and to help move emerging technologies from the laboratory to the marketplace rapidly and efficiently.

CASP is one of seven CCDS with responsibilities in the COMET program. The Center for Advanced Materials, Columbus, Ohio will provide screening and selection services for COMET payloads developed by the CCDS and their industrial partners.

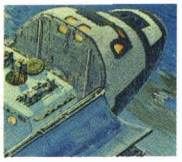
A Westinghouse official displays a model of the COMET (Commercial Experiment Transporter) service module, a key element of a new system that will enable long duration commercial space experimentation and allow recovery of some payloads for analysis on Earth; the system is shown in closeup below.

Other CCDS will monitor specific areas of development and operation:

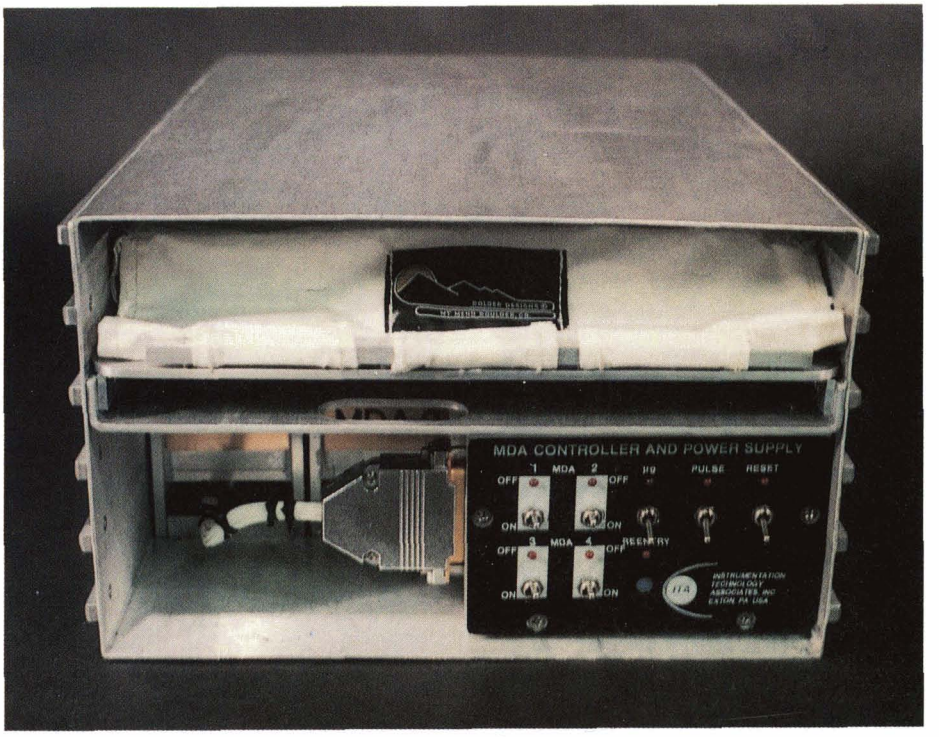
- Bioserve Space Technologies, University of Colorado (Boulder), recovery system and services
- Center for Power, Texas A&M University (College Station), service module
- Consortium for Materials Development in Space, University of Alabama (Huntsville), launch vehicle and services
- Center for Macromolecular Crystallography, University of Alabama (Birmingham), payload integration
- Space Vacuum Epitaxy Center, University of Houston (Texas), orbital operations.

The COMET system is described by program manager Joseph F. Pawlick, Jr. of CASP as "the initial step toward establishing an entirely new U.S. commercial space transportation industry." The system offers potential for reduced costs of on-orbit experimentation. It also offers a new means of access to orbit for commercial payloads, relieving the intense competition for payload space aboard the tightly-scheduled Space Shuttle Orbiter.

Additionally, launch of COMET payloads by expendable launch vehicles gives experimenters flexibility in selecting orbital parameters different from those of the Shuttle Orbiter. The freeflyer can stay in orbit much longer than the Shuttle Orbiter and it can carry industrial research materials that might be hazardous to the Orbiter's human crew. Initial COMET launch is targeted for September 1992.



Commercial Space Research



Get Away Specials, are installed in standardized, cylindrical containers accommodated in the Orbiter's cargo bay.

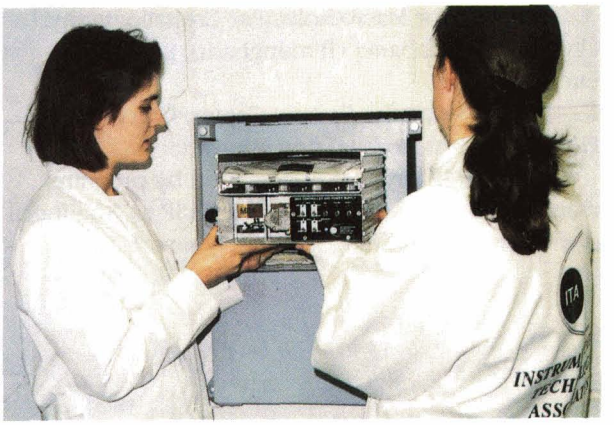
Much of the experimentation carried out by NASA's Centers for the Commercial Development of Space is accomplished in secondary payload facilities aboard the Space Shuttle Orbiter. Some experiments are performed in the pressurized area of the Orbiter's middeck, where they can be activated and tended by the crew. Others, known as Get Away Specials (GAS), are installed in standardized, cylindrical containers accommodated in the Orbiter's cargo bay. These latter payloads must be "autonomous," meaning that they are essentially independent of the Orbiter and the experimenter is responsible for providing — in the payload package — electrial power, heating/cooling and data acquistion systems. Middeck and GAS payloads are exemplified by three Shuttleborne research tasks accomplished in 1991.

In April, on Shuttle flight STS-37. the Orbiter *Atlantis* carried in its middeck lockers two biological space processing payloads. One, sponsored by Bioserve Space Technologies, University of Colorado (Boulder), was BIMDA (Bioserve ITA Materials Apparatus), a joint development with Instrumentation Technology Associates (ITA). The payload consisted of four Materials Dispersion Apparatus (MDA) Minilab units and a Bioserve-developed Bioprocessing Testbed. At **top**, is the fully assembled BIMDA payload; in photo **at right**, technicians have mounted a BIMDA unit in a Shuttle middeck locker mockup.

The MDA is a privately-financed facility designed to allow a large number of simultaneous experiments at low cost. Each MDA Minilab can accomodate as many as 150 samples for growing protein crystals, casting thin film membranes, and conducting biomedical and fluid science experiments.

Bioserve's Bioprocessing Testbed contains hardware for six bioprocessing modules and six cell syringes. The entire BIMDA package is flown in a temperature-controlled Refrigerator/Incubator Module.

On STS-37, a total of 182 MDA sample wells were activated by astronaut Jerome Apt. The samples



provided data for 47 experiments designed by 25 government/industry principal investigators.

The other CCDS package flown on STS-37 involved flight test of a new hardware configuration developed by the Center for Macromolecular Crystallaography (CMC) at the University of Alabama (Birmingham) to support a PCG (protein crystal growth) experiment.

Crystallography is the science that deals with the form, structure and properties of crystals. CMC is seeking knowledge of the three-dimensional structure of proteins; such knowledge enables a more systematic approach to learning how protein molecules function and how they can be altered to create new components that have broad potential in medical, pharmaceutical and agricultural research.

The key to this effort is growing large, high quality crystals for analysis, and research indicates that crystals grown under microgravity conditions are far superior and offer a greater capability for determining a protein's molecular structure than do crystals grown in Earth's gravity.

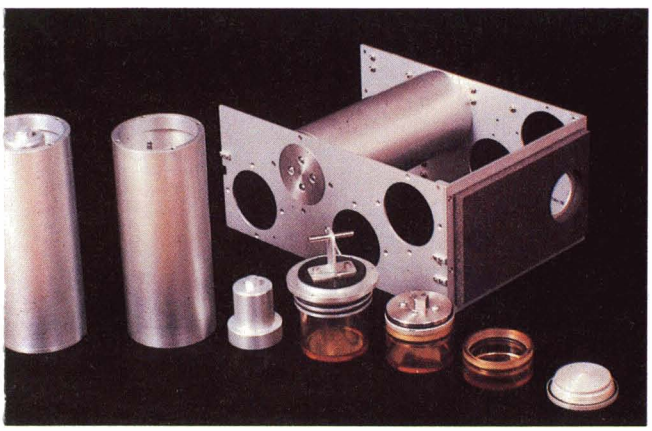
CMC and its industrial affiliates have sent several PCG payloads into orbit aboard the Shuttle Orbiter. Until the l99l flight, only small microliter-level volumes had been flown. On STS-37, the new hardware allowed crystal growth on a large scale. The STS-37 experiment also introduced an entirely new concept for crystallation in microgravity, a technique that utilizes temperature—rather than vapor diffusion — to initiate crystal growth. The new system offers some major advantages: the crystallation rate can be accurately controlled by slight changes of temperature, and convection is minimized, creating a more uniform environment for crystal growth.

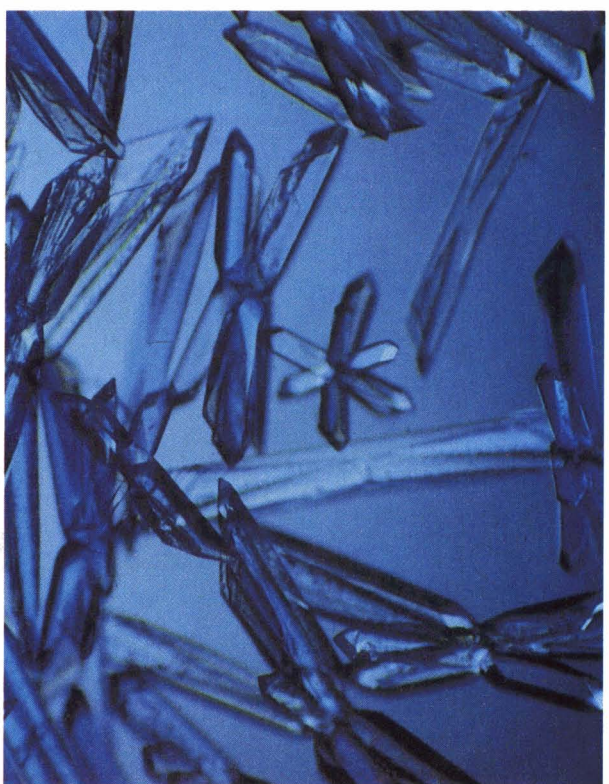
On flight STS-40 in June, the Orbiter *Columbia* carried a GAS payload known as G-l05, co-sponsored by the Consortium for Materials Development in Space (CMDS) and the U.S. Space and Rocket Center, both of Huntsville, Alabama. The G-l05 payload contained six experiments in a 200-pound canister that was purged, filled with dry nitrogen gas and sealed before the flight; the compact experiment package is shown **below**, with examples of the crystals grown.

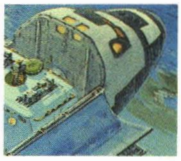
Four of the six experiments involved microgravity studies. One investigated technology used to refine and process organic materials, such as medical samples. Two other experiments processed organic films and crystals that could be used in optical communications and computers. The fourth microgravity experiment focused on electroplating metals to study the special catalytic and refractory properties of metals such as nickel and cobalt, materials that could have commercial applications as catalysts.

The two other experiments involved cosmic ray research. One, sponsored by CMDS, collected cosmic ray interactions on film emulsions, information that will enable fine-tuning of the design of large cosmic ray detectors intended for future Shuttle or space station missions. The other experiment, sponsored by the U.S. Space and Rocket Center, studied the effects of cosmic radiation on the chromosomes and genes of a common yeast.

Crystallo-graphy is the science that deals with the form, structure and properties of crystals







Commercial Earth Observation

The data can be put to practical use in a wide variety of applications

Remote sensing is the process of acquiring information from a distance, for example, obtaining data on Earth features from sensors aboard a satellite or an airplane. The data can be put to practical use in such applications as agricultural crop forecasting, land use management, mineral and petroleum exploration, mapping, rangeland and forest management, water quality evaluation, disaster assessment and scores of other applications.

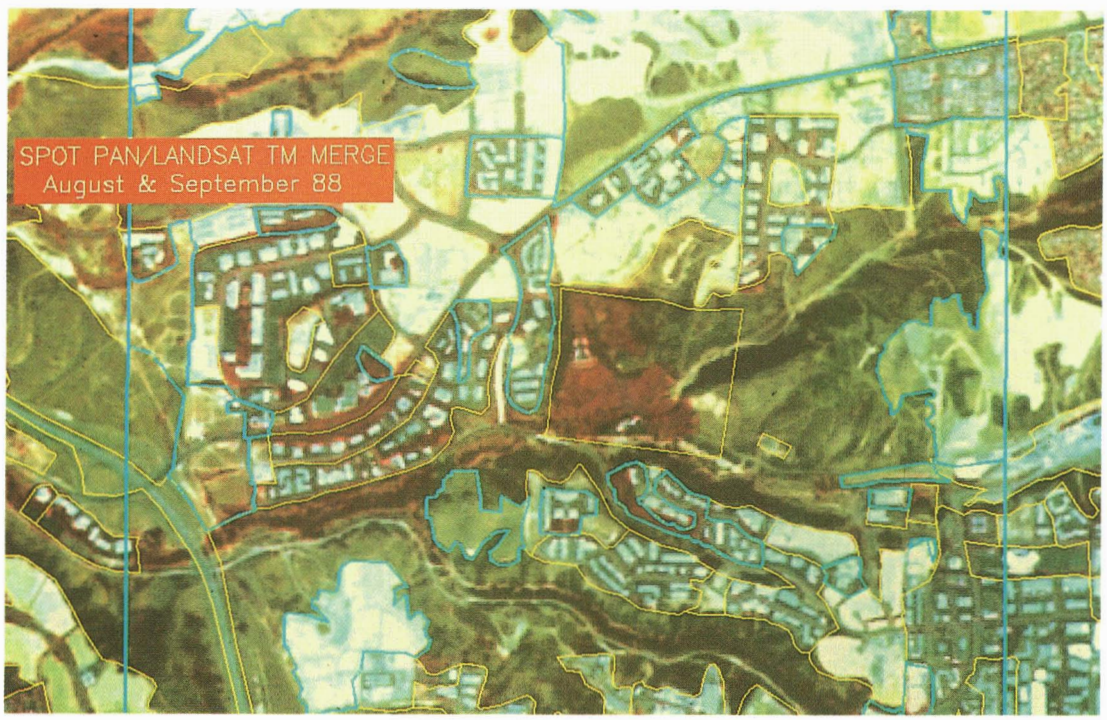
NASA's pioneering research in remote sensing technology led to commercialization of the U.S. Landsat Earth resources monitoring satellite and spawned broad expansion of airborne remote sensing. NASA is now engaged in an effort to help private industry develop and commercialize new applications of space-based and airborne remote sensing technologies.

The program — known as the Earth Observations Commercial Applications Program (EOCAP) — provides government co-funding to encourage private investment in, and broaden use of, NASA-developed technology for gathering and analyzing information about Earth and ocean resources. An example is shown **below**. The image is a merged Landsat/SPOT image in which land use of an area in San Diego is shown for the years 1986 and 1988, allowing study of the changes that occurred.

Participants include private sector organizations, educational institutions, nonprofit organizations and government agencies. Each participant incorporates an industry partner responsible for commercial implementation of the project. Investigator teams are required to provide substantial co-funding. Through this program, businesses are encouraged to invest, over several years, in the development and marketing of high-risk products and services useful to both the private and public sectors.

Projects are selected by interested groups in response to a NASA solicitation. The program was launched in 1987 with the first EOCAP solicitation, which drew 120 proposals. Twenty projects were selected for contracts and funded over a three-year period. They involved remote sensing applications ranging from estimating potato production and inventorying forest land, to development of a specialized algorithm for ocean color imaging that offers benefit to the fishing and ocean transportation industries.

A second solicitation in June 1990 brough 50 proposals and 12 were selected for contracts in December 1990. These projects are exploring such remote sensing applications as hazardous waste detection, disaster assessment, hydrologic forecasting, pipeline monitoring and management, and wetlands information services.



Highway Mapping

In the United States, it is estimated that unreported deteriorating road conditions cost the nation some $16 billion a year in wasted fuel, excessive vehicle repairs and time lost from jobs.

Ohio State University's Center for Mapping (Columbus) is developing a system designed to reduce the time and money needed to gather information on highway conditions. The Center for Mapping, one of NASA's 16 Centers for the Commercial Development of Space, is spearheading a multi-organizational 18-month pilot project called the Global Positioning System for Transportation Planning.

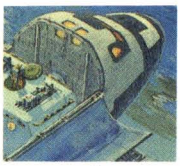
The project employs a prototype ground vehicle (**below**) that can automatically map and record transportation systems, including bridges, highways, railways, grass-mowing areas, equipment locations and secondary roads. The system offers additional utility in locating roadways in need of repair and other hazardous conditions, including the sites of fatal accidents.

Operation of the vehicle — a standard van — draws upon NASA-developed imaging technology and navigation data from the Navstar Global Positioning System (GPS), a constellation of satellites operated by the Department of Defense to provide precise positioning information for aircraft, surface vessels and ground vehicles. As two video cameras in the van scan the local terrain and acquire images, the van's GPS receivers record — with an accuracy of one to five meters — the latitude and longitude of the imaged scene. The positioning data is processed, stored in digital format, and eventually downloaded into computers used for geographic purposes, called Geographic Information Systems (GIS).

In addition to providing a visual record of transportation features, the system is ideal for mapping. This application alone is expected to save highway departments a great deal of time and money. Virtually all government agencies that use maps are switching to electronic databases. However, digitizing maps is expensive and time consuming. With the mobile unit, the digitizing is already done. The data can be entered into the database and converted into a format acceptable for processing in a GIS.

Other organizations participating in the project include the Federal Highway Administration, 38 state transportation departments and the Canadian province of Alberta. Corporate sponsors are Trimble Navigation, Sunnyvale California, which donated two GPS receivers, and COHO Camera Company, San Diego, California, which supplied the system's digital video cameras. Demonstrations and performance evaluations have been completed in Louisiana and Virginia and are planned for Colorado, Ohio, Florida and along the West Coast.

The project employs a prototype ground vehicle that can automatically map and record transportation systems



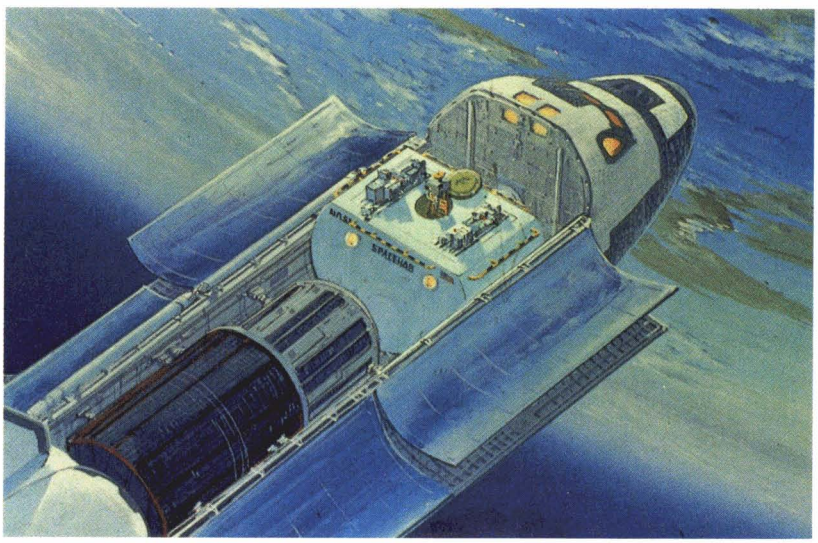
Commercial Use of Space

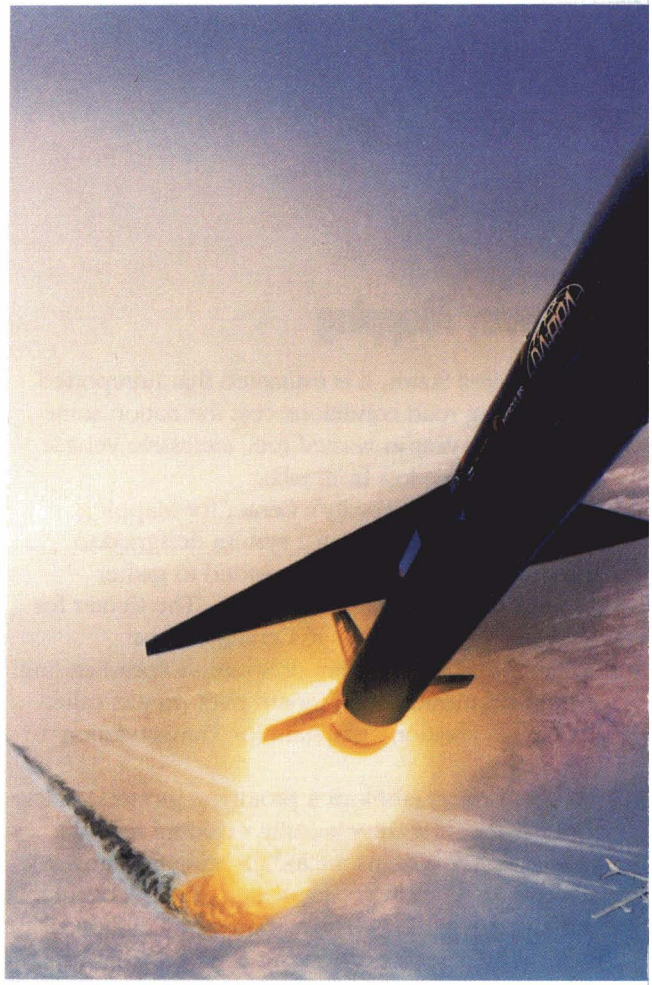
Commercial Space Developments

Increasing activity at NASA's Centers for the Commercial Development of Space (CCDS), together with other commercial space ventures, is generating requirements for orbital experiment space far exceeding the accomodations available in the Space Shuttle Orbiter's middeck. NASA has taken a step to make additional experiment space available through a lease agreement with SPACEHAB, Inc., Washington, D.C., whereby the company will provide the services of a SPACEHAB commercial middeck augmentation module.

The leased module will be carried in the Orbiter's payload bay **(bottom left),** be accessible through the air lock and will add the volume equivalent of about 50 middeck experiment lockers. The lease contract, which was signed in December 1990 and covers a five-year span through 1995, calls for SPACEHAB, Inc. to provide for the integration of the module and experiments; power, cooling and data management; and crew training spread over six flights occurring at intervals of about six months. The initial flight is targeted for late 1992.

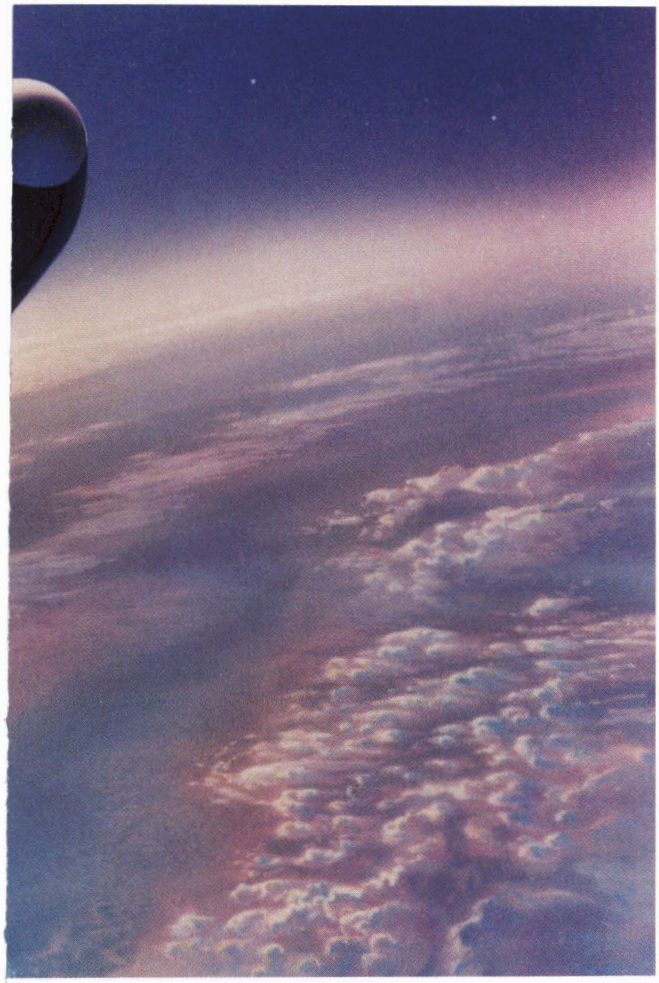
NASA is leasing two-thirds of the module's volume over a six-flight profile; this volume will be used to provide flight opportunities for the CCDS and for NASA/industry Joint Endeavor Agreements. SPACEHAB, Inc. will market to commercial users the remaining volume. The lease contract is managed by Johnson Space Center.





Under another commercial space agreement, NASA is providing support to Orbital Sciences Corporation (OSC), Fairfax, Virginia for the company's Pegasus **(above)** and Taurus commercial launch vehicles. The agreement allows OSC to enter into specific sub-agreements with NASA installations wherein NASA will provide — on a cost-reimbursable basis — access to the agency's launch support property and services. The NASA installations involved are Kennedy Space Center, Lewis Research Center, Goddard Space Flight Center and Marshall Space Flight Center. NASA had earlier negotiated similar "umbrella" agreements with four other firms —General Dynamics, LTV Corporation, Martin Marietta and McDonnell Douglas — in the interests of fostering a strong U.S. commercial launch vehicle industry.

In a late 1990 development, NASA signed a memorandum of understanding whereby the agency will exchange — with Technical and Administrative Sciences Corporation (TADCORPS), Washington, D.C. — research information associated with closed environment systems related to food production on Earth and in space.

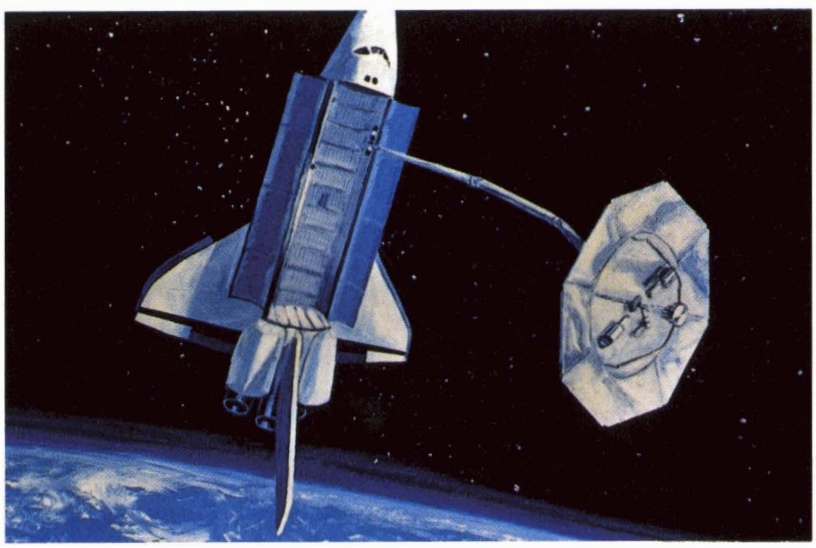


NASA is interested in exploring controlled environment systems and hydroponics (waterless plant growing) technology to develop the food production systems essential to long duration space missions; NASA is also investigating the chemical processes associated with waste management and recycling. TADCORPS is exploring concepts for test facilities that could provide technology applications for domestic farm crop enrichment in hostile environments in remote regions of the world.

Under the two-year agreement, NASA and TADCORPS will share information generated by studies in three areas: potential development of hydroponic systems and orbital agricultural experiments; chemical processing technology in support of hydroponics and life support systems; and terrestrial applications of hydroponics and closed environment systems.

A novel experimental program in the development stage is the Wake Shield Facility (WSF) being developed by Space Industries, Inc., Houston, Texas for the Space Vacuum Epitaxy Center at the University of Houston. Epitaxy is a term for the growth of crystals in a special, atom-by-atom, layer-by-layer manner to produce varying crystalline structures. Epitaxial growth under high vacuum conditions can produce crystalline thin films of higher quality and purity than can be grown on Earth. Such films offer promise of important advances in superspeed computers, lasers, communications and infrared devices, and many other high technology microelectronic applications.

The WSF makes orbital epitaxial research possible. Carried in the payload bay of the Space Shuttle Orbiter, it includes power, command and control units supporting a 10-foot-diameter disc. Extended from the Orbiter's bay by the remote manipulator arm **(bottom right),** or released to operate as a recoverable freeflyer, the disc sweeps an orbital wake, creating an ultravacuum region behind the disc where epitaxial thin films can be grown. Experiments are being developed by SVEC and the center's affiliates; first flight is planned for early 1993.



Space Operations: To the Moon and Mars

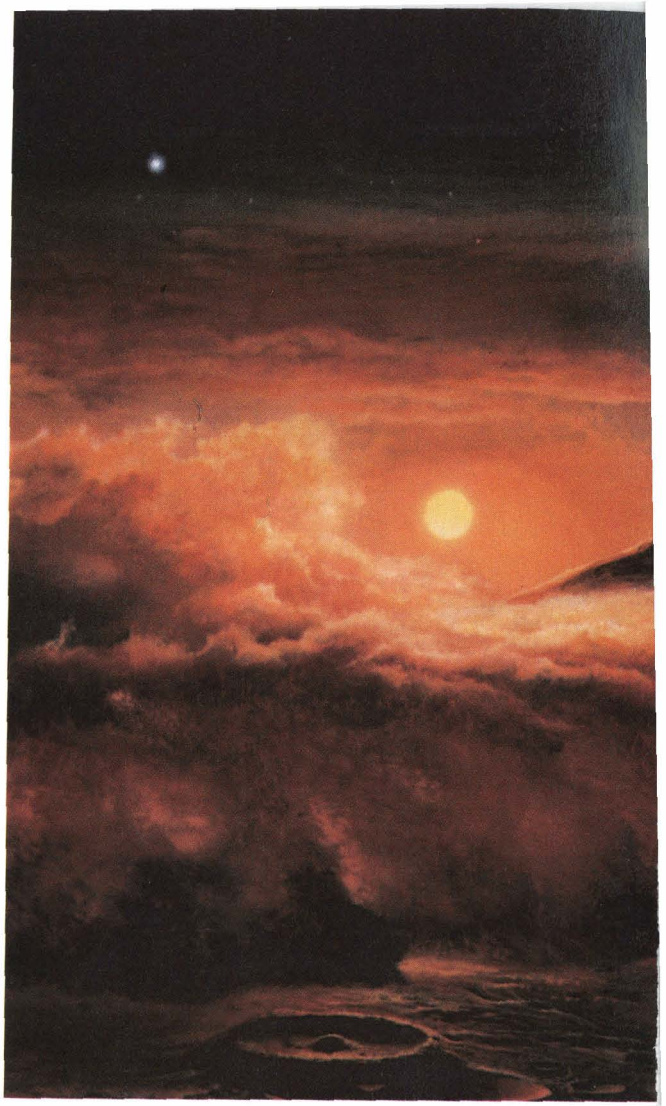
The Space Exploration Initiative and Space Station Freedom highlight NASA's thrust toward expanding human activities in space

"There are times when seemingly small decisions reverberate through the centuries. Now is such a time. The decisions we make now for space will set the nation's course for decades, if not centuries to come. The legacy we leave to future generations may well be decided in the next few years." These are the opening words of "America at the Threshold," the report on the Space Exploration Initiative (SEI) of the Synthesis Group, chaired by former astronaut Lieutenant General Thomas P. Stafford, USAF (Retired).

SEI, says the report, is a key element in attaining the "six visions that guide and direct our space effort," the national benefits that space promises. They include:

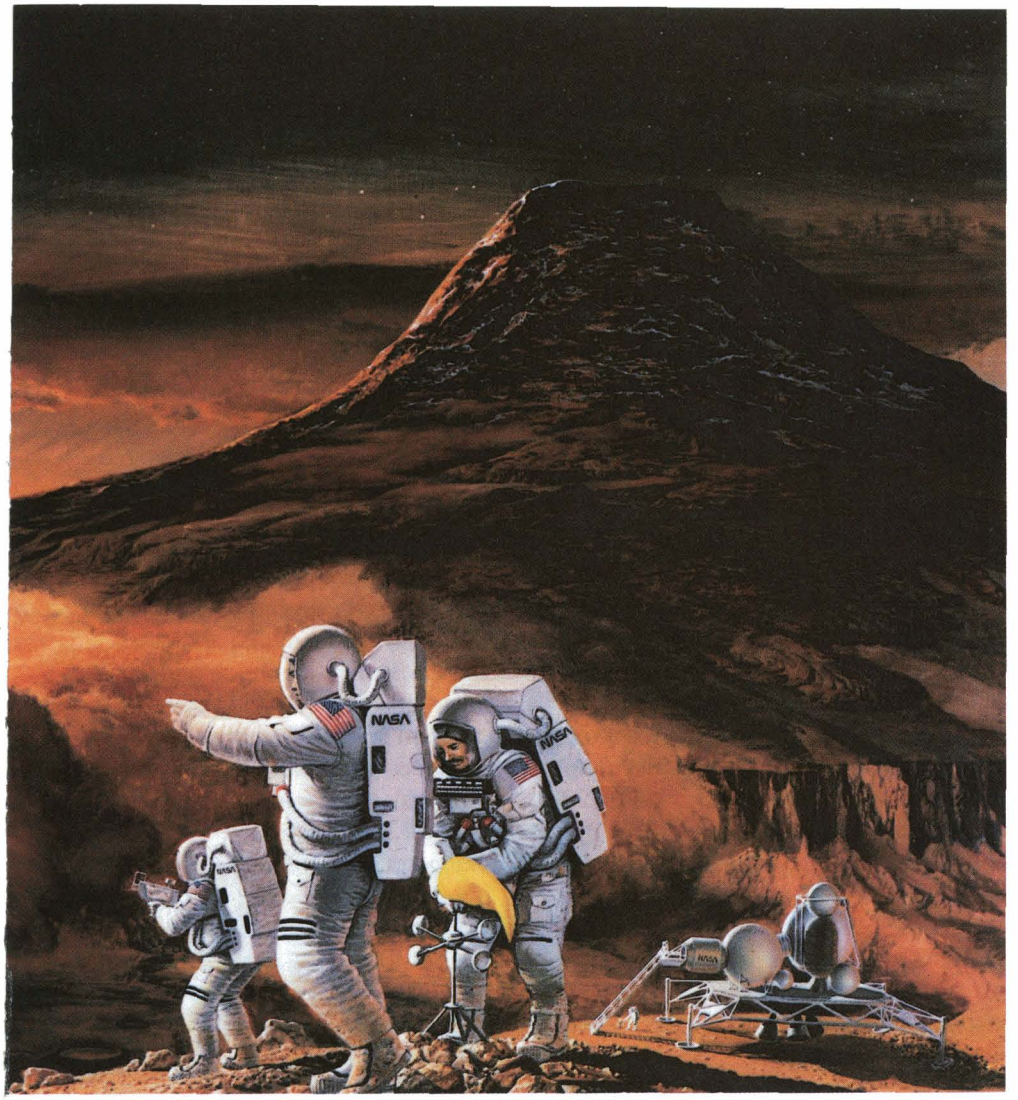
- Knowledge of the universe, greater understanding of the origin and history of the solar system, the origin of life and the ultimate fate of the universe.
- Advancement in science and engineering, including stimulus to the national education system and student motivation.
- Re-establishment of American preeminence in technological innovation and space leadership.
- Development of innovative products that find abundant application in the world consumer marketplace; SEI offers potential for such far-reaching gains as energy from space, advances in solar power and fusion fuels, materials for advanced communications, new resources and medical breakthroughs.
- Space commercialization; there is a "limitless, untapped source of materials and energy awaiting industrial development for the benefit of humanity."
- A strengthened U.S. economy; technologies developed for SEI can translate into enhanced U.S. competitiveness and a greater U.S. share of the global market and, therefore, "the Space Exploration Initiative is an investment in the future of America."

The Synthesis Group, composed of a 27-member steering committee backed by 81 government and industry space experts, screened and analyzed more than 1,500 innovative ideas from a broad cross-section of the nation on how to accomplish the Moon/Mars missions envisioned by President Bush in his July 1989 declaration of space goals. The group distilled and integrated the many submissions into a strategy that offers four alternative approaches, or architectures, to achieving the goals (an architecture is defined as a set of objectives and a sequential series of missions to implement the objectives).



The architectures have a common thread in that a period of lunar research and operations precedes Mars exploration in all cases; the differences lie in the areas of emphasis. The alternatives are:

- ***Mars Exploration***, which contemplates an initial mission to the Moon in 2005. The emphasis is on Mars exploration and science; the Moon is explored in the course of developing operational concepts for Mars, but the lunar infrastructure is developed only to the degree necessary to test and gain experience with Mars systems and operations. The first human mission to Mars would occur in 2014 and involve a surface stay of 30 to 100 days; a second mission would begin in 2016, with a 600-day stay planned.
- ***Science Emphasis for the Moon and Mars***, in which lunar/Mars science are equally emphasized. The initial human mission to the Moon would take place in 2003, followed by a decade of extensive human activity on the lunar surface, backed by human-controlled robotic operations.



An artist's conception of the first human landing on Mars, circa 2019 in the vicinity of the mountain Olympus Mons. In the foreground, astronauts are conducting scientific observations and recording planetary features with a hand-held camera. In the background at right is the excursion vehicle in which the explorers descended to the surface from a much larger interplanetary transfer vehicle.

After development of surface capabilities for construction, maintenance and operations, including deployment of portable observation instruments, emphasis would shift to larger scientific instruments and experiments. Continuous exploration, including activities on the surface and in lunar orbit, would yield a significant scientific return and pave the way for an initial expedition to Mars in 2014.

- ***The Moon to Stay and Mars Exploration***, which emphasizes permanent human presence on the moon, beginning in 2004, combined with Mars exploration. A major objective for the lunar outpost is development of life support self-sufficiency for breathing gases and food production. Science on the Moon would emphasize exploration and observation; with a permanent lunar human presence, advanced and sophisticated astronomical observatories can be built. Lunar surface and orbital operations would provide the necessary life sciences and engineering data to prepare for the Mars mission, which would commence in 2014.
- ***Space Resource Utilzation***. This architecture emphasizes making maximum use of space resources for direct support of exploration missions. It seeks to develop lunar resources for transportation, construction, habitation, life sciences, energy production and other long term space activities. A robotic experimental resource producing plant would be landed on the Moon in 2003, followed by the initial human mission to the Moon in 2004 and the Mars expedition in 2016. After basic exploration of Mars on the first two missions, additional resource development would be conducted on the Red Planet.

The Synthesis Group concluded, after study of the various options, that "chemical propulsion from low Earth orbit, as used in the Apollo program, is still the preferred way to get to the Moon." However, the report noted, significantly greater lift capability is needed to support any of the architectures. The group called for development of a heavy lift launch vehicle with a minimum capability of 150 metric tons and design growth potential for 250 metric tons.

For Earth to Mars transfer, the report states, "the nuclear thermal rocket is the preferred propulsive system to allow significantly reduced mass to low Earth orbit, shorter transit times and greater operational flexibility."

The Exploration Directorate of NASA's Office of Aeronautics, Exploration and Technology is analyzing the options presented by the Synthesis Group. Over the next two years, NASA will be developing a strategic plan to meet the President's objectives for space exploration. *(Continued)*

Space Operations

Space Operations: To the Moon and Mars (Continued)

In a March 1990 policy statement by President Bush, NASA was designated the principal implementing agency for the Space Exploration Initiative (SEI).

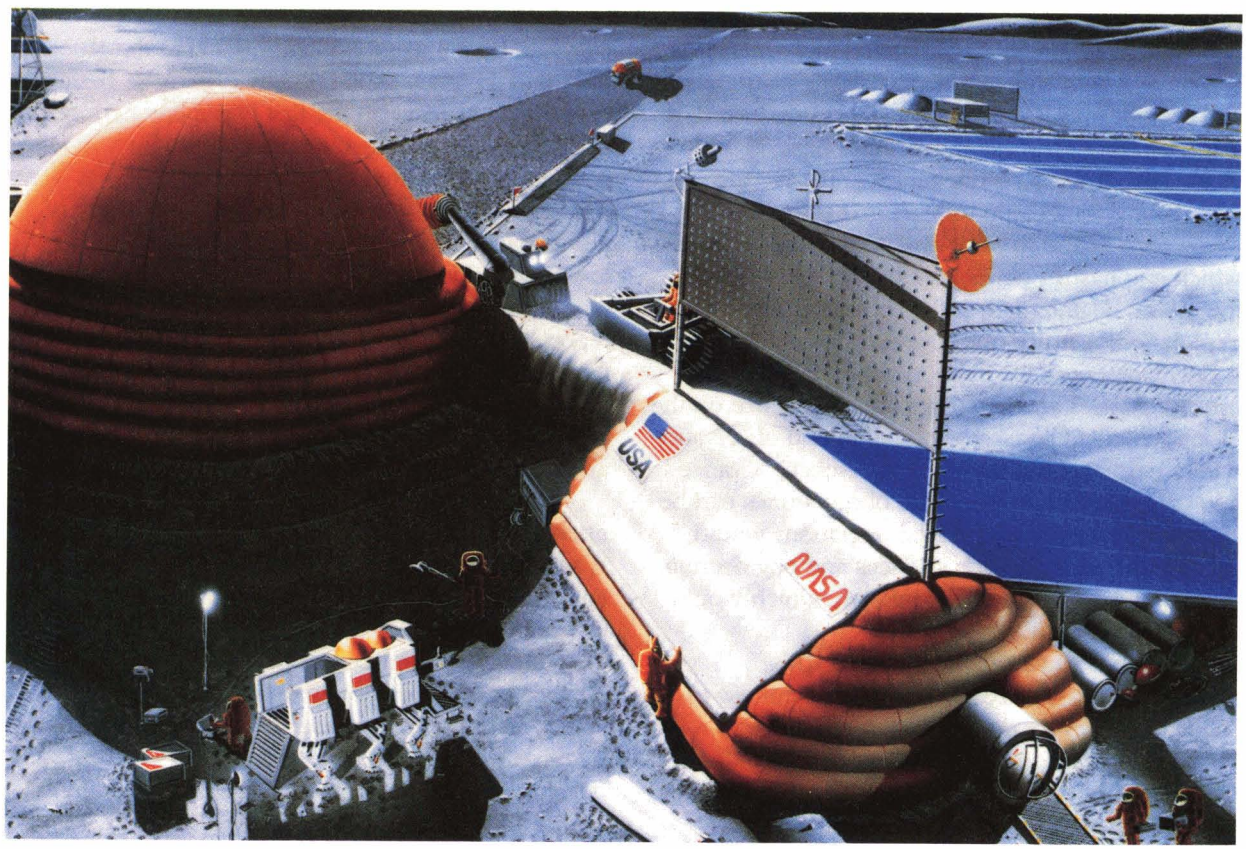
The Departments of Defense and Energy have major roles in SEI concept definition and technology development. In the 1990s, NASA will be working with these and other agencies laying the foundation for 21st century execution of the advanced missions contemplated.

SEI is not yet a fully defined program. It is, according to Arnold D. Aldrich, NASA Associate Administrator for Aeronautics, Exploration and Technology, "an integrated set of activities leading to the establishment of a permanent lunar base and culminating in the human exploration of Mars. SEI envisions exploration of the Moon and Mars as a continuous endeavor encompassing both human beings and robotic systems. SEI is not 'the next manned hardware program.' Rather, it is a strategic horizon that will direct, focus and integrate many of NASA's and the nation's current and future space activities."

NASA's strategy for the initial phase of SEI calls for investment of a small amount of money — now — in detailed preparatory work to define policy, cost and schedule options that enable sound decisions as to how to proceed.

Accomplishment of SEI goals requires a broader science and technology base than currently exists. NASA is building that base in several ways: through an expanded technology program that addresses generic fundamental research; an ongoing initiative that focuses on near-term transportation systems, technologies to support science investigations, and technologies to enhance Earth orbital operations; and an exploration technology program devoted to development of critical capabilities that will make possible a wide range of manned and robotic missions.

The Synthesis Group's report lists 14 areas that merit priority in technology development, among them a heavy lift launch vehicle for increased payload capacity on Earth-to-orbit and lunar missions, and a nuclear thermal propulsion system for Mars missions *(see preceding page)*.



An artist's conception of a lunar outpost, including a construction "shack" at far right and an inflatable habitat (orange dome) that houses 12 Moon explorers.

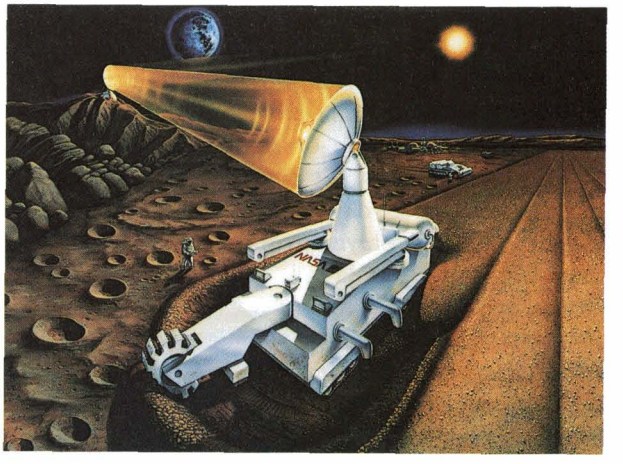
In development at Jet Propulsion Laboratory is an experimental planetary rover equipped with stereo cameras and an arm to grasp surface samples. It is semi-autonomous; a human operator plans its route but the vehicle can maneuver itself around sensed obstacles.

In addition, the list includes nuclear electric surface power systems capable of generating power to a megawatt level, and a nuclear electric propulsion system for unmanned cargo missions where transit time is not an important constraint.

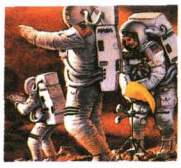
Key human support technologies on the group's list are a closed loop life support system, zero gravity countermeasures, radiation protection and human factors for long duration missions; the latter includes such factors as habitat design, human-machine interfaces, environmental considerations (such as lighting and ventilation), and psychological/ psychosocial considerations (crew selection for compatibility, optimal crew size and mix, provision for recreation).

A life support requirement of particular importance is a new, much advanced extravehicular space suit, which must protect the astronaut from vacuum, low pressure atmosphere; extremes of temperature; clinging particles of dust; micrometeorites; and soils that are potentially chemically reactive. The suit must be reliable, mobile, dextrous, comfortable and easily maintainable, and it must be able to contend with gravity levels ranging from zero to three-eighths Earth's gravity.

Rounding out the group's list are systems for automated rendezvous and docking of large masses; cryogenic fuel transfer and long term storage; telerobotics; lightweight structural materials and simplified construction techniques; and equipment/ techniques for on-site evaluation and processing of resources.



The NASA-sponsored University of Wisconsin (Madison) Center for Space Automation and Robotics developed this concept of a robotic system for extracting gases from lunar soil.



Space Shuttle Operations

At right is the newest addition to the Space Shuttle fleet, the Orbiter *Endeavour,* which was rolled out of its construction facility at Palmdale California and formally delivered to NASA on April 25, 1991. Built by Rockwell International's Space Systems Division, *Endeavour* was mated to NASA's Boeing 747 Shuttle Carrier Aircraft and flown to Kennedy Space Center for installation of its main engines and orbital maneuvering system.

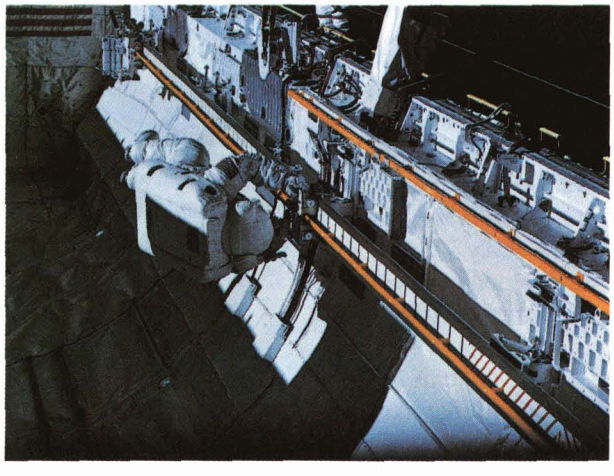
Endeavour's *delivery restored the Shuttle fleet to four Orbiters*

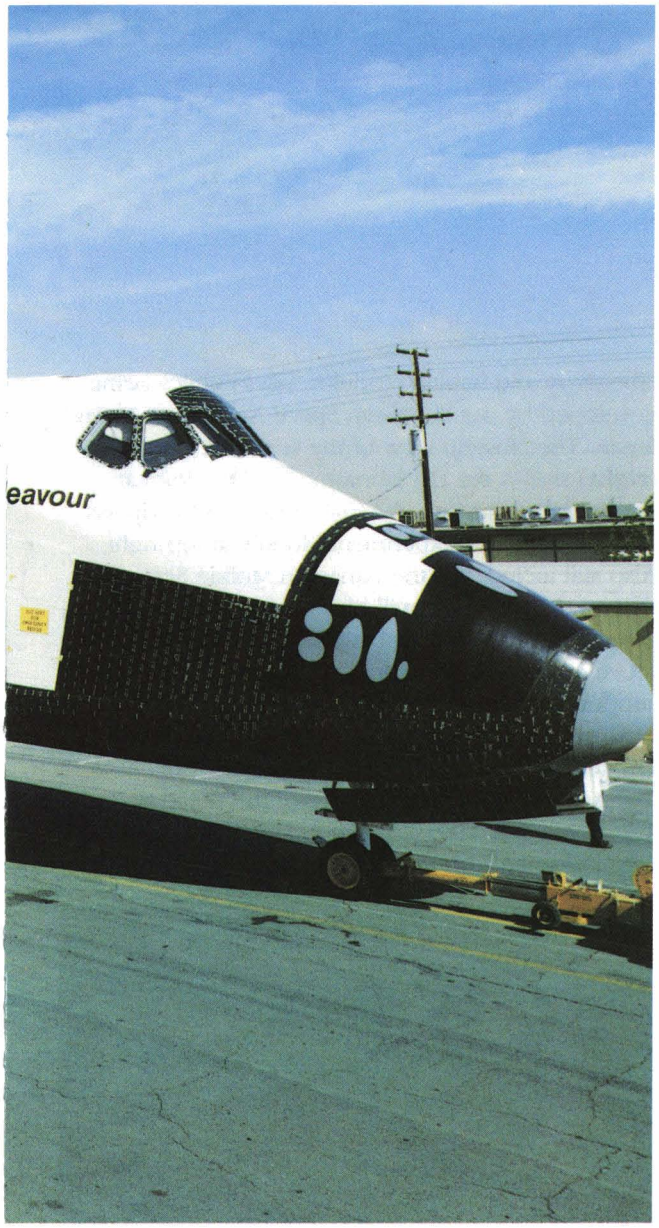
Endeavour's delivery restored the Shuttle fleet to four Orbiters. The new Orbiter is scheduled for its initial flight in May 1992.

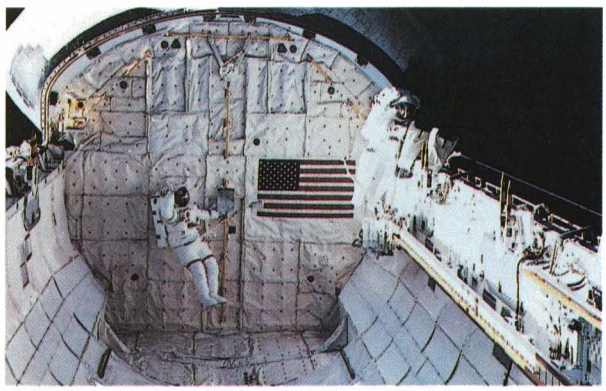
Earlier in April, NASA marked 10 years of Space Shuttle operations with the April 11 completion of flight STS-37, flown by the Orbiter *Atlantis.* The Shuttle flight program began with STS-1, Orbiter *Columbia,* on April 12, 1981.

The *Atlantis* flight, the 39th Shuttle flight, was a highly successful six-day mission whose primary assignment was deployment of the 17-ton Gamma Ray Observatory, or GRO (**see page 15**). The crew also accomplished several secondary objectives, including the first extravehicular activity (EVA) in five years. The initial spacewalk was an unscheduled event, necessitated when the GRO high-gain antenna boom became stuck during the deployment sequence. Astronauts Jerry Ross and Jerome (Jay) Apt donned EVA suits, managed to free the stuck boom and maneuver the antenna into place, demonstrating the extra insurance of human-aided satellite deployments.

A second, planned EVA involved a test of personnel carts and equipment-moving devices known as Crew and Equipment Translation Aids. Apt and Ross tested three carts, one manually moved, one powered by a mechanical pump, and the third an electrically-powered cart driven by a hand-cranked generator; the carts were run along a 47-foot track in *Atlantis'* open payload bay. **At left** Apt moves along the rail on one of the carts; **at far right**, Ross (in center photo) and Apt wave at their fellow crew







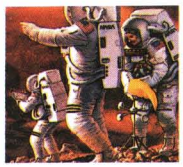
members in *Atlantis'* cabin on completion of the 6 1/2 hour evaluation of the devices' suitability for use on Space Station *Freedom.*

STS-37 was the first Shuttle flight of 1991. The second, STS-39, came on April 28 with the launch of the Orbiter *Discovery* carrying multiple Department of Defense experiments associated with the Strategic Defense Initiative. On this first unclassified Shuttle defense mission, *Discovery* carried two primary payloads: the Infrared Background Signature Survey (IBSS) and an instrument package designated Air Force Program 675.

The IBSS experiment involved deployment (and later retrieval) of a free-flying Shuttle Pallet Satellite (SPAS-2) built by the German firm Messerschmitt-Boelkow-Blohm. The pallet was released from the Orbiter and the Orbiter moved away so that the instruments on SPAS-2 could observe the rocket plumes from firings of the Orbiter's maneuvering and re-entry engines. At distances up to 10 kilometers, the SPAS instruments recorded images of the plumes in ultraviolet, infrared and visible wavelengths, obtaining data that will be used to enhance computer simulations of attacking nuclear missiles. In another series of experiments, SPAS-2 observed and recorded data from chemical and gas clouds created by canisters released from the Orbiter.

The Air Force Program 675 experiment included five instruments that remained in the Orbiter's payload bay. The instruments made infrared, ultraviolet and x-ray measurements of the Earth, stars and the Orbiter *Discovery,* providing both scientific data and information applicable to strategic defense research.

On the year's third shuttle flight, STS-40, Orbiter *Columbia* was launched June 5 for a 10-day life sciences investigation designated SLS-1, the first of several Spacelab Life Sciences missions planned for the 1990s. SLS-1 involved study of the effects of microgravity on human, animal and plant life; the living subjects were the human science crew, 29 rats and 2,478 jellyfish (**see page 20**).



Space Station Freedom

A stepping stone into the future

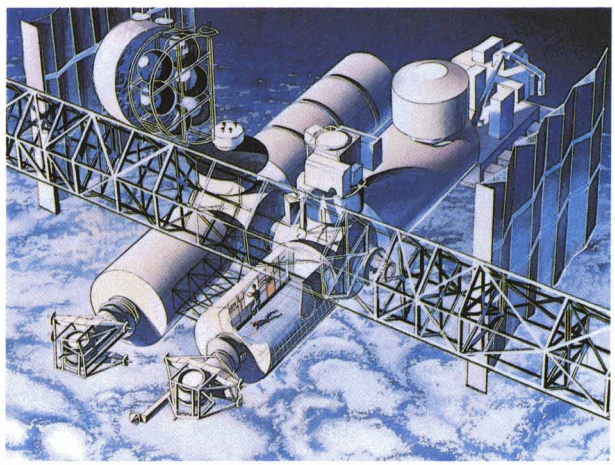
Shown below is an artist's conception of a new version of Space Station *Freedom*, which has been extensively redesigned to meet Congressional budgetary mandates. The new design is cheaper, smaller, easier to assemble in orbit and will require fewer Shuttle flights to build.

Freedom remains nonetheless a quality facility that will provide, in the words of NASA Associate Administrator for Space Flight William B. Lenoir, "a research laboratory unsurpassed in the world for life sciences and microgravity research, and a stepping stone into the future, enabling NASA to conduct the research and planning necessary for human exploration of the solar system."

The redesigned station maintains its international character. It still includes, along with the U.S. laboratory and habitat modules, lab modules being developed by the European Space Agency (ESA) and Japan. The closeup view of the central segment (**right**) shows the U.S laboratory and the habitat modules at lower left, the ESA laboratory at top left and the Japanese Experiment Module at top right. Also still included is the Canadian Mobile Servicing System (MSS), which will play a major role in assembling *Freedom* and thereafter will be used to move equipment and supplies around the station, support astronaut extravehicular activity (EVA) and load/unload materials from docked Space Shuttle Orbiters.

Among major new features of the space station are shorter U.S. laboratory and habitat modules and a "pre-integrated" truss. In the earlier design, the truss

was to have been assembled, like a massive erector set, by spacewalking astronauts. In the new design, truss segments will be built, assembled and checked out on the ground. NASA estimates this technique will cut assembly EVA by more than 50 percent.



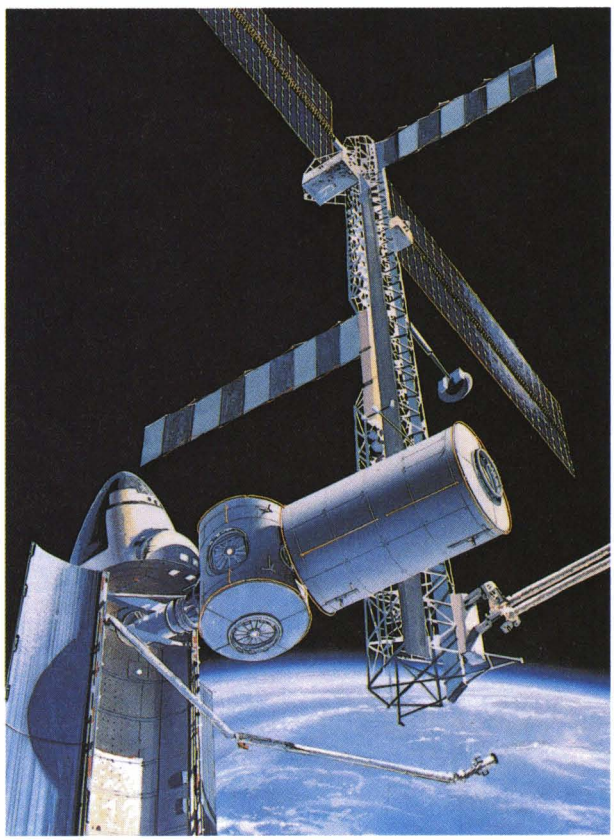
The U.S. modules are some 40 percent shorter than in the previous design but — at 27 feet long and 14.5 feet in diameter — still roomy for a crew of four. The smaller size allows complete outfitting and testing of the modules on the ground before their delivery to orbit.

Another new feature is the Assured Crew Return Vehicle, to be available by the time the station is permanently occupied, that will permit crew evacuation of the station and return to Earth in an emergency.

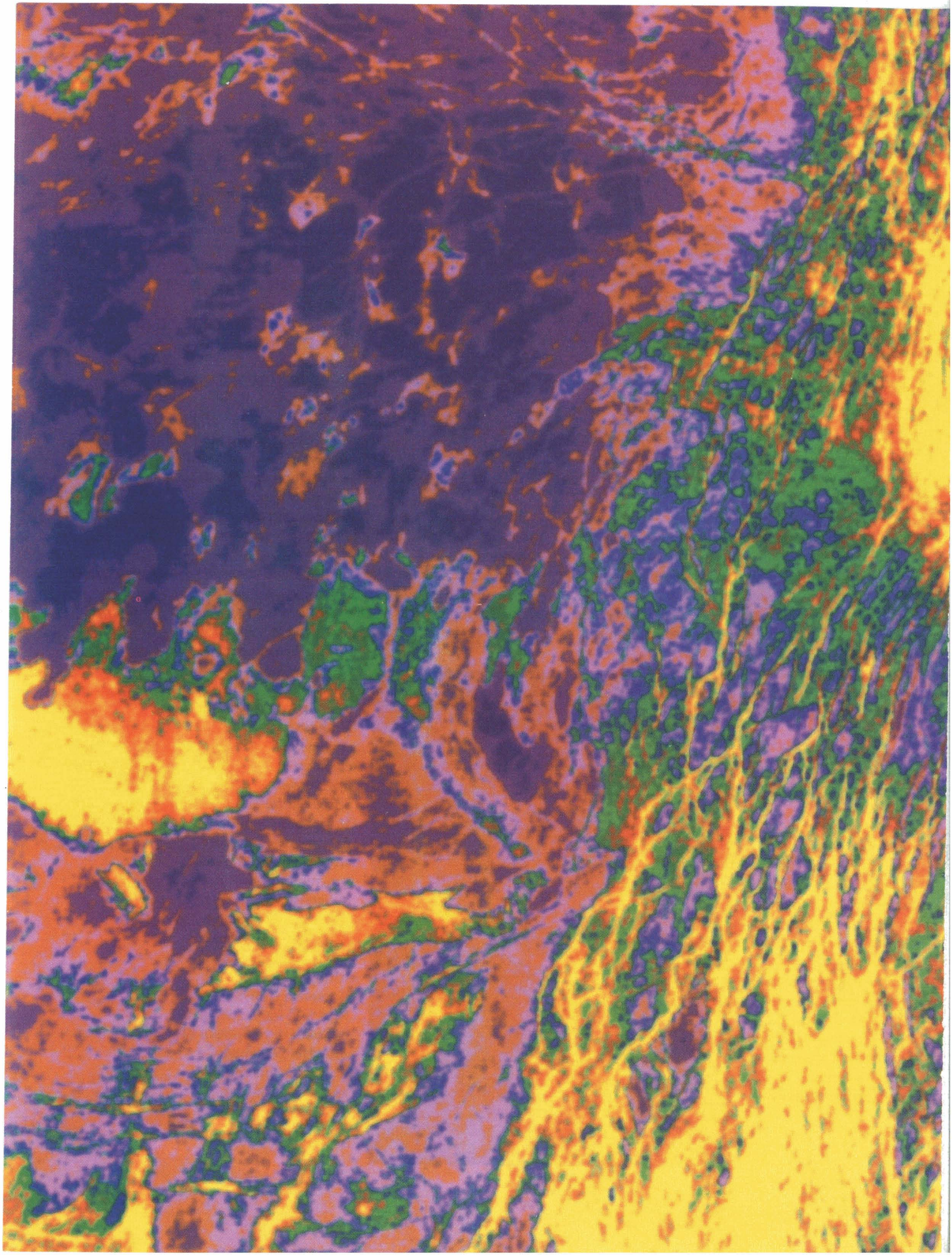
The restructured program calls for the first element launch of space station components in the second quarter of 1996, and man-tended capability in the third quarter of 1997. In the man-tended phase, astronauts delivered to the station by Shuttle Orbiter will be able to work in the U.S. laboratory for periods up to two weeks, living aboard the Orbiter. The man-tended configuration is shown in the **bottom** photo.

The permanently manned configuration is targeted for Fiscal Year 2000; this configuration includes the U.S.-built habitat, the U.S., ESA and Japanese laboratories, the MSS, accomodations for a live-in crew of four, and three sets of solar arrays supplying 56 kilowatts of electrical power. It will take six Shuttle flights to achieve man-tended capability, 17 flights for the permanently manned configuration.

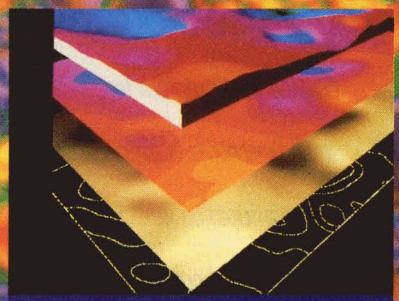
Freedom is being developed by three teams of contractors performing as many "work packages" under the supervision of three NASA centers. Marshall Space Flight Center, with prime contractor Boeing Aerospace Company, has responsibility for the U.S. laboratory and habitation modules, associated systems, logistics elements and payload operations. Johnson Space Center and McDonnell Douglas Astronautics Company are teaming on the truss structure, resource node outfitting, various flight systems, crew training and flight operations. Lewis Research Center, with prime contractor Rocketdyne Division of Rockwell International, is covering development of *Freedom's* complete power system and associated software.



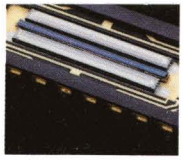
The restructured program calls for the first element launch of space station components in the second quarter of 1996



Technology Twice Used

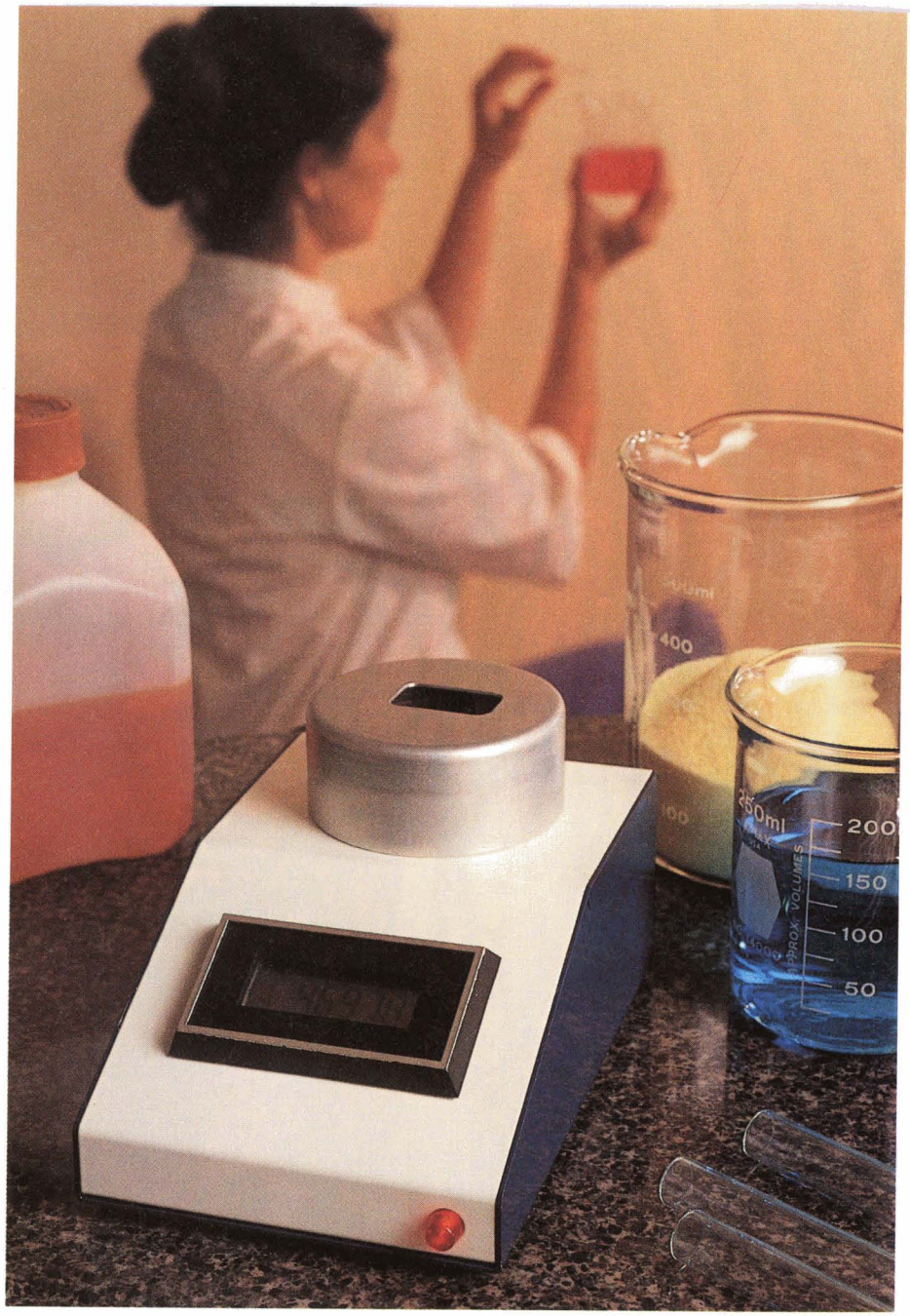


A representative selection of new products and processes adapted from technology originally developed for NASA mainline programs, underlining the broad diversity of spinoff applications and the social/economic benefits they provide



Small Business Innovations

A special research and development program for small businesses is expanding their participation in aerospace technology development and transfer



Pictured in a laboratory environment is a Femtometrics Model 200-1 SAW Mass Microbalance (foreground) developed under the NASA Small Business Innovation Research program. The microbalance is a highly sensitive instrument for detecting dust particle concentrations in clean rooms, measuring aerosols in the upper atmosphere, or monitoring the presence of toxic vapors in industrial environments.

The Small Business Innovation Research (SBIR) program was established by Congress in 1982. Its dual objectives were to increase participation of small businesses in federal high technology research and development activities, and to stimulate conversion of government-funded research into commercial applications. The program has been eminently successful in attaining both objectives.

Each technology-generating federal agency that has an extramural R&D budget of more than $100 million annually is obliged to set aside one and one-quarter percent of those funds for SBIR projects. There are 11 such agencies, each administering its own program independently under policy guidelines set by the Small Business Administration.

NASA's SBIR program has been particularly successful, both for NASA and the nearly 800 small businesses involved. The program provides NASA an additional source — beyond traditional aerospace companies — of R&D talent and innovative thought. Hundreds of new systems and components that advance NASA's capability for aerospace research and operations have emerged from the SBIR program. Similarly, NASA/SBIR contracts give small businesses an opportunity to hone their developmental skills and expand their technological capabilities.

There is another beneficiary: the U.S. economy, which benefits from the jobs created and the contributions to the nation's Gross National Product that result when an SBIR project generates a spinoff commercial application. In NASA's SBIR program, spinoffs have resulted in about one of every three projects completed.

A NASA/SBIR project starts with a proposal by the small business, in response to NASA's annual solicitation, for development of a novel idea or

concept. The agency evaluates the proposal from the standpoint of potential usefulness to NASA and the potential for becoming a commercial product or process. The best concepts are rewarded with six-month Phase I contracts for up to $50,000, under which the company determines the technical feasibility of the innovation it has proposed.

Phase II contracts are awarded competitively from proposals — submitted by Phase I contractors — that include the results of Phase I research; about half of the Phase I projects continue into Phase II, which can run as long as two years and be funded up to $500,000.

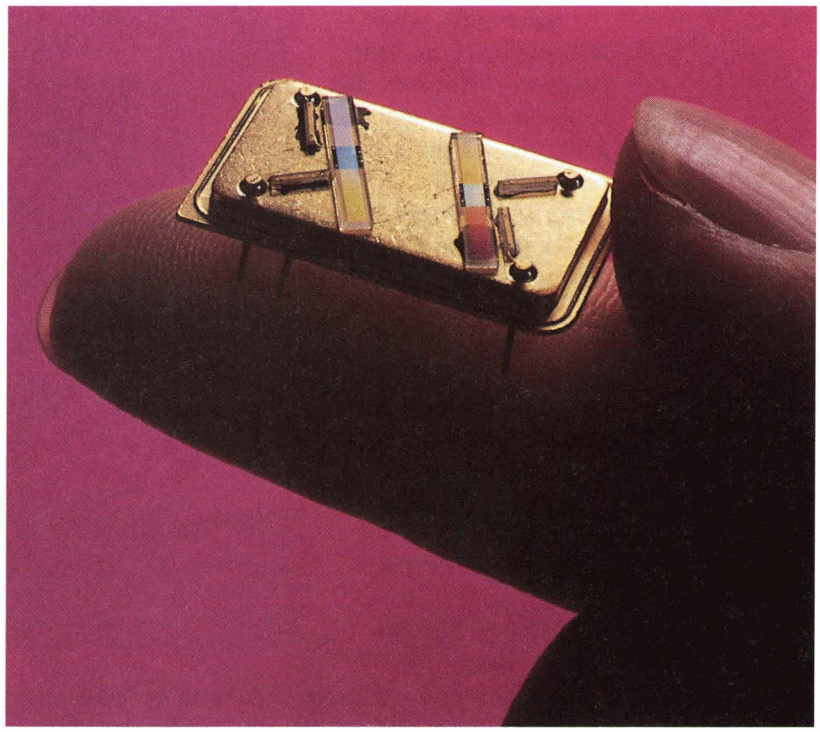
In Phase III, the small business participant may apply the results of Phase I/II research to development of a product or process for the commercial market, using private capital to do so. Phase III may also involve NASA's continued development and purchase for its own use of the products of Phase II — but NASA may not use SBIR set-aside funds for such purposes.

A NASA/SBIR project conducted by Femtometrics, Costa Mesa, California illustrates how a company conceived and developed an advanced instrument for government research, then adapted the same technology to creation of a commercial product of importance in the industrial workplace.

Since 1979, Langley Research Center has been using a NASA-developed instrument known as the QCM (short for quartz crystal microbalance cascade impactor) for collection and measurement of aerosol particles in the upper atmosphere. The system detects aerosols — tiny solid particles or liquid droplets — that collect on the quartz crystal, segregates them in 10 size categories and weighs them, providing information to environmental researchers on the size distribution and mass concentration of aerosols in the atmosphere.

Femtometrics responded to NASA's SBIR solicitation with a proposal for an advanced, much more sensitive aerosol detector to meet a perceived need for measurement of extremely low concentrations of aerosols and detection of sub-micron particles in clean rooms where aerospace systems are assembled. The proposal won Femtometrics a Langley Research Center Phase I SBIR contract and the results led to Phase II development of the instrument.

The resulting product is described as "the next generation of aerosol mass microbalance technology," an instrument of extreme sensitivity due to use of a new type of sensor, the surface acoustic wave (SAW) piezoelectric crystal. It offers a mass resolution two orders of magnitude greater than the crystal in the QCM.



Shown above is the fingernail-size sensor unit located in the cylinder atop the instrument; it is actually two separate crystals, one the active sensor, the other a reference.

Femtometrics used the technology to develop a commercial product, the Model 200-1 SAW Mass Microbalance, which provides a 400-fold increase in mass sensitivity per unit area over the conventional bulk crystal microbalance. The instrument can be used for real-time particle monitoring in clean rooms. It also has utility in measurement of chemical vapors in very low concentrations; the SAW crystal is coated with a thin chemical film that reacts with and detects the particular vapor. This provides a means of measuring target chemicals in the stratosphere that are of interest to environmental researchers because of the key roles of these chemicals in climate and stratospheric chemical composition. The same technology enables detection of toxic chemicals in the industrial environment; the small size, low cost and high sensitivity of the Model 200-1 SAW Mass Microbalance makes the instrument attractive for use as an industrial toxic vapor monitor.

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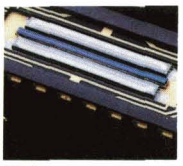
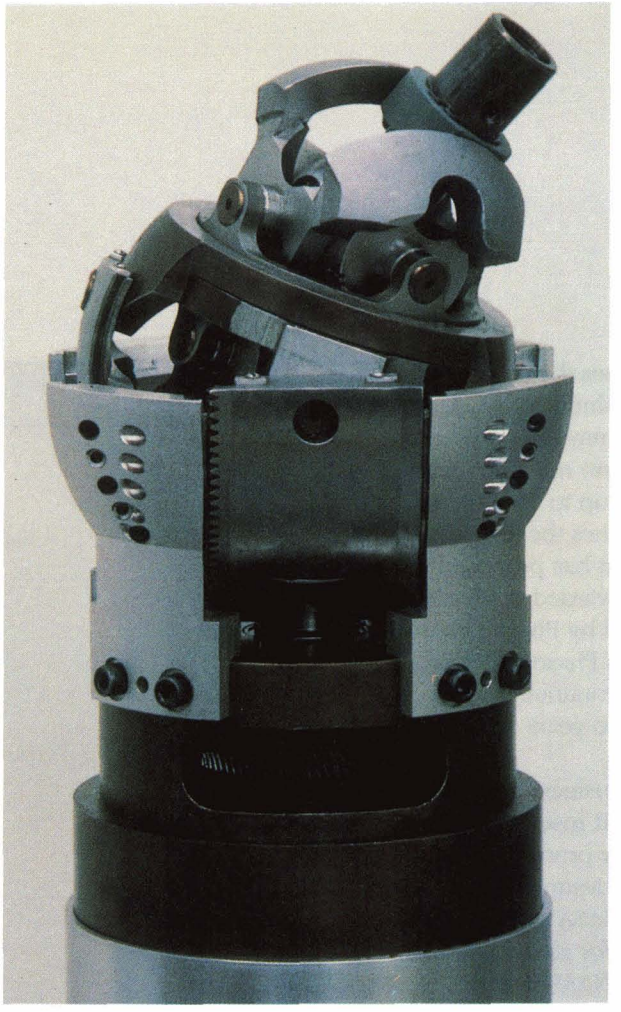


Prologue



Ross-Hime Designs, Inc. developed the Omni-Wrist robotic arm with humanlike dexterity and greater-than-human range of motion.

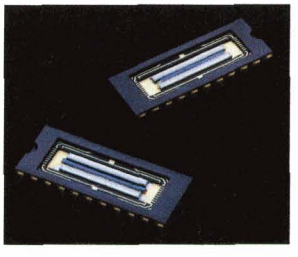
Small Business Innovations

(Continued)

Since 1983, when NASA initiated its SBIR program, the agency has sponsored more than 1,500 Phase I projects handled by 765 companies; by mid-1991, 632 of those projects had proceeded into Phase II with 377 firms participating.

NASA has obligated a total of $348 million for SBIR contracts, which are managed by NASA field installations as part of their overall R&D activities. Nearly 300 Phase II projects have been completed and roughly half of the innovations produced have been used in NASA programs or are planned for use. The bottom line, from the standpoint of economic benefit, is that about a third of the completed projects have generated commercial applications.

Here are some examples:



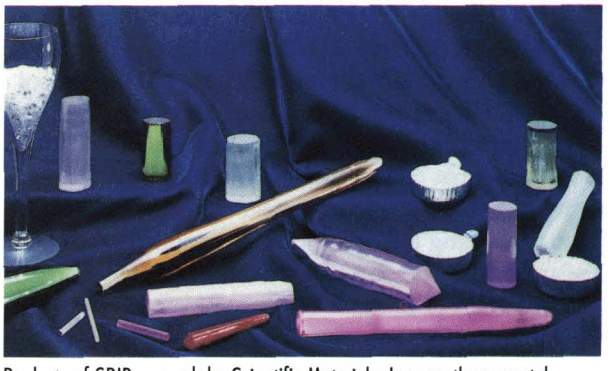
SBIR work by Epitaxx, Inc. led to commercial development of these high performance infrared photodetectors for remote sensing, fiber optics and other applications.

Ross-Hime Designs, Inc., Minneapolis, Minnesota developed what company literature calls "the first successful singularity-free high-precision (robotic) wrist." Singularity is a phenomenon of robotics that can cause a joint to jam as it attempts to move in an area where it has no axis of rotation or range of motion; singularity can cause damage to equipment or tooling.

Under a Langley Research Center SBIR contract, Ross-Hime developed a commercially available Omni-Wrist™ actuator, which has a 25-pound capacity, 180 degrees of pitch/yaw and 360 degrees of roll (another version, Omni-Wrist II, offers a 100-pound load capacity and the same range of motion). Applications include spray painting, sealing, ultrasonic testing, welding and a variety of nuclear industry, aerospace and military uses.

Epitaxx, Inc., Princeton, New Jersey received a Goddard Space Flight Center SBIR contract to develop a linear detector array for satellite imaging applications. The array employs indium-gallium-arsenide alloys and can operate at room temperature; earlier detectors have to be cooled to extremely low (cryogenic) temperatures and that is both difficult and expensive.

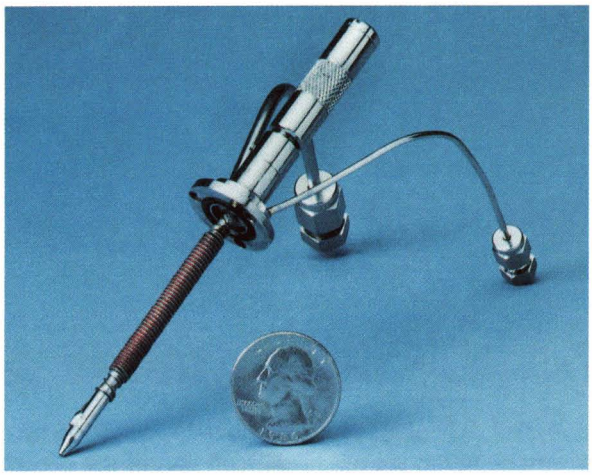
Epitaxx used the same technology to create a series of commercial products, including the Epitaxx Near Infrared Room Temperature Indium-Gallium-Arsenide Photodetectors. The basic device is a photodetector that provides an electrical signal when it is exposed to a scene that radiates energy in the near infrared. It has applications as a laboratory tool for generating optical spectra, and for remote sensing, fiber optic and laser position-sensing applications.

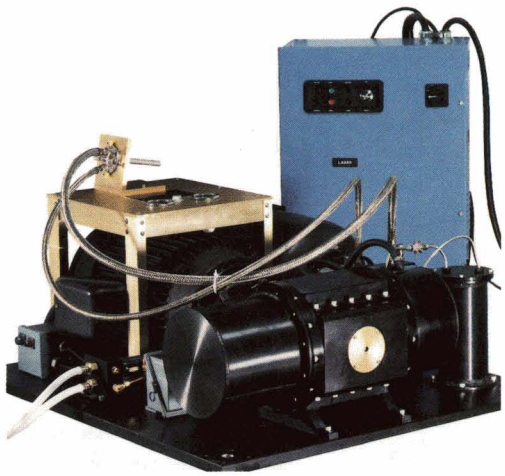


Products of SBIR research by Scientific Materials, Inc. are these crystal components for solid state lasers.

For Kennedy Space Center, General Pneumatics Corporation, Scottsdale, Arizona developed a special Joule-Thomson (JT) expansion valve that is far less susceptible to clogging by particles or condensed contaminants in the flow than are conventional JT valves. The company employed the technology in a commercial anti-clogging cryostat that liquefies gases by expansion from high pressure through a nozzle to produce cryorefrigeration. The cryostat is combined

An employee of Lightwave Electronics is holding a Series 122 MISER ring laser, which has applications in fiber sensing, communications and laser radar.



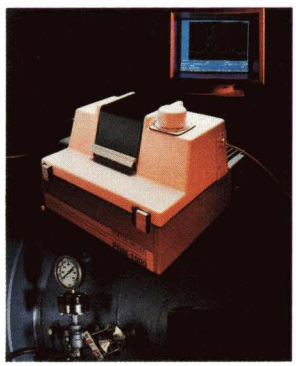


General Pneumatics Corporation's participation in a NASA SBIR project resulted in two commercial products: a non-clogging cryostat (left) to liquefy gases for extremely low temperature cryorefrigeration, and the cryocooler (right) used to generate cryogenic cooling for infrared sensors, superconductors, supercooled electronics and cryosurgery.

with the company's non-contaminating compressor in another General Pneumatics commercial product, a closed cycle Linde-Hampson cryocooler used to generate cryogenic cooling for infrared sensors, super conductors, supercooled electronics and cryosurgery.

Lightwave Electronics Corporation, Mountain View, California, received an SBIR contract from Jet Propulsion Laboratory for a Prototype Laser Diode-pumped Solid State Transmitter. The company delivered a low noise ring laser with voltage tuning that could be used as a local oscillator in an optical communications system. The voltage tuning feature allows "phase-locking" the lasers, making them "electronic", similar to radio and microwave electronic oscillators. From this technology, Lightwave developed the Series 120 and 122 non-planar diode pumped ring lasers for applications in fiber sensing, coherent communications and laser radar.

Foster-Miller, Inc., Waltham, Massachusetts, in SBIR cooperation with Langley Research Center, developed the first analytical system capable of directly measuring the chemistry of advanced composite materials. It employs an infrared fiber optic sensor, embedded in the composite material, to track the molecular vibrational characteristics of a composite part while it is being cured in a press or an autoclave. Thus, says a company official, it "provides first hand information about chemical reactions as opposed to measuring a secondary change." The patented In Situ Fiber Optic Polymer Reaction Monitor, which won a 1990 R&D 100 award, could lead to significantly higher yields in the manufacture of complex composite parts, with consequent reduction in cost. It is expected to find broad research and commercial utility in aerospace, industrial and environmental applications.



An award-winning innovation by Foster-Miller, Inc. is a technique and a system for monitoring chemical reactions in composite materials while they are undergoing cure in a press or autoclave.

Scientific Materials Corporation (SM), Bozeman, Montana, under a Langley SBIR contract, developed a SciMax™ line of improved Nd:YAG crystals for laser and electro-optic applications (Nd:YAG is short for the materials involved — neodymium, the dopant, with yttrium aluminum garnet). SM's research provided a process for producing uniform laser rods in which the amount of water trapped in the crystal during growth is reduced, thereby improving efficiency, and the properties that affect optical quality are also improved for a further gain in crystal efficiency. SM is producing the crystals for the commercial market; applications include fiber optics, telecommunications, welding, drilling, eye surgery and medical instrumentation.

™Omni-Wrist is a trademark of Ross-Hime Designs, Inc.

™SciMax is a trademark of Scientific Materials Corporation.

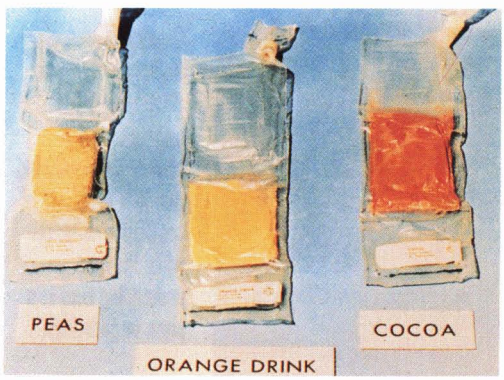
A Dividend in Food Safety

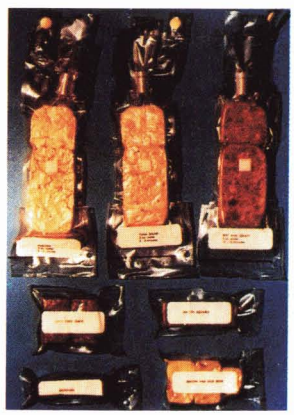
Among technology transfers that contribute to enhanced public safety is a broadly-used space-derived food processing control system

In 1959, NASA started planning for manned space missions. Along with the myriad difficulties of developing complex systems to sustain life in space, NASA faced a seemingly mundane but vitally important problem: How and what do you feed an astronaut in a sealed capsule under weightless conditions?

There were two principal concerns: barring crumbs of food particles that might contaminate the spacecraft's atmosphere or float their way into sensitive instruments; and assuring absolute freedom from potentially catastrophic disease-producing bacteria and toxins. To help solve these problems, NASA enlisted the aid of one of the nation's foremost food producers, The Pillsbury Company, Minneapolis, Minnesota. Over the following decade, Pillsbury designed some of the first space foods and produced astronaut meals for the Mercury, Gemini and Apollo manned space flight programs. (Pillsbury was acquired in 1988 by the United Kingdom-based Grand Metropolitan PLC.)

Pillsbury solved one of the two major concerns in short order by developing bite-size foods coated with a material that would prevent the product from crumbling. The other part of the problem did not succumb as easily. Dr. Howard E. Bauman, now a food industry consultant in St. Louis Park, Minnesota and formerly a Pillsbury executive who worked on the initial space food program, states that the most difficult part of the program was "to come as close as possible to 100 percent assurance that the food products we were producing for space use would not be contaminated by pathogens, bacterial or viral, that could cause an illness that might result in a catastrophic mission."





"We quickly found," he adds, "by using standard methods of quality control there was absolutely no way we could be assured there wouldn't be a problem. This brought into serious question the then prevailing system of quality control in our plants....If we had to do a great deal of destructive testing to come to a reasonable

Above and at right center are examples of food and drink products carried aboard spacecraft on early manned missions. Measures developed by The Pillsbury Company to assure astronaut protection from food poisoning evolved into a comprehensive food safety system used by Pillsbury and other manufacturers.

conclusion that the product was safe to eat, how much were we missing in the way of safety issues by principally testing only the end product and raw materials?

"We concluded after extensive evaluation that the only way we could succeed would be to establish control over the entire process, the raw materials, the processing environment and the people involved."

Using that approach, Pillsbury developed the Hazard Analysis and Critical Control Point (HACCP) concept, potentially one of the most far-reaching space spinoffs. HACCP is designed to prevent food safety problems rather than to catch them after they have occurred. It is essentially a two-part concept. The Hazard Analysis portion involves a systematic study of the ingredients, the product, the conditions of processing, handling, storage, packaging, distribution and consumer use directions to identify sensitive areas that might contribute a hazard. Hazard Analysis provides a basis for blueprinting the Critical Control Points to be monitored (a Critical Control Point is any point in the chain from raw materials to finished product where loss of control could result in an unacceptable food safety risk).

A significant feature of the HACCP concept is that food production is regarded as an interlocking *system,* not only a farm or a processing plant or a supermarket or a consumer, but all of those, along with the distribution elements of the system.

Each link in the chain is analyzed and controlled individually, but for satisfactory results each link is dependent upon the links preceding it and following it. Unexpected or unknown safety problems with raw materials, unrecognized or uncontrolled abuse in the distribution system, careless or otherwise improper handling by the consumer — these and other matters that can create food safety problems must be identified in the Hazard Analysis phase and addressed by appropriate monitoring of Critical Control Points.

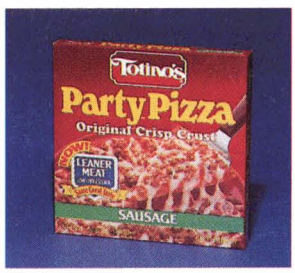
With this system, food producers can control any area in the food system that could contribute to hazards, whether it involves contaminants, bacteria, physical objects, chemicals, raw materials, a process, consumer use directions or storage conditions.

The Pillsbury-manufactured food that went to the Moon aboard Apollo spacecraft was produced under the HACCP system. Within two years of the initial lunar landing in 1969, Pillsbury plants were producing food for regular consumers following the same food safety control system. Later, Pillsbury taught a course in HACCP for personnel of the Food and Drug Administration (FDA). In the mid-1970s, FDA published the Low Acid Canned Foods Regulations, which employ the HACCP concept to ensure safety of all canned foods in the U.S.

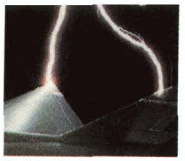
In 1985, HACCP was recommended by the National Academy of Sciences as the method of choice for preventing microbiological food safety problems. In 1988, it was further recommended by the National Advisory Committee on Microbiological Criteria for Foods. HACCP has been endorsed by components of the World Health Organization, suggesting, in the words of Dr. Bauman, "that some day the world food industry may be playing with the same deck of cards."

In the United States, three other government agencies are taking preliminary steps toward extending HACCP to meat/poultry and seafood inspection operations *(see following page).*

Today, Pillsbury plants are still operating under HACCP and their managers are delighted with the results. Says Pillsbury: "There have been more than 130 food safety-related recalls of product from the marketplace from 1983 to 1991. None were Pillsbury products. HACCP works!" *(Continued)*

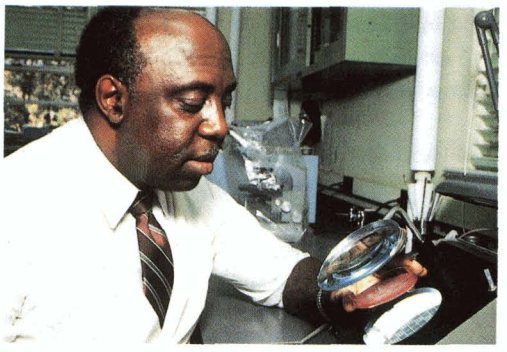


Above and at left is a sampling of Pillsbury consumer products manufactured under the spinoff system of food processing control that ensures maximum food safety.



Public Safety

A Dividend in Food Safety (Continued)



The U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS), the public health agency responsible for inspecting meat and poultry, each year inspects more than 120 million head of livestock, six billion birds, and billions of pounds of meat and poultry products. It is, says FSIS Assistant Administrator Dr. Catherine E. Adams, "the most intensive food inspection system in the world." Nonetheless, FSIS is engaged in a major effort to improve it. Dr. Adams elaborates:

"It is the industry's job to produce safe, wholesome, accurately labeled meat and poultry products. It is the agency's job to see that industry does its job well and consistently.

"We are committed to the continuous improvement of our inspection program to better protect public health. We believe the inspection job can best be done by *preventing* potential problems from occurring — including microbial and chemical contamination. The FSIS is convinced the Hazard Analysis and Critical Control Point (HACCP) system will serve as the best mechanism for preventing unsafe and unwholesome product."

Following up on recommendations from the National Academy of Sciences and the National Advisory Committee on Microbiological Criteria for Foods, FSIS is conducting a study to determine the best way to incorporate HACCP into the meat and poultry inspection program. Dr. Adams is executive director of the HACCP project; Dr. Wallace Leary, a 20-year FSIS employee, heads a HACCP Special Team that is conducting workshops, pilot plant tests and evaluations. Says Dr. Leary:

"The HACCP study will allow us — and industry — to develop and test model HACCP plans for specific products and processes. We'll then test the HACCP plans in volunteer plants, working with our in-plant employees. The process will allow us to see how HACCP works under realistic conditions."

Dr. Leary believes that HACCP will permit inspection personnel to do an even better job of protecting public health. The focus of inspection will

The Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture is conducting an extensive study to determine how the spinoff Hazard Analysis and Critical Control Point concept can best be incorporated into the FSIS meat and poultry inspection program. The photos illustrate some FSIS inspection and test operations. Top left, a microbiologist is observing bacteria on a blood sample plate; above, a food inspector is checking the internal temperature of sausages to ensure the product is safe to eat; at right, a veterinarian at a hog slaughter plant screens hog carcasses for contamination; at top right is a closeup of a "quick test" that shows whether roast beef has been sufficiently cooked to destroy disease-producing bacteria, such as salmonella.

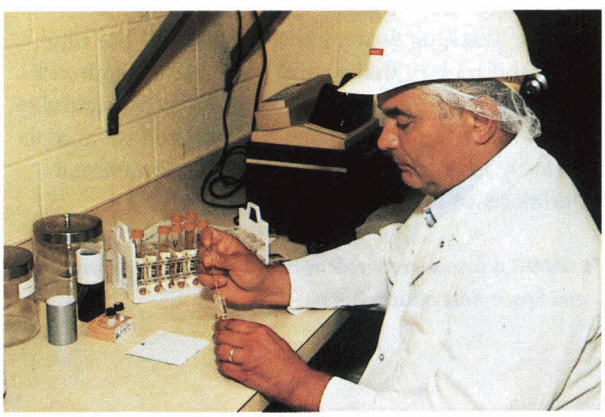
change, with less emphasis on the final product and greater attention to the safety steps along the way where contamination could occur. To explain HACCP, he cites an example: production of cooked turkey breast that is vacuum packaged and then pasteurized.

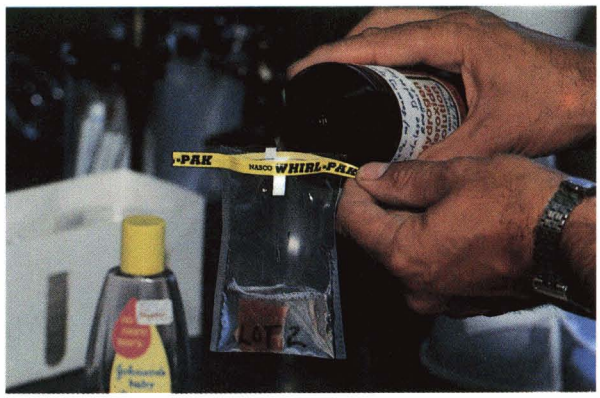
"The first step is to identify the Critical Control Points (CCPs), or those steps in the process that could result in an unsafe product if not properly followed. In this example, CCPs could include cooking, chilling, rehydrating, pasteurization, chilling again, and storing. Once you've determined the CCPs, you then set the criteria that must be met for each one, as well as the monitoring and verification methods.

"In our example, according to current regulations, the cooking CCP would require the turkey to be cooked to a 160 degree Fahrenheit internal temperature. Plant personnel would be required to check and record the cooking temperature regularly; the inspector would check the plant's records for authenticity and accuracy, verify that the thermometer measured the temperature accurately, and periodically double-check the internal temperature of the product.

"This example illustrates the simplicity of HACCP, but when the CCPs are determined, monitored and verified on an ongoing basis, you have a sophisticated process control system with little chance of manufacturing an unsafe or otherwise contaminated product."

The FSIS study began at the end of 1989. Initial steps in 1990 included public hearings and consultations with consumer groups, industry and FSIS employees to get their input. A series of workshops with food industry technical experts got under way in February 1991. FSIS expects to complete in-plant tests and evaluation in 1993.





In another government program, the Food and Drug Administration (FDA) and the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration are planning a HACCP-based voluntary inspection service for seafood.

Seafood is regulated at the federal level primarily by the FDA. NOAA Fisheries operates a voluntary fee-for-service seafood inspection program. The two agencies cooperate under an agreement whereby NOAA Fisheries ensures that clients' operations and products meet FDA requirements as well as NOAA Fisheries' own quality and identity requirements.

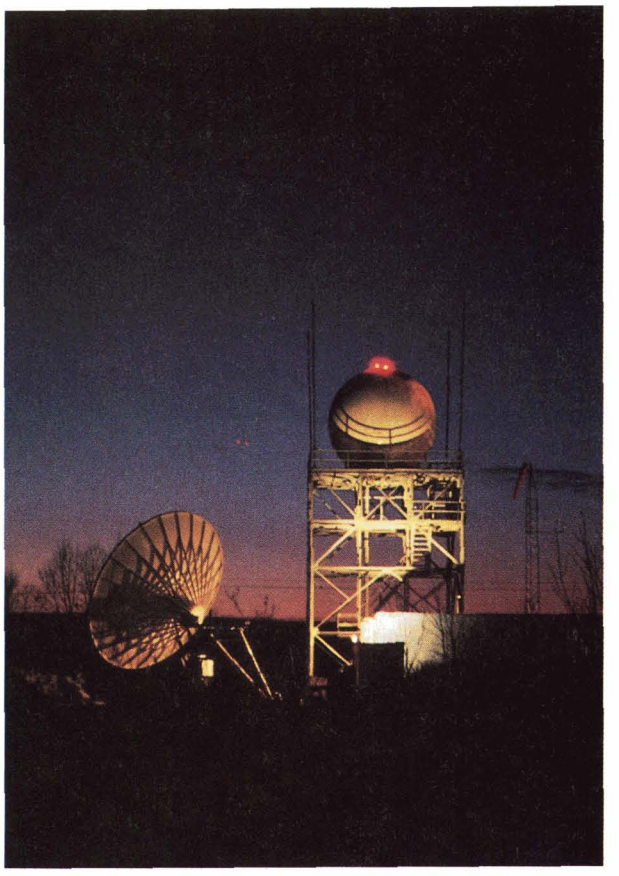
The new Voluntary Fish and Fishery Products Program will generally follow the HACCP approach, expanded to include economic and sanitation parameters. It will emphasize the industry's role in continuous problem prevention/problem solving, from "water to the table," rather than reliance on periodic government inspection and product sample analyses.

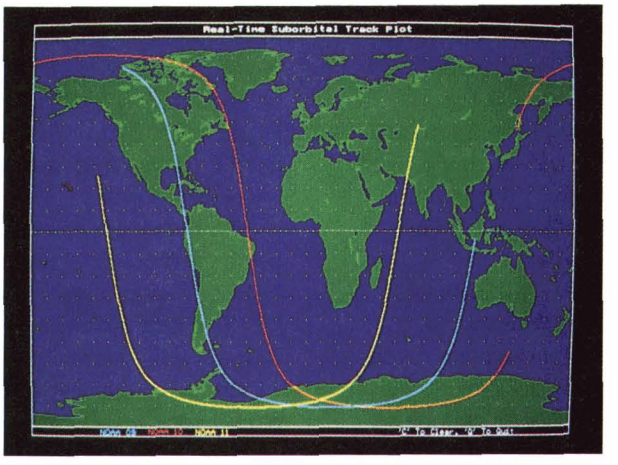
The program involves substantial self-monitoring of CCPs by participating firms. To assure its effectiveness, there will be regular fee-for-service monitoring inspections and less frequent verification inspections by FDA and NOAA Fisheries. These inspections will enable the agencies to determine whether each HACCP-based system is in compliance with a plant's HACCP plan.

FDA and NOAA Fisheries expect the joint program to lead to more efficient regulation of the seafood industry and provide further assurance of food safety, wholesomeness and truthful labeling. It will also provide recognition to firms operating successfully under HACCP in the form of a government mark, or seal, that indicates the product comes from a facility that is meeting program requirements.

Satellite Tracking System

A satellite tracking system enables accurate antenna pointing for error-free signal reception





The NASA-developed TIROS weather/environment satellites, now operated by the National Oceanic and Atmospheric Administration (NOAA), obtain high resolution images of Earth's atmosphere for use in such applications as cloud top temperature monitoring, hazardous weather prediction and crop monitoring.

Data from the three satellites has also enabled researchers to create infrared images of Earth's temperature, helped scientists to detect atmospheric changes — ozone depletion, global warming, acid rain — and monitor the concentration of infrared-absorbing gases in the air.

For real time utilization of the satellites' information, researchers at the Center for Aerospace Sciences of the University of North Dakota (UND), Grand Forks, North Dakota have developed a Satellite Tracking System. The system is designed to predict the satellites' location at any given time, enabling accurate computer-directed pointing of ground-based antennas at the satellites' transmitters for error-free signal reception.

In **the top photo** is UND's antenna system, which automatically picks up a satellite as it comes above the horizon and tracks it until it drops below the horizon. The computer system plots the satellite's position for any requested time. The **lower image** shows a computer-generated ground track plotted as the system tracked all three NOAA satellites simultaneously; their flight paths are shown in different colors.

Predicting future satellite locations is complex. Because of the complexity of the task and the importance of accurate calculations, UND researchers used proven NASA satellite-tracking technology: computer programs known as SANDTRACKS, ODG and NORAD in developing their system. The programs were supplied to UND by NASA's Computer Software Management and Information Center (COSMIC)® located at the University of Georgia **(see page 140).**

SANDTRACKS computes the time history or groundtrack of the satellite, its field of view, and the point where the satellite is visible from a ground station; the program allows estimation of the longitude, latitude and altitude of the satellite.

ODG allows plotting a view of Earth as seen by the satellite. NORAD makes it possible to compute sighting directions, visibility times and the maximum elevation angle attained during each orbit. UND researcher Mike Hennes states that use of the NASA technology "lent validity" to the design of the Satellite Tracking System and saved UND the time, effort and money that would have been required to develop alternative software. With its new capability, UND's Earth System Science Institute will be able to routinely monitor agricultural and environmental conditions of the Northern Plains.

®COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Structural Analysis

Below is an offshore platform under construction. Such large steel structures are used for discovery and subsequent recovery of oil or gas from deep wells beneath the ocean floor. Platforms like this one must be constructed to withstand extreme environmental hazards, such as North Sea winter storms or Gulf of Mexico hurricanes. The structure must also withstand damage from dropped objects, boat impacts and general use loads on the structure.

Engineers at Engineering Dynamics, Inc., Kenner, Louisiana, faced a difficult reconstruction task when the bracing element of an 800-foot-tall offshore oil recovery platform collapsed under the action of hydrostatic pressure; a number of reinforcing external ring stiffeners in the tubular brace were also damaged. The problem was twofold: the engineers had to learn the cause of the collapse and analyze the proposed repairs to the structure.

For computer structural analysis, Engineering Dynamics selected STAGSC-1, a program with the needed geometric nonlinear and buckling analysis. The program was obtained from NASA's Computer Software Management and Information Center (COSMIC) at the University of Georgia **(see page 140)**.

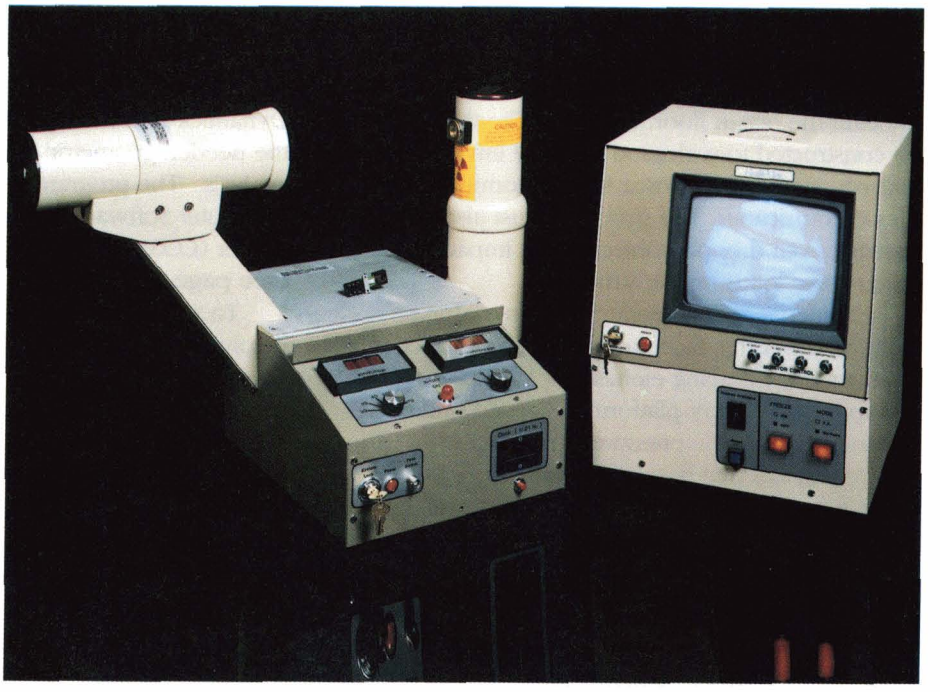
To stress analyze the structural elements involved in the repair task, STAGSC-1 required engineers to describe the damaged area in mathematical terms, giving the geometry, external loadings — such as hydrostatic pressure at the depth of the brace — and other environmental loadings imposed on the brace by platform actions. The type of material used to construct the platform was also a key factor in the stress analysis.

Given these variables, STAGSC-1 calculated the stress values on the brace and provided researchers with a buckling analysis coefficient that allowed them to determine the overall deflected shapes and buckling shapes of the modeled structural elements. This permitted visual imaging of the structure right at the point where it would begin to buckle under hydrostatic pressure. It was then determined that the proposed repairs would restore the platform to its designed state. Engineering Dynamics reports that the excellent technical capabilities of STAGSC-1 played an important part in enabling completion of the repair task within the allowed time frame.

Stress analysis software aided a difficult reconstruction task

X-ray Imaging System

An industrial-use device represents a third generation spinoff from technology originally developed for x-ray astronomy



At right is the Model 60007A InnerView Real-time X-ray Imaging System, produced by National Imaging Systems, a division of HealthMate, Inc., Northbrook, Illinois. It is an industrial-use device that offers low cost and operational safety for such x-ray applications as airport and building security (inspection of luggage, containers, boxes, etc.), non-destructive testing, quality control inspection and production inspection.

The InnerView device represents a third generation spinoff from technology originally developed for x-ray astronomy, where imaging at extremely low intensity is required. Goddard Space Flight Center adapted the imaging technology to a novel Earth-use product: a small, portable, isotopic, minimal radiation x-ray instrument known as the Low Intensity X-ray Imaging Scope; it was designed principally for medical emergencies, for example, on-site use to examine injuries at an accident scene or a sports contest.

NASA licensed the technology for commercial applications to several companies, among them HealthMate, Inc. HealthMate used it to develop the FluoroScan medical x-ray system for hospital operating rooms and physicians' offices; the company replaced the isotopic penetrating source with a variable power x-ray tube and added a number of improvements while retaining the small size and light weight of the Goddard system. Because of the low intensity imaging technology, the Food and Drug Administration allows use of the FluoroScan without the lead aprons, film badges or lead lined walls that other x-ray systems require.

The InnerView imaging is a direct spinoff from FluoroScan. The system consists of an x-ray tube, a TV camera and a detector/intensifier (all packaged within the compact unit at left in the photo) and a nine-inch black and white display monitor. It is also available in a mobile unit in which the monitor is transported on a wheelbase and the x-ray tube, camera and detector/intensifier are mounted on a swinging "C-arm" affixed to the monitor.

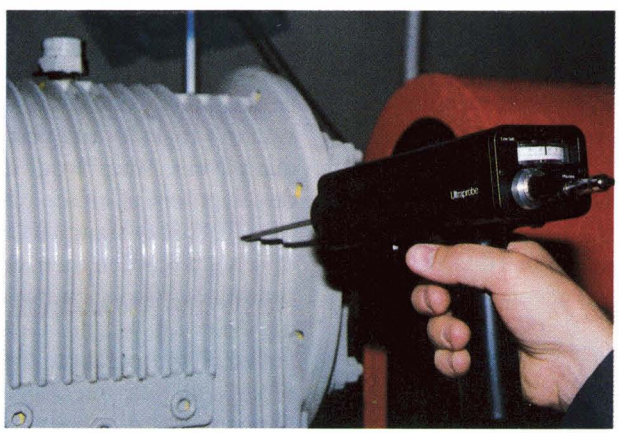
In industrial use, the x-rayed object casts a shadow that is converted to a visible light image on a scintillator screen. After being reduced in size by a fiber optic taper, the image is intensified 50,000 times by an electron multiplier known as an MCP (microchannel plate intensifier). The closed circuit TV camera deposits the images on the monitor.

Ultrasonic Maintenance

Until the 1970s, inspection of bearings in industrial machinery was conducted by uncertain techniques — such as a mechanic's subjective ear testing — or by very costly methods, such as vibration analysis or heat change sensing. In the seventies, research on bearings for a gyroscope used in NASA's Skylab program, conducted by Marshall Space Flight Center, significantly advanced bearing failure detection techniques.

Working under contract to Marshall, Mechanical Technology, Inc. (MTI), Latham, New York, discovered that bearings on the verge of failure send ultrasonic signals indicating their deterioration; as bearings begin to succumb to fatigue, a deforming of the metal produces an increase in the emission of ultrasonic waves. Changes in amplitude indicate incipient bearing failure and these changes can be measured well before the warning can be detected by other means, such as heat and vibration changes. MTI and Marshall developed a method and a prototype ultrasonic system for monitoring incipient bearing failure.

That technology is employed in the Ultraprobe 2000, shown **above**. A hand-held ultrasonic system that detects indications of bearing failure by analyzing changes in amplitude, the system is manufactured by UE Systems Incorporated, Elmsford, New York. The Ultraprobe employs a proprietary Trisonic Transducer so sensitive it can "hear" the interior movement of a wristwatch more than three feet away. The information the Ultraprobe provides, analyzed over a period of time, helps operators determine not only when a bearing will fail but why.



Because ultrasound is beyond the range of human hearing, the system changes the ultrasonic signals detected to audible signals. The operator hears the signals in his earphones and gages their intensity by deflections of the meter (shown in closeup **at left**) in the unit. The Ultraprobe was designed as a multi-use inspection system for both mechanical analysis and leak detection, so the meter is bimodal: it presents a real time response for leak detection as well as bearing condition information.

Metal fatigue produces an increase in the emission of ultrasonic waves

Collision Avoidance System

In the mid-1950s, when increasing air traffic caused congested skies over the U.S., government and aviation industry groups began a search for an airborne system to complement ground-based air traffic control and warn pilots of collision threats. A number of concepts were developed and tested over a span of more than two decades, but the technology of that era was not up to the complicated demands of collision warning.

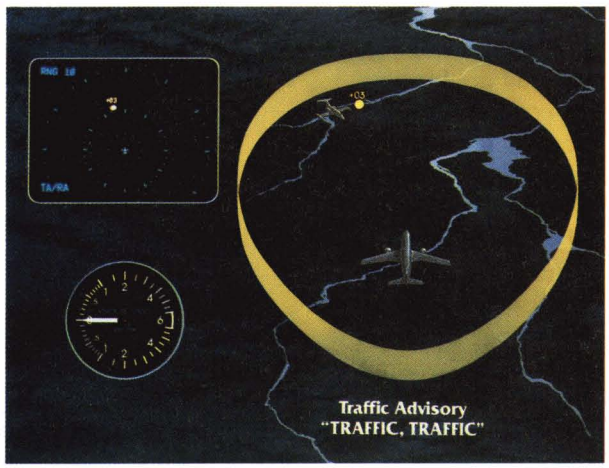
By the 1980s, however, advancing technology permitted development of a commercially viable system, the Traffic Alert and Collision Avoidance System (TCAS II). In a concerted effort by the Federal Aviation Administration (FAA), the member airlines of the Air Transport Association, aircraft manufacturers, producers of avionic equipment and other aviation groups, TCAS II was thoroughly tested and specifications for its use in airline service were developed.

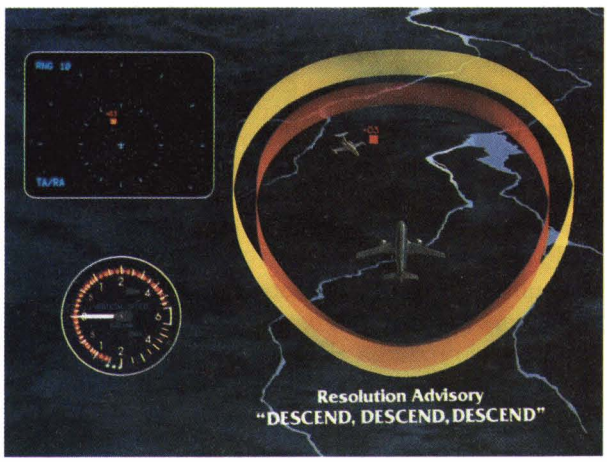
TCAS is designed to alert pilots to the presence of other aircraft in their vicinity

In 1989, following a Congressional mandate, the FAA ruled that TCAS would be required on all passenger carrying aircraft, including planes operated by U.S. flag airlines and those of foreign registry serving U.S. cities. Airline aircraft with more than 30 seats must have a TCAS II installed and operating by the end of 1993; passenger aircraft with 10 to 30 seats must have a TCAS by 1995.

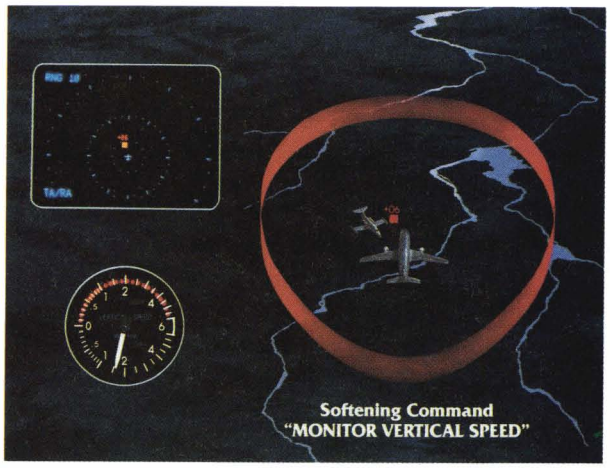
These rules were published after extensive TCAS II testing by several carriers in actual airline service. NASA's Ames Research Center played an important role in laying the groundwork for the airlines' in-service evaluation, teaming with the FAA to study the human performance factors associated with the use of TCAS II in an operational environment.

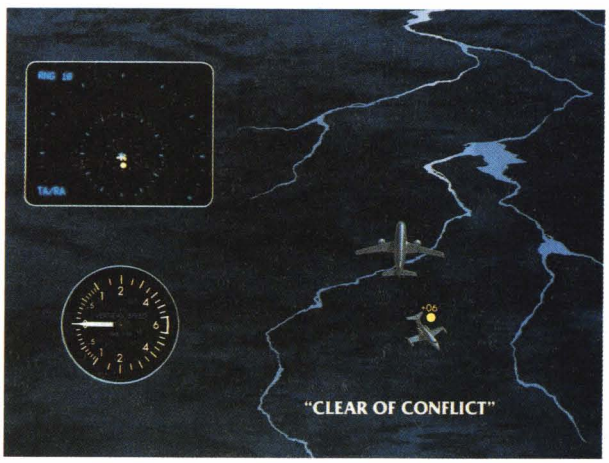
Using ground-based flight simulators flown by airline flight crews, Ames verified that pilots can accurately and quickly use TCAS II. The NASA program generated improvements in TCAS displays that resulted in both speed and accuracy increases for the pilots' responses, and validated a set of pilot performance parameters that were coded in the system's logic for the best collision-evading maneuvers. Ames' work also contributed to development of airline pilot training procedures.





TCAS is designed to alert pilots to the presence of other aircraft in their vicinity, to identify and track "intruders" whose course and speed make them threats to safety, and to recommend action to avoid collision. In operation, the TCAS-equipped airplane sends a general interrogation signal to the transponders of other aircraft within the system's range. The transponders send reply signals to the TCAS aircraft, whose computer initiates a track for each replying aircraft, computes its range, bearing, altitude and other factors, and presents this information on a display in the cockpit. Display warnings are backed by automatic voice messages delivered through a cockpit speaker.





A display unit shows the TCAS aircraft as the center of the local airspace volume and indicates intruders in that airspace, as shown **at upper left**. Here an intruder has come close enough to trigger a Traffic Advisory. The computer changes the intruder's display symbol, previously a white diamond (non-threat) to a yellow circle (potential threat); the +03 adjacent to the circle means that the intruder is 300 feet higher than the TCAS aircraft. Simultaneously with the appearance of the yellow circle, the pilot hears the vocal Traffic Advisory "Traffic, traffic."

At lower left, the intruder has moved closer on a collision course and passed the inner ring on the display; it is now a definite collision threat. TCAS II issues a Resolution Advisory; it changes the intruder's symbol to red and the cockpit speaker delivers a vocal message announcing the required evasive action: "Descend, descend, descend." To find out how rapidly he must descend, the pilot consults the vertical speed indicator on his display, on which TCAS II has colored a portion of the dial red and green. The pilot must maneuver the airplane so that the needle moves out of the red area into the green target area; in this instance he must descend at 1,500 feet per minute.

The illustration at left shows his maneuver successful; there is now 600 feet of vertical separation between the two aircraft. **Below,** TCAS II indicates — by changing the intruder's symbol back to a yellow circle — that the crisis has passed; the voice message confirms "Clear of conflict."

Ames Research Center conducted three laboratory experiments to determine pilots' performance in responding to TCAS advisories. From the first study, Ames concludes that pilots were able to use TCAS II correctly within the allowable five-second response time and that TCAS was effective in reducing the severity of simulated traffic conflicts.

In the second experiment, Ames tested pilots' responses to changes in the avoidance advisories, for example, a second Resolution Advisory commanding an increase in the earlier-recommended climb or descent rate. Recorded reaction times suggested that pilots are able to respond to these changes within the targeted two seconds.

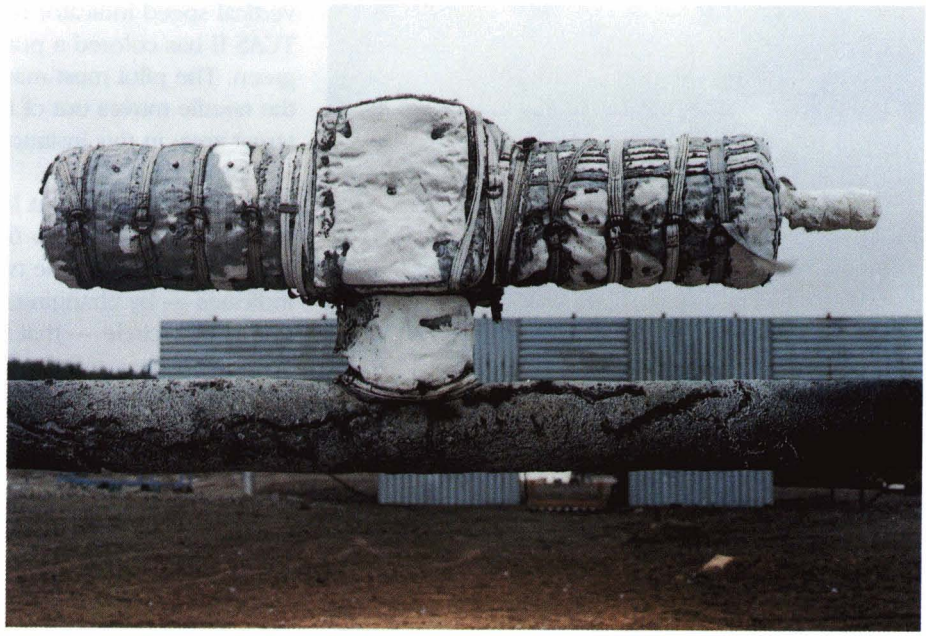
In the third experiment, pilot reactions to alternative TCAS displays were examined. For example, the vertical speed indicator was modified to include a green-lighted target vertical speed rate in addition to the red-lighted area. The results showed pilot preference to the red-and-green display over the red-only display and the TCAS II was changed accordingly. These studies contributed significantly to the airlines' evaluation of TCAS II and to improved air traffic system safety.

NASA studies contributed significantly to the airlines' evaluation of TCAS II and to improved air traffic system safety

Fire Protection Jacket

The jackets protect the equipment from the extreme temperatures of intense hydrocarbon fires

At right is one of the PC1200 Series Fire Protection Jackets developed by Paul-Munroe Engineering, Orange, California, to protect the oil conduit system that carries crude oil and gas from wells beneath the sea to an offshore drilling platform. The jacket is shown after protecting a valve actuator from a 30-minute exposure to high velocity, gas-fed flames.



Fitted over pumps, cable trays, electrical equipment, riser tensioners, valve actuators and other apparatus, the jackets protect the equipment from the extreme temperatures of intense hydrocarbon fires that cause buckling and could cause structural failure of the entire platform. Protection of vital structural components can save lives and give firefighters additional time to extinguish oil field fires.

The jackets are designed to withstand temperatures of 2000 degrees Fahrenheit for four hours or more; this window of extra time before destruction of equipment is significant in relation to improved evacuation methods and health/safety standards. The flame-proof jacketing was developed from a combination of ceramic cloth and other laminates used in astronaut space suit designs. The ceramic material developed for the cloth is similar to that developed by NASA for the tiles that protect Space Shuttle surfaces from the heat of re-entry.

Paul-Munroe was aided in the jacketing development by NERAC, Inc., Tolland, Connecticut, one of 10 NASA-sponsored Industrial Applications Centers that provide informational and problem-solving assistance to industrial and other clients. Through information obtained from NERAC, Paul-Munroe was able to locate specialists that used the Shuttle-type ceramic fibers and as a result they concluded an agreement for production and marketing of the jacketing system.

Flight Simulation

A software system allows real time computer simulation of rotor blade dynamics for designing advanced helicopters and other rotorcraft

Rotary wing aircraft are aerodynamically much more complex than fixed wing aircraft. Real time computer simulation of rotor blade dynamics for designing advanced helicopters and other rotorcraft could, until recently, be accomplished only on expensive mainframe computers.

NASA and Army researchers sought a more cost effective method of computer-modeling designs for the next generation of advanced rotorcraft, whose higher speeds, greater maneuverability, hingeless rotors and precision control systems require expanded bandwidth, real-time simulations that include structural dynamics and aeroelastics (blade flexing).

In the summer of 1990, accomplishing such simulations by parallel processing — rather than conventional step-by-step sequential processing — was explored by a research group that included NASA's Ames Research Center; the Army Aeroflightdynamics Directorate; and Advanced Rotorcraft Technology, Inc. (ART), Mountain View, California.

ART expanded an already-detailed blade element model in which the rotor blades are divided into a number of small segments and the action of each segment calculated. This simulation model was demonstrated in real time on two commercial parallel processing computers. Both computers were interfaced with the Army's Crew Station Research and Development Facility (located at Ames) to judge human pilot interaction (**left**). The experiments showed that the new software architecture could provide real time simulation of high performance rotorcraft that closely matched actual flight performance at substantially lower computational cost.

Advanced Rotorcraft Technology used the simulation technology developed for the NASA/Army demonstrations, together with parallel processing technology acquired under an earlier Department of Defense contract, to develop the FLIGHTLAB system, now offered commercially as a design/analysis tool for aerospace companies or a simulation system for pilot training.

FLIGHTLAB is a turnkey system that combines object-oriented dynamic modeling with parallel processing software support tools and state-of-the-art computer hardware to provide a total environment for simulation development, operation and engineering analysis. The heart of the system is a parallel processing workstation capable of processing sophisticated mathematical models in real time. FLIGHTLAB includes Engineer's and Programmer's Workstations that provide on-line design analysis and software checkout, and a Pilot's Workstation that enables pilot evaluation of a design early in the design process. FLIGHTLAB advantages, officials say, are less expensive computer operations and a substantial reduction of the time required for the aircraft design process.

Performance Testing

A safety-enhancing system tests workers' visual/motor responses

In the mid-1960s, preparing for future long duration space missions, NASA conducted a test in which four men were sealed in a realistically simulated space station for 90 days. The experiment had a dual purpose: testing components of an advanced life support system, and obtaining data on the physiological and psychological effects of long confinement.

Of particular importance was the measurement of the subjects' abilities to perform certain tasks and determination of how much their abilities were impaired by long isolation. Ames Research Center contracted with Systems Technology, Inc., Hawthorne, California, for development of an electronic Critical Tracking Task (CTT) system for analyzing and rating the subjects' visual/motor responses. Systems Technology was also asked to prepare a series of tracking tasks to be accomplished by the subjects.

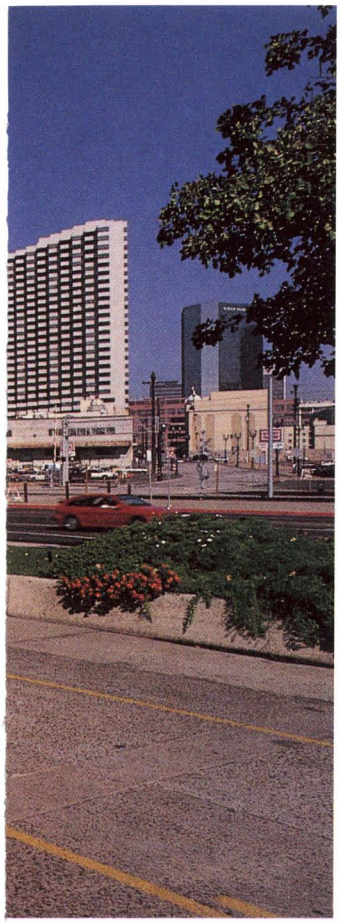
The CTT technology has been used by government agencies in the years since: by NASA in astronaut function tests, by the Air Force to check pilots' abilities to control unstable aircraft, and by the National Highway Traffic Safety Administration in an experimental program to detect intoxicated drivers. In 1990 it was introduced to the commercial marketplace as FACTOR 1000®, a computer-based testing device that can be used daily to assess the fitness of employees involved in safety-related jobs. Performance Factors, Inc., (PFI), Alameda, California, is marketing the service to industry under a license agreement with Systems Technology, Inc.

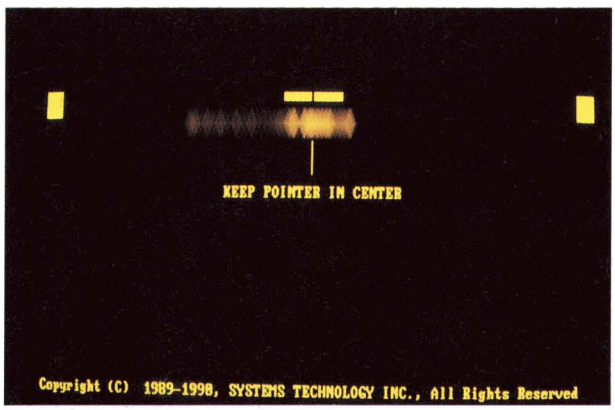
According to PFI, employee impairment — the inability of workers to perform their jobs safely and effectively — costs American businesses an estimated $100 billion a year in terms of accidents, lost wages, damaged merchandise, medical claims and increased insurance premiums.

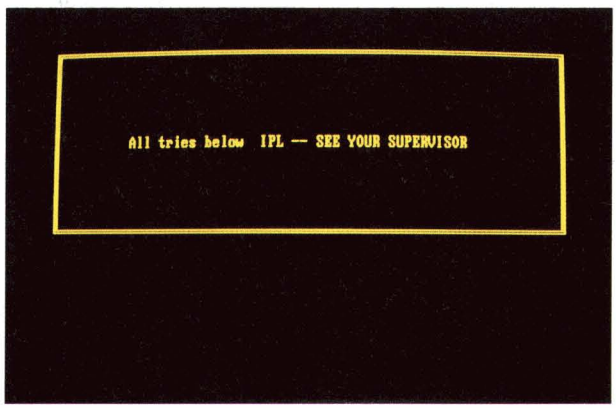
FACTOR 1000 detects impairment from a broad range of causes, including stress, fatigue, illness, drugs, or alcohol. With a non-invasive, self-administered test that takes less than a minute, the system provides an assessment of each employee's physical coordination skills prior to the start of each workday. By identifying the seriously impaired employee before the start of a shift, company management is better able to protect the safety of employees, the public and co-workers.

The use of FACTOR 1000 is illustrated by the experience of Old Town Trolley Tours, San Diego, California, one of the first companies to use the system. Old Town Trolley is a tour bus operation whose vehicles **(left and above)** wind through the narrow streets of Old Town and along the busy streets of the waterfront in downtown San Diego. The driver is also the tour guide; he must describe the sights and historical points of interest, answering many questions from his passengers, all the while staying alert to the hazards of vehicular traffic and the wanderings of pedestrians who constantly cross his path. It is not a job for an impaired operator.

To prevent that possibility, each Old Town driver undergoes a daily FACTOR 1000 assessment







before he starts work. In the **top photo**, a company driver sits at a personal computer ready for the video-based test, which will evaluate her hand/eye coordination. She is first asked to identify herself by a password; the reason is that the computer program will compare today's result with the driver's baseline performance, established by previous tests. In this manner, the driver is tested against his own average level of performance, rather than an arbitrary skill standard or the standards of other drivers. This assures an objective, personalized measure of performance.

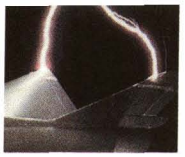
The driver is required to manipulate a control knob to keep a randomly-moving pointer centered between two boundary markers on the computer screen **(center)**. The computer is programmed to make the task increasingly difficult as the test proceeds. Each individual's performance on the test is compared with his or her own personal baseline to determine fitness for duty. The test takes about 30 seconds.

FACTOR 1000 does not diagnose the specific cause of impairment. Test results are available to company management immediately after each test. When there is a "below baseline" report **(bottom)**, a supervisor knows that the driver's hand/eye coordination is not functioning normally and he or she can take appropriate action. Such a process also encourages early identification of employees in need of help.

Also used in precision and heavy manufacturing retail distribution and cargo transportation, FACTOR 1000 is an effective and relatively inexpensive way of reducing the liabilities and costs related to accidents, product or equipment damage, workers compensation and health claims. It costs less than one dollar per workday per employee.

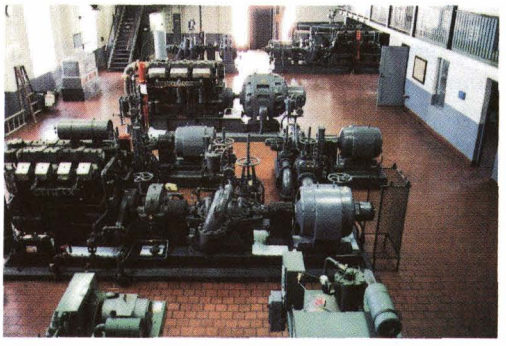
The system detects impairment from a broad range of causes, including stress, fatigue, illness, drugs, or alcohol

®FACTOR 1000 is a registered trademark of Performance Factors, Inc.



Signal Isolators

NASA Tech Briefs, a monthly publication intended to advise potential users what new NASA technology is available for transfer, is a major source of spinoff applications. On occasion, *Tech Briefs* reports contain sufficient information by themselves to inspire and guide development of a spinoff product or process. More often, *Tech Briefs* provides an initial lead; prospective users can follow up by requesting a Technical Support Package (TSP) that supplies more detailed information about a particular innovation **(see page 141)**.



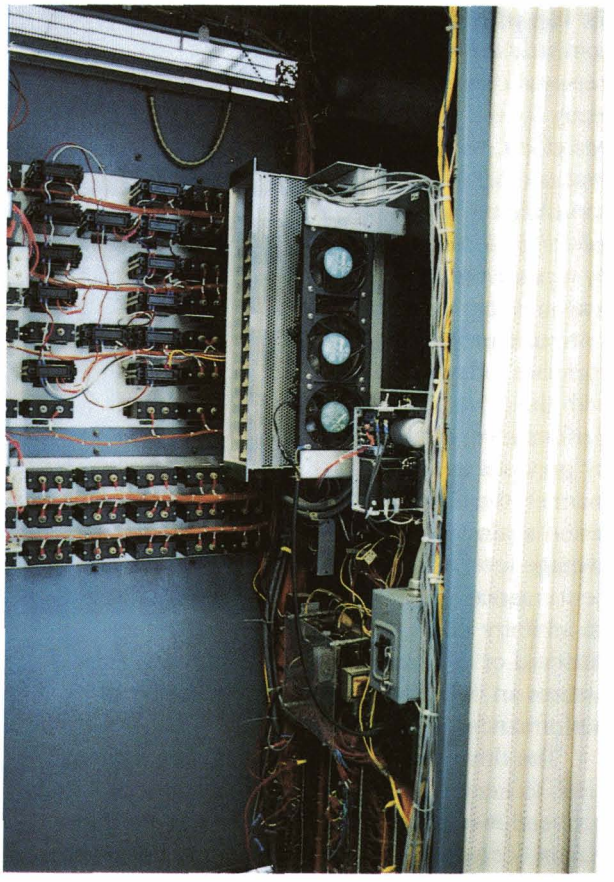
A NASA technical report provided a solution for computer system failures

The City of Dubuque (Iowa) used the latter approach to solve a problem with the computer system operated by the Water Division of the Utility Department. The system gathers data, both analog and digital, from remote tanks, pumping stations, wells and the division's main plant.

Shortly after the computer system became operational, the division began experiencing failures of the analog inputs ranging from signals out of tolerance by more than 30 percent to intermittent — and sometimes complete — loss of signals. Investigation traced the problem to lack of signal isolation on the analog input cards, which made the inputs vulnerable to interference from storms and machinery. Most of the problems originated in the main plant pump room shown **above**; the pumps have thermocouples mounted on the bearings and their signals are not isolated from the computer inputs.

The division purchased commercial isolation modules that solved the immediate problem. But the Water Division's tight budget demanded a more cost effective long term solution.

Division electronic technician Bob Ervolino read an article in *Tech Briefs* — "Output Isolation and Protection Circuits" — describing an Ames Research Center solution to a problem similar to the Water Division's. He sent for the TSP, studied details of the Ames invention, and learned the name of the vendor supplying the isolation circuit described in the article, Analog Devices, Norwood, Massachusetts. That company suggested other devices, which the Water Division acquired and installed. Ervolino reports that the information supplied by *Tech Briefs* and the vendor solved the problem and saved the Water Division more than 50 percent of the cost of commercial signal isolators. The solution — the signal isolators — is pictured **below**.

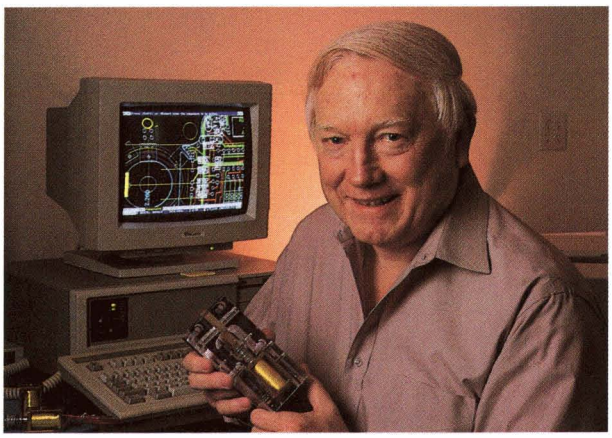


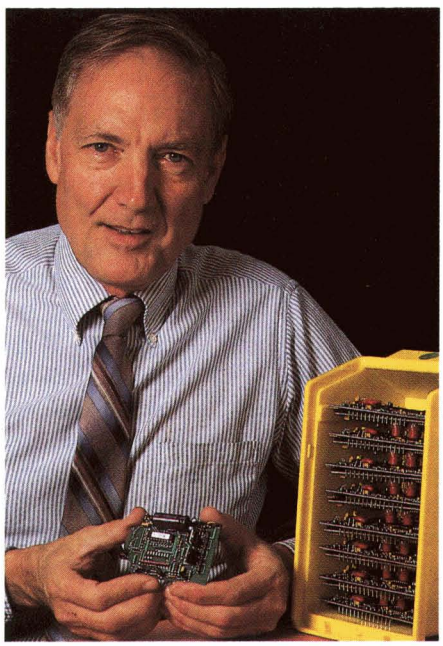
Safe Lock

More than two decades ago, NASA and the Navy jointly sponsored development of an "acoustic pinger," an underwater transmitting device for location and recovery of sounding rocket research payloads lowered by parachute to the ocean. The device was developed under contract to Langley Research Center by Burnett Electronics Lab, Incorporated, San Diego, California. Pinger spinoffs have now been installed on flight recorders in virtually every commercial aircraft.

The development spawned a broad line of Burnett underwater sound/search systems and related equipment used for such widely varied purposes as distress signal transmission for scuba divers, position location for drilling ocean core samples, and military location/recovery of submerged mines (the device was used in Operation Desert Storm).

Long functioning life is a vital requirement for Burnett's underwater pingers; efficient power management is the key to extended lifetime. In what amounts to a spinoff from a spinoff, Burnett Electronics modified the microprocessor-based unit that manages power distribution for the company's line of sound/search systems and used it as the basis for a new product: a battery-powered microprocessor-controlled spring latch for home or office safes. In the **upper photo**, Frank Fogelman, president of KeyOne, Inc., San Diego, California, is holding a Model 1150 electronic spring latch; KeyOne is marketing the Burnett-developed device. In the **lower photo**, Don Burnett, president of Burnett Electronics, displays the time delay board, the element of the Model 1150 that represents the pinger-spinoff technology.

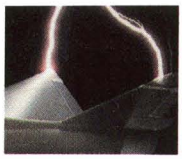




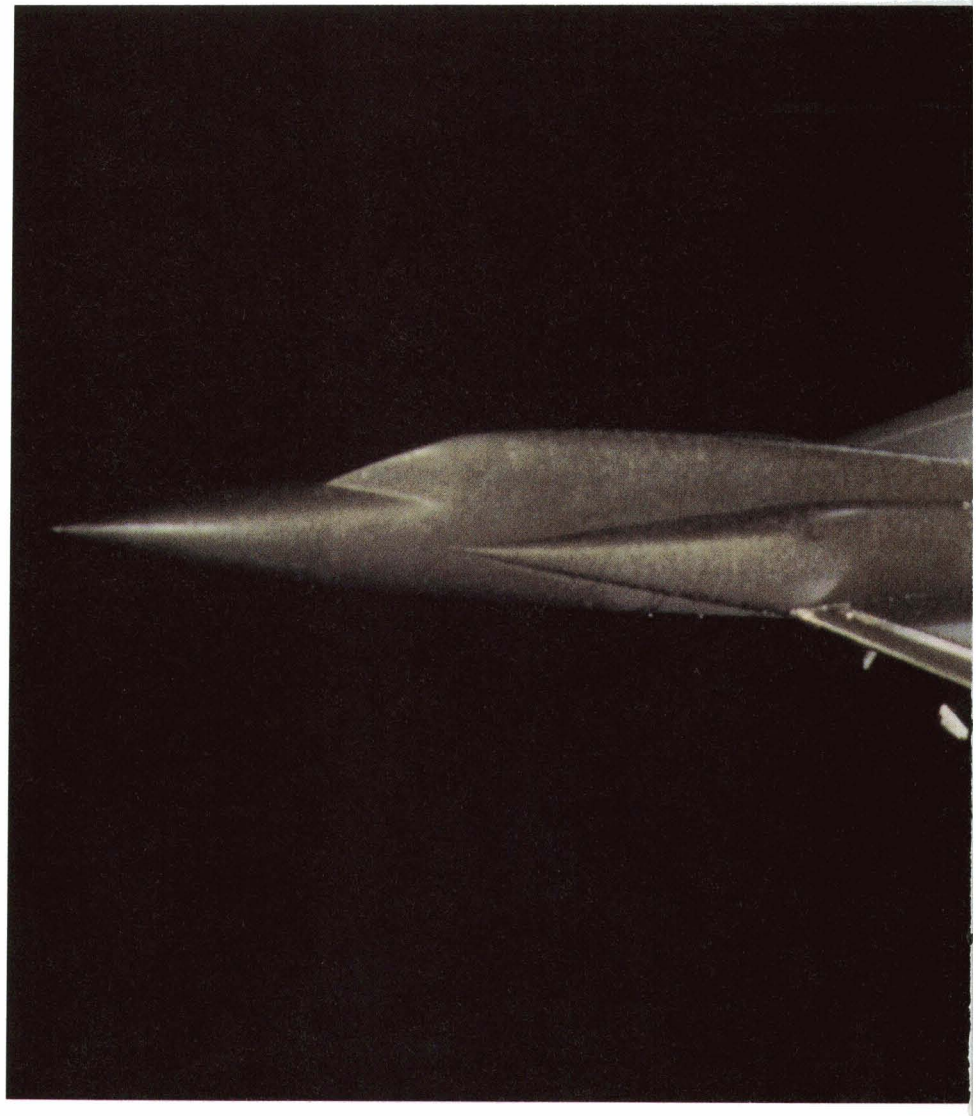
The Model 1150 is intended for use in timed entry safes, typically used by convenience stores and other businesses with high cash turnover. The latch provides controlled and timed access to the inner and outer compartments of a safe. Outer safes are generally used for petty cash and accessed frequently. The bulk of a business' daily money intake is dead-dropped into the inner safe, which operates under different time sequences (for example, once a day for armored car pickup).

Model 1150 employs the pinger power management technology to get long life out of the battery power source. Burnett Electronics and KeyOne say that the system offers a clear signal with less noise interference and battery power makes the unit less susceptible to outside influences — such as system override by thieves — than AC electric current.

Pinger spinoffs have been installed on flight recorders in virtually every commercial aircraft



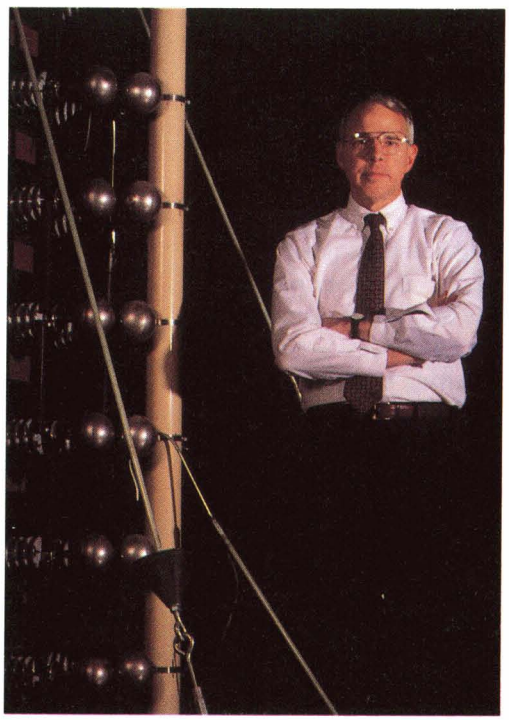
Lightning Protection



The project employed a specially-equipped research airplane, whose job it was to seek out thunderstorms

In the complex business of aerospace development, advancing technology on occasion heightens an existing problem — and therefore spawns further advancements of a corrective nature.

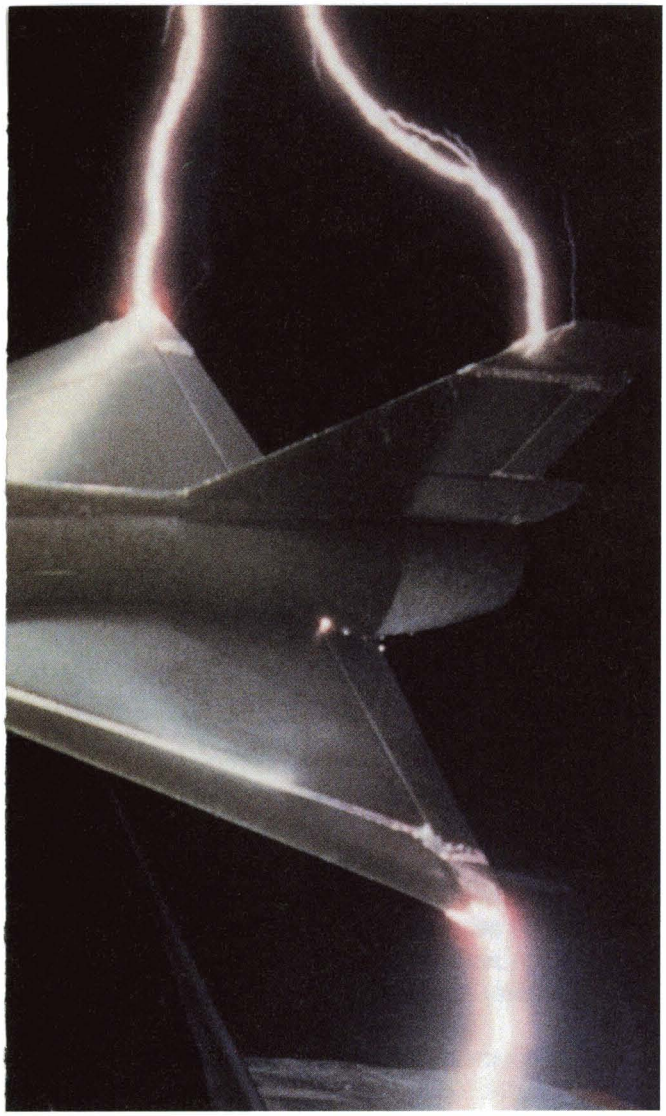
An example is the increasing use of composite materials, introduced to aircraft design to gain strength while reducing weight, and digital electronic systems that offer greater efficiency in flight and engine control. Both technologies tend to make aircraft more susceptible to lightning damage. But research by NASA, the Federal Aviation Administration (FAA) and other aviation groups has substantially improved understanding of how lightning affects aircraft and produced countermeasures that allow plane builders to incorporate these performance-enhancing technologies while improving safety.

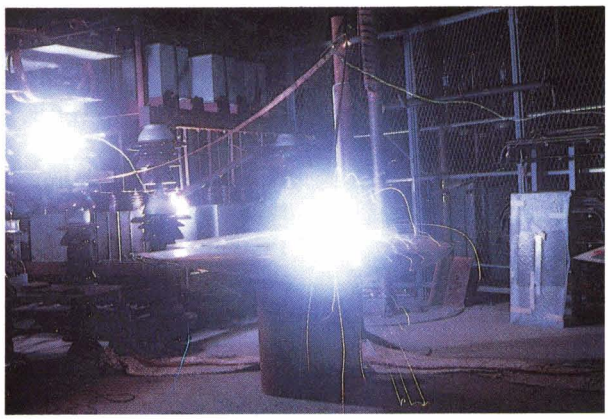


NASA played the leading role in lightning investigations with its seven-year (1980-86) Storm Hazards Research Program, undertaken at Congressional direction — by Langley Research Center — to determine the dangers of thunderstorms to commercial aviation. The project employed a specially-equipped, protected F-106B research airplane, whose job it was to seek out thunderstorms in the hope of getting struck by lightning. It was highly successful — more than 800 strikes were recorded. The program proved to be a giant step in advancing knowledge of lightning hazards and generating protective technology.

A key player in both the research program and the transfer of the technology to the aircraft industry is Lightning Technologies, Inc., Pittsfield, Massachusetts, a small engineering and testing firm engaged in design and verification of protection against lightning and other electrical hazards. Lightning Technologies is a spinoff company. It was founded in 1977 by president J. Anderson Plumer, a former employee of a NASA contractor — General Electric Company's High Voltage Laboratory — who had acquired extensive experience in lightning investigations. Shown **at left** beside a 1.5 million volt generator used for lightning simulations, Plumer is an example of the personnel-type of spinoff, wherein NASA technology is transferred to the private sector by the occupational shift of a scientist or engineer once engaged in NASA research activity.

In addition, much of the company's technological capability stemmed from its work as supporting contractor for the Storm Hazards Research Program, which involved assisting NASA in





planning the program, improving and verifying the lightning protection for the F-106B and, together with other organizations, analyzing the data. Both the company and its president worked extensively with the SAE Lightning Subcommittee, which formulates standards for aircraft lightning protection. The experience and technology thus gained has made the company a leader in lightning protection for aerospace systems.

Among the findings of the Storm Hazards Research Program, Langley researchers learned that multiple-burst lightning strikes inject a large number of randomly occurring electric currents into the airplane, producing rapidly changing magnetic fields that can induce erroneous responses, faulty commands or other upsets in sophisticated electronic systems.

This led the FAA — and airworthiness certifying authorities in other countries — to require, beginning in 1987, that aircraft electronic systems which perform flight-critical functions be protected from damage or upset due to the effects of the multiple-burst lightning environment.

The NASA research produced another important finding: that lightning strikes may hit almost any spot on an airplane surface, not just — as earlier believed — the plane's extremities, such as wings, propeller tips and certain other areas. That finding is of great importance to designers employing composite materials, which are less conductive, hence more vulnerable to lightning damage than the aluminum alloys they replace.

Lightning Technologies uses its NASA-acquired experience and technology to develop protective measures for both electronic systems and composite structures, including better electrical bonding and shielding methods for interconnecting wiring and methods of increasing system immunity through improved computer software and application of surge-suppression devices. The company also provides protection design and verification testing services for complete aircraft systems or their individual components; it numbers most major aircraft and component manufacturers among its worldwide clients.

The accompanying photos illustrate some of Lightning Technologies work: **the center photo** shows a simulated lightning strike on a model of an F-106 similar to the one used in the NASA research program; **above right**, a full-size aircraft component undergoes a high-voltage lightning test; **at right**, a company technician prepares a model of an airplane fuselage for computer analysis.

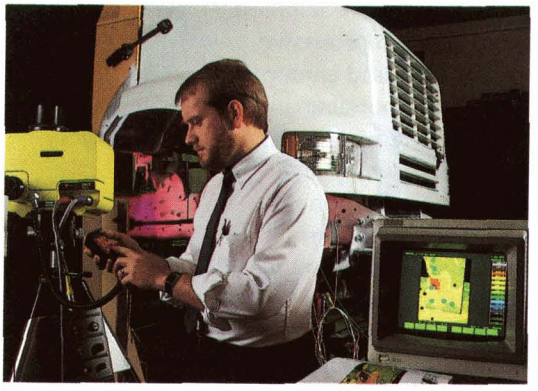
Multiple-burst lightning strikes inject a large number of randomly occurring electric currents into the airplane

Aids to School Bus Design

Technology transfers that help assure safety and reliability in pupil transport highlight spinoffs in the field of transportation

Historically, a school bus chassis was nothing more than a medium truck chassis. However, escalating parent demands for maximum safety and reliability prompted some manufacturers to introduce chassis designed specifically for the special considerations of school transport.

The industry leader is Navistar International Transportation Corporation, Chicago, Illinois, manufacturer of the International® line of truck and bus chassis. Engineers at the Navistar Technical Center, Fort Wayne, Indiana, devoted two years of sophisticated research and development to the company's 3000 Series Bus Chassis, designed expressly for school bus applications. The first of this series was introduced in 1989; the latest, the International 3900 FC, was introduced in 1991. Design of all of the 3000 Series was aided by NASA technology originally developed for aviation and space use.



Shown in use at Navistar Technical Center is the SPATE 9000 system (yellow scanner and display unit), which measures stress in truck and bus components by detecting temperature changes.

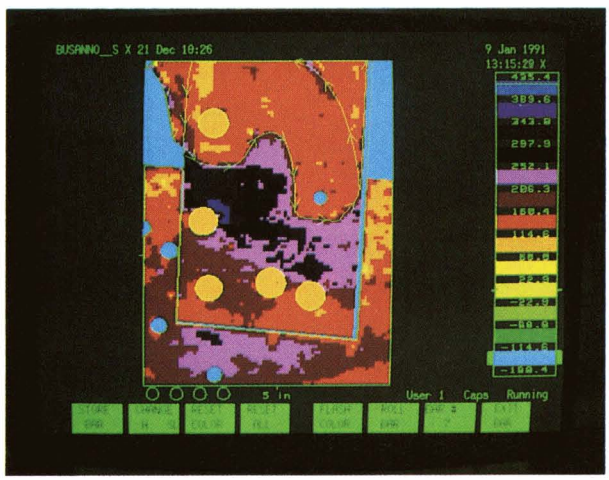
Navistar International does not manufacture school bus bodies. For the Series 3000, the company provides the chassis — which includes the frame, wheels and powertrain — the hood, cowl and instrument panel; other manufacturers integrate their bodies with the International chassis. Navistar prides itself on the durability, reliability and safety of its chassis, due in no small part to the Technical Center's exacting analysis and testing in every phase of the product development process.

An instrument that evaluates "ride quality" (box in foreground) awaits loading aboard a school bus for testing. It is one of three NASA technologies employed by Navistar International in designing school bus chassis.

In development of a new product line like the Series 3000, the Technical Center employs a state-of-the-art Unigraphic CAD/CAM (computer aided design and manufacturing) system. It enables designers to create three-dimensional models of the product and each of its parts and subject them to exhaustive analysis "to see if it all works" before actual construction. Three separate NASA-developed technologies contribute to this process.

For structural analysis of chassis and components, the Technical Center uses the MSC/NASTRAN® computer program. NASTRAN is an acronym for NASA Structural Analysis; MSC/NASTRAN is an enhanced proprietary version by MacNeal-Schwendler Corporation. NASTRAN mathematically analyzes a design and predicts how it will hold up under the various conditions of stress and strain it will encounter in operational service. The program permits Navistar engineers to study the structural behavior of different designs before locking in on the final design.

Another type of stress analyzer in use at the Technical Center is the SPATE 9000 system, which is based on infrared stress measurement technology developed by Langley Research Center in the 1960s. Manufactured by Ometron Ltd., London, England, and distributed in the U.S. by Ometron Inc., Herndon, Virginia, the SPATE 9000 is a non-contact system (not attached to the structure it is testing) that



A typical stress display; the black area (center photo) represents the greatest temperature change, reflecting the area of greatest stress.

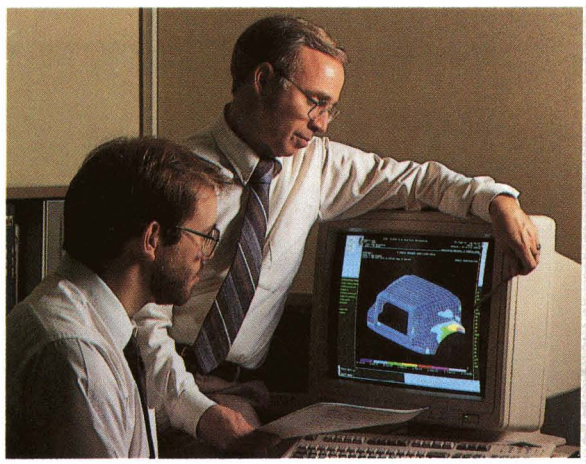
relies on infrared detection of minute temperature fluctuations that accompany changes in stress levels.

The SPATE 9000 includes a scanner and a data processing unit with a visual display. The display presents a stress map, in calibrated colors, of parts as small as a pencil or as large as the side of a tractor cab. The data is used for stress measurements, load transfer mechanisms, detection of hidden material flaws, and for monitoring structural changes that occur during fatigue testing.

The third NASA technology employed by the Technical Center is the Wyle Ride Quality Meter, developed by Langley Research Center as an aid to passenger aircraft design and manufactured under NASA license by Wyle Laboratories, Hampton, Virginia. The meter is a vehicle design aid which assures that passengers get a smooth, comfortable ride by providing an *accurate* measurement of the "ride quality" of the vehicle being developed, obviating reliance on the imprecise subjective judgments of individuals involved in the test program.

Mounted on the vehicle being tested, the Ride Quality Meter employs a package of sensors to measure vibration and a sound level meter to measure noise. The vibration signals are computer processed to get a set of indices representative of the subjective discomfort level produced by vibration. It serves, in effect, as a "passenger jury," advising vehicle developers of the vehicle's ride quality in order that they may improve it if necessary.

These technologies are part of a much broader, sophisticated process of design, analysis, test and construction that has made the International line of trucks and buses highly respected and captured for the company an estimated 45-48 percent of the total school bus chassis market.



Navistar's Pat Gerardot (standing) and Les Grundman model a school bus hood, using a NASA computer program that predicts where areas of stress may lead to material fatigue.

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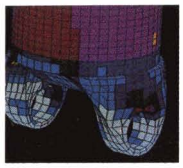


Business Jet

Shown below is the CitationJet business aircraft, developed by Cessna Aircraft Company, Wichita, Kansas, and introduced to flight test in 1991. It is the first business jet to employ natural laminar flow (NLF), a technology developed by NASA's Langley Research Center and refined for the CitationJet application by Cessna.

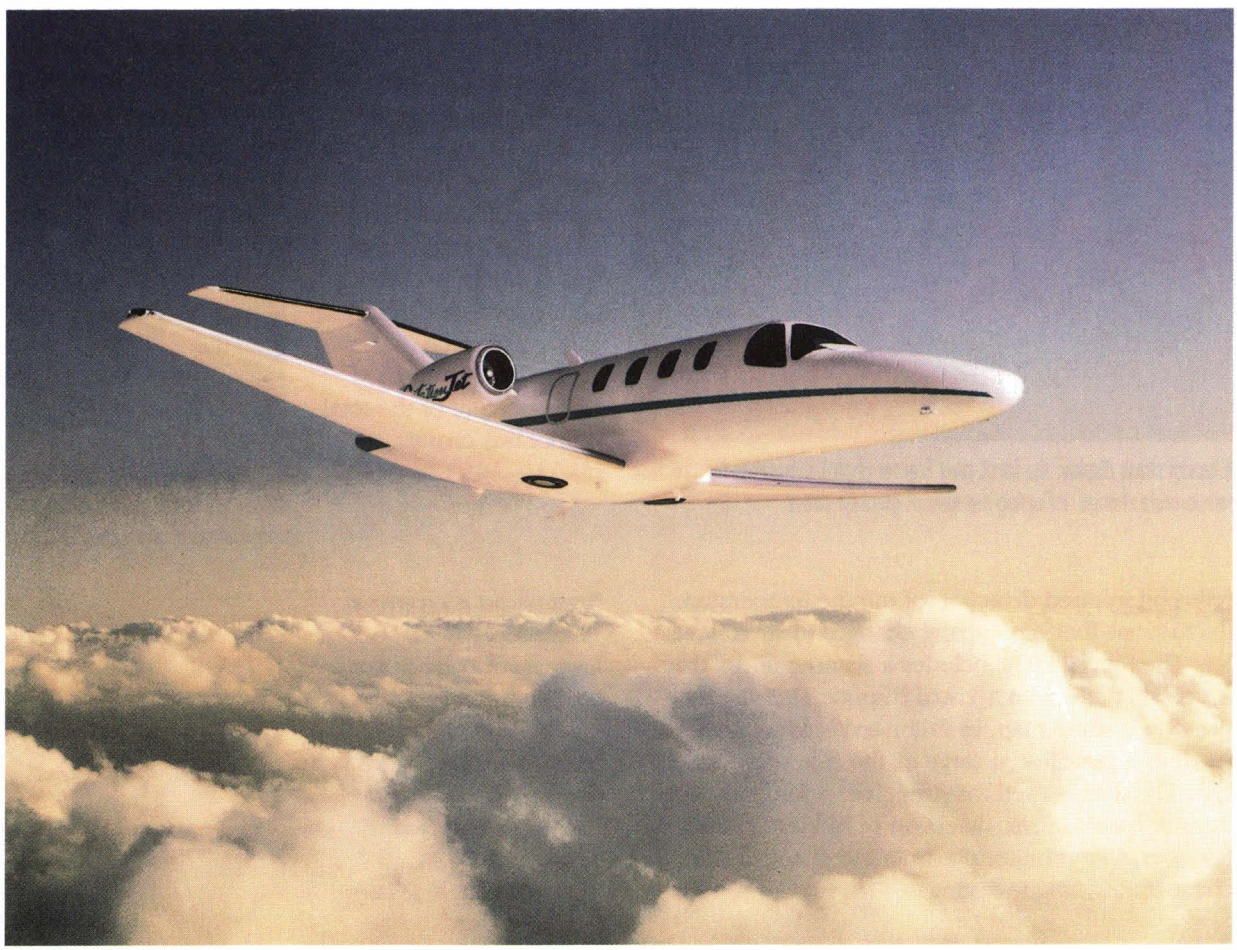
NLF is a means of keeping the airflow over a wing smooth, or laminar, solely by the shape of the wing surface. Near the leading edge, air moves over the wing in smooth, aerodynamically efficient sheets called "laminas." As the air moves farther across the wing, friction between the air and the wing causes the laminas to expand and the air becomes turbulent. The turbulence creates added drag, which limits the airplane's speed and increases its fuel consumption.

NASA has developed technology for a number of ways of maintaining laminar flow, among them a series of NLF airfoils shaped to keep the air smooth for a longer time as it progresses over the wing. With a conventional wing, the onset of turbulence occurs near the wing's leading edge. With the CitationJet's NLF wing, the design goal is to extend laminar flow across 35 percent of the wing's chord. NASA's Central Industrial Applications Center, Rural Enterprises, Inc., Durant, Oklahoma, and its Kansas affiliate, Kansas Technology Enterprise Corporation, Topeka, Kansas, and Wichita State University assisted Cessna in the transfer of the NLF technology.

NLF and other design elements combine to give the CitationJet cruise speeds up to 437 miles per hour, a range of 1,500 miles and the ability to operate from airstrips of less than 3,000 feet.

Cessna describes the nine-passenger CitationJet as an "entry level" business jet and claims it is "the lowest priced business jet you can buy" at $2.5 million. Within two days of the announcement of its availability, the first production block of 50 airplanes was sold out. Certification by the Federal Aviation Administration and first deliveries are expected in October 1992.

The design goal is to extend laminar flow across 35 percent of the wing's chord



Automotive Design

Analytical Design Service Corporation (ADSC), Ann Arbor, Michigan, specializes in solving problems faced by automotive companies engaged in design and product improvement programs. ADSC researchers get an assist from NASA technology, specifically from use of the NASTRAN (NASA Structural Analysis) computer program in tests on automotive parts to diagnose problems and help redesign structures in the interest of customer acceptance and passenger safety. NASTRAN was supplied to ADSC by NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia **(see page 140).**

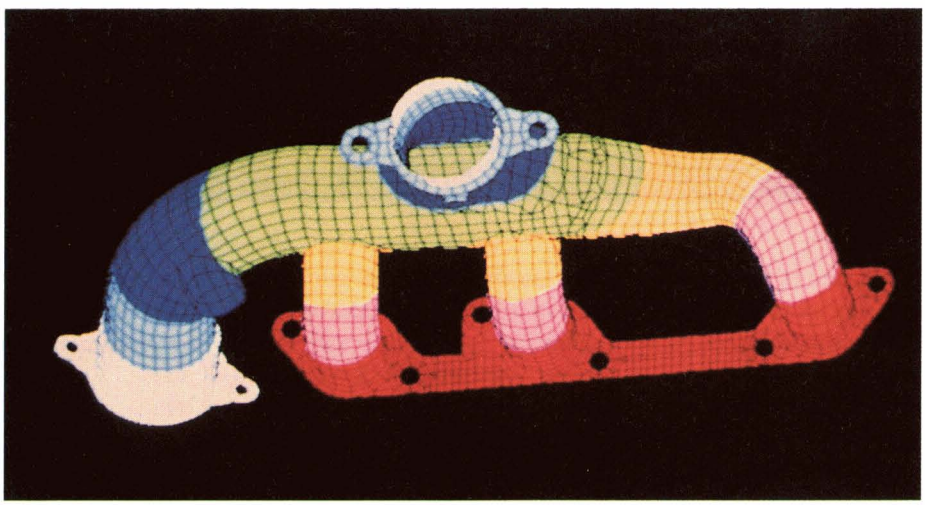
NASTRAN analyzes a design and predicts how a particular part will perform on the road under certain conditions of loading and stress. NASTRAN gets input from a preprocessor-created database containing geometry, boundary conditions and material properties; the program uses this input to calculate and display the stress, deflection and dynamic characteristics of the part. A typical NASTRAN-developed image is pictured **at left below;** it shows the temperature distribution of an exhaust manifold, with red areas hottest. **At bottom left** is a NASTRAN image of the stress distribution in a universal joint yoke (red represents greatest stress).

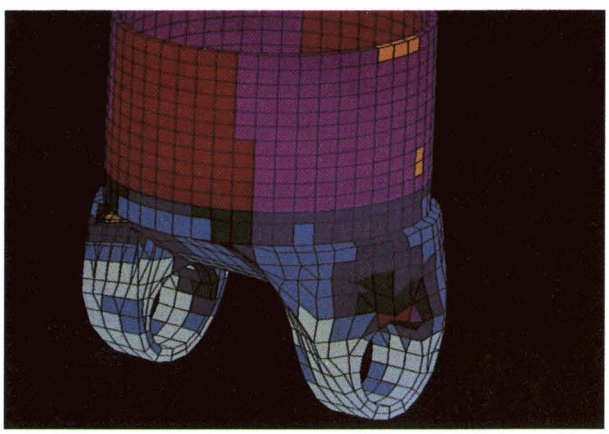
When the stress exceeds designated limits, ADSC analysts can change the design or specifications to improve the part's performance. The NASTRAN program has been used successfully in redesigning manual and automatic transmissions, engine cooling systems, internal engine parts, body components and other automotive subsystems.

ADSC also uses NASTRAN to produce designs for future automobiles which, says Dr. Khalil Kabiri, Senior Research Engineer, will be smaller, lighter and more fuel efficient. He believes that, by the end of the century, about 30 percent of a car's mass will consist of composites and plastics, lighter yet stronger than the metals they will replace; they will be used mainly in body panels and bumpers. The outer body will have a smoother, more rounded aerodynamic design to reduce drag and improve fuel economy.

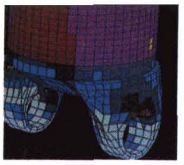
Analytical software, such as NASTRAN, can save auto companies and design consulting firms millions by allowing computer-simulated analysis of an auto's operational performance before prototypes are actually built. Computer simulations also reduce the need for expensive and time-consuming impact tests.

Analytical software can save auto companies and design consulting firms millions





COSMIC® is a registered trademark of the National Aeronautics and Space Administration.



Corporate Jet

An efficient new wing was designed with the aid of several NASA-developed computer programs

At right is the Gulfstream IV (G-IV), newest member of a family of business aircraft manufactured by Gulfstream Aerospace Corporation, Savannah, Georgia. The G-IV features an advanced, lighter, more aerodynamically efficient new wing that was designed with the aid of several NASA-developed computer programs.

At right center is a cockpit view of the G-IV; **the far right photos** show features of the G-IV's luxurious interior.

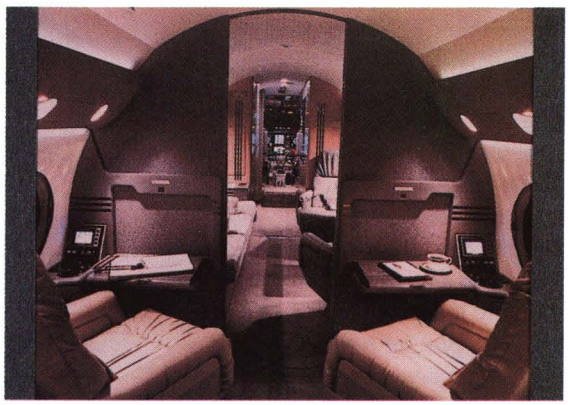
The 19-passenger airplane, which holds the international record in its class for round-the-world flight, has a fully computerized, automated flight management system, a range of 5,000 miles and a maximum speed capability of Mach 0.88, meaning 88 percent of the speed of sound or about 580 miles per hour at cruising altitudes. Flying at near this maximum speed, the airplane encounters a phenomenon known as transonic drag rise, an increase in the drag force created by shock waves that develop on the wing as the airplane approaches the speed of sound. This drag rise reduces fuel efficiency.

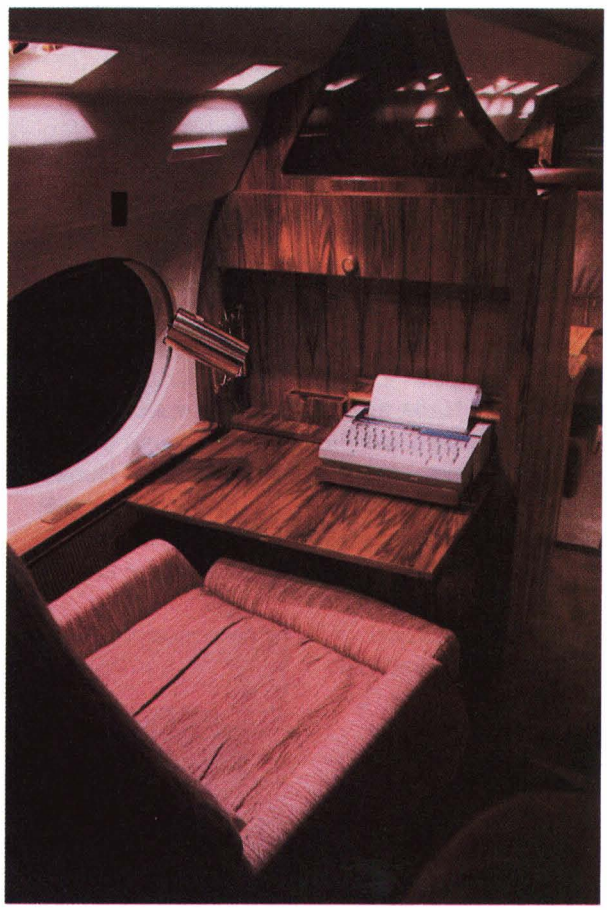
Gulfstream Aerospace engineers used an enhanced version of a NASA program called WIBCO to analyze aerodynamic design features intended to reduce transonic drag. For other elements of the design, they used the programs STANS5 and PROFILE.

Another NASA program — GASP — may play a part in a major undertaking the company hopes to initiate in cooperation with Sukhoi Design Bureau, a Soviet organization: development of an intercontinental supersonic business jet.

Gulfstream Aerospace researchers intend to use GASP in conjunction with other programs in development of a dynamically new aircraft configuration. Originally developed to perform tasks associated with the preliminary phases of aircraft design, GASP will help researchers determine gross weight, range, speed, payload and optimum wing area for the new airplane. The aerodynamic and propulsion segments of the program will allow evaluation of the type of engine required to meet payload specifications.

The GASP program was specifically developed to compare configurations and assess performance of general aviation aircraft or small transports; it was modified to fit Gulfstream Aerospace's current applications.

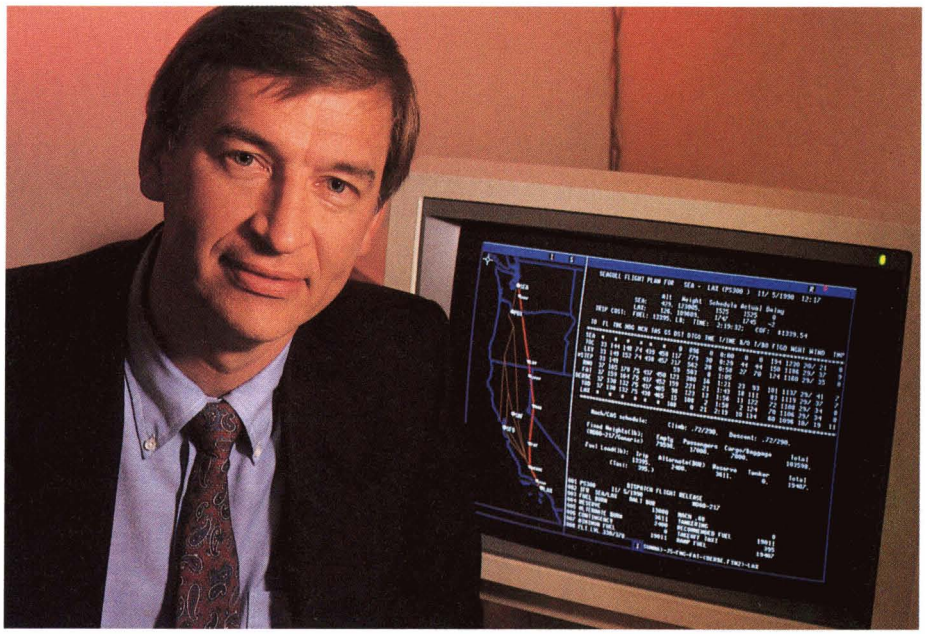




Use of the NASA programs allows company engineers the freedom to experiment

Use of the NASA programs allows company engineers the freedom to experiment with different geometries to arrive at the optimum parametric requirements for their new aircraft. By using already developed programs, the company saves the cost of developing new software and effects additional economies in reduced man-hours and overall design time. WIBCO, STANS5, PROFILE and GASP were provided to Gulfstream Aerospace by NASA's Computer Software Management and Information Center (COSMIC). Located at the University of Georgia, Athens, Georgia, COSMIC supplies government-developed computer programs adaptable to secondary uses to government, industry, and academic institutions **(see page 140).**

Flight Planning



The direct operating cost of an airplane is basically the sum of the time flown and the fuel burned. In the case of an airline operating thousands of flights, millions of gallons of fuel could be saved annually if the airline could fly precise point-to-point trajectories optimized for fastest time or minimal fuel expenditure.

However, it is far more complex than it sounds to develop a computer program for devising optimal trajectories, due to the many considerations of airline flight, such as air traffic control constraints, weather and winds, local climb and descent requirements, airplane weights and payloads, and a variety of other factors.

Millions of gallons of fuel could be saved annually if an airline could fly precise point-to-point trajectories

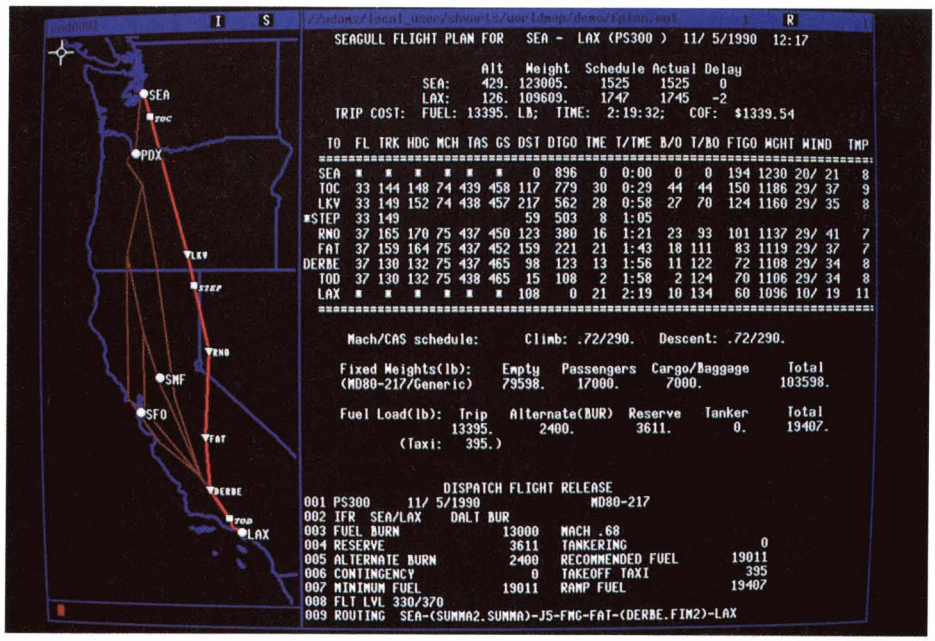
In 1979, NASA took a first step toward development of a comprehensive optimum trajectory software package; Dr. Heinz Erzberger and Homer Q. Lee of Ames Research Center developed a basic system for computing the most fuel-efficient flight path. This concept formed the basis for the first generation flight management systems used by the commercial airlines in the 1980s. It was estimated at that time that such a system could save the airlines some $200 million a year in fuel costs.

The Ames software served as a departure point for subsequent NASA-sponsored steps toward an advanced flight management system. One step was an extensive survey of the airlines to determine how they generate flight plans and what features are the really important operational considerations. The survey was conducted by Seagull Technology, Inc., Sunnyvale, California, a company that provides engineering design/analysis and develops special purpose software products. Seagull also produced an experimental computer program that would generate optimal flight plans between a pair of cities.

From the survey of the airlines' flight planning capabilities, it was apparent that there was need for a new commercial flight planning computer program that would minimize direct operating costs while complying with the various airline operating constraints. In 1985, Seagull received a Small Business Innovations Research grant from Langley Research Center for development of such a program. Under the grant, Seagull produced STAFPLAN (Seagull Technology Advanced Flight Plan), specifically designed for small to medium sized

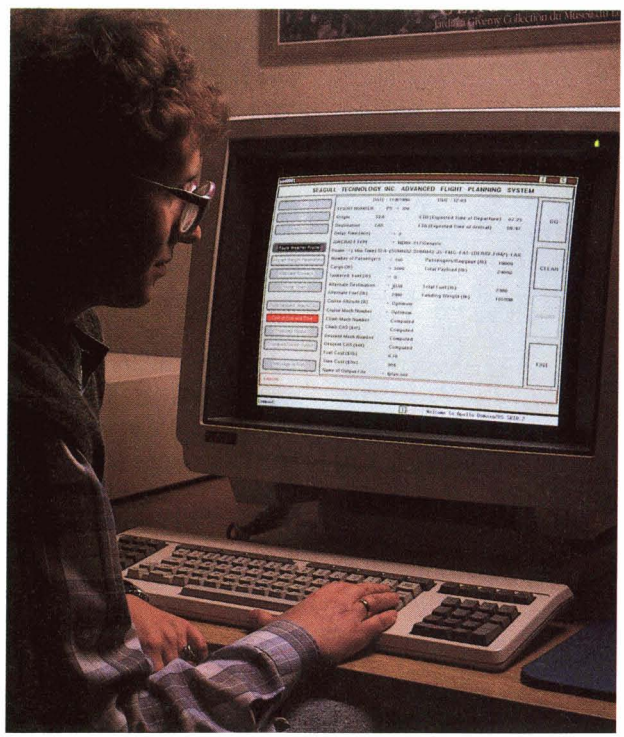
airlines that might not have in-house capabilities for optimal trajectory planning.

At left is Dr. John A. Sorensen, president and founder of Seagull Technology. **At lower left,** Sorensen is pictured with Susan Dorsky, primary STAFPLAN systems designer; on the console screen, and shown in closeup **at right,** is a STAFPLAN display that gives the airline dispatcher optimization information for a flight plan from Los Angeles to Seattle (STAFPLAN can compute flight plans for any pair of cities).



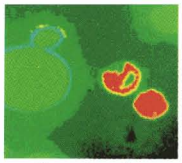
STAFPLAN incorporates four input databases: weather and associated meteorological data (**below,** company programmer Ann Shvarts is working on route weather profiles); route data with associated navigational aids and airport information; performance data on airline aircraft and engines; and flight-specific data, such as scheduled departure and arrival times, payload, assigned aircraft type and crew, and cost of fuel.

In sequential steps, STAFPLAN provides the dispatcher the precisely correct amount of fuel the flight needs, with allowance for a safety margin (excess fuel costs money because it takes extra fuel to carry the excess fuel); optimal cruise altitude; step climb and step descent points; optimal cruise speed; and optimal flight path. If a fixed cruise speed is specified by the airline, STAFPLAN computes the "minimum time track" for best direct operating cost.



Seagull's NASA-sponsored experience in flight planning research and flight management system development has led to a number of other work assignments for the company, including contracts with Ames Research Center involving development of an on-board aircraft performance monitoring system and multiplane air traffic control simulations. For the Federal Aviation Administration, Seagull is assisting in design of a method for computing optimal schedules for approaching aircraft to optimize runway utility. Seagull is also developing, for flight path generation and cost analysis, a Transport Aircraft Synthesis Program for airlines and aircraft component manufacturers.

A software system provides the dispatcher the precisely correct amount of fuel the flight needs



Skin Damage Assessment by Ultrasonic Waves

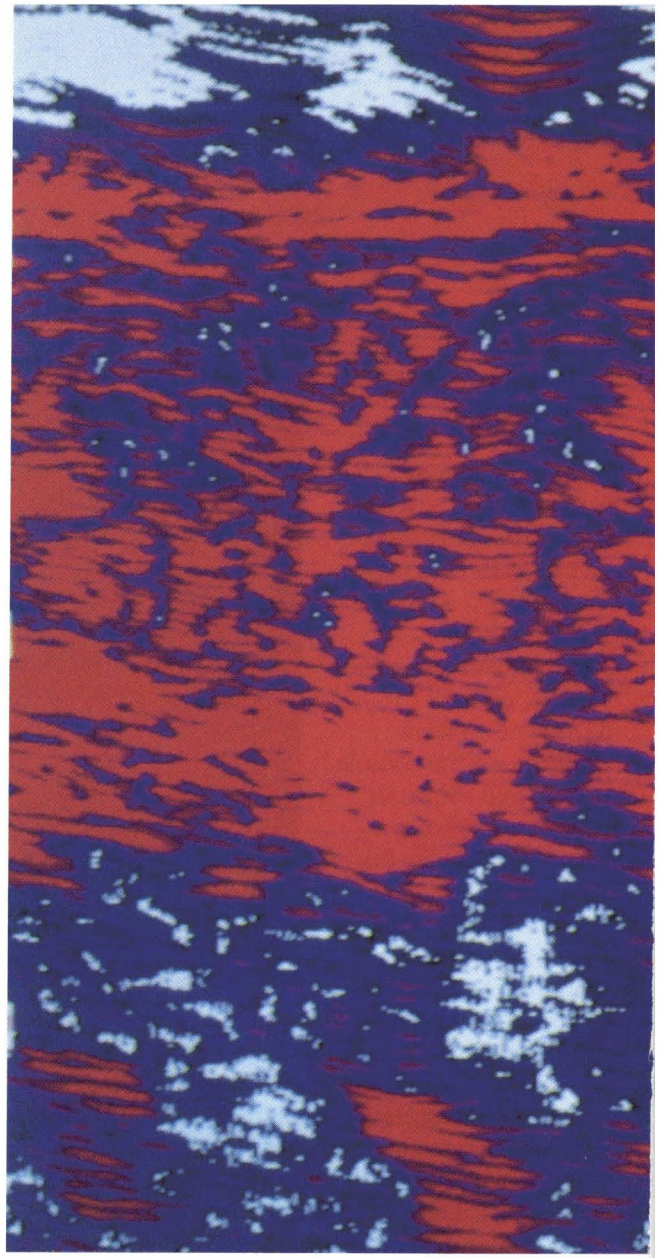
Heading spinoffs in health and medicine is an instrument for improved diagnosis and treatment of burns and skin disorders

Each year about two million Americans suffer serious burns. A large number of them require hospital treatment and 10-12,000 die from their injuries. Among those hospitalized, some 70,000 receive intensive care and the cost of such treatment runs to several hundred million dollars a year.

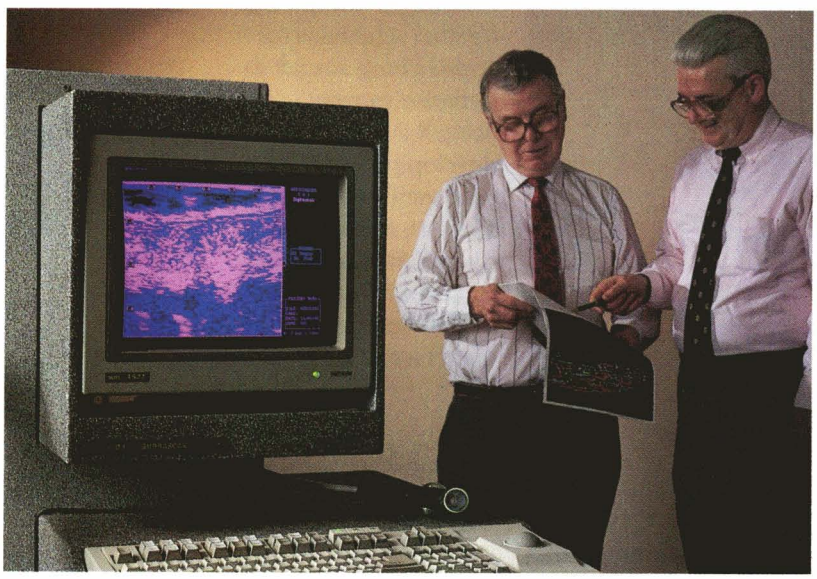
The application of NASA ultrasound technology, originally developed as a means of detecting microscopic flaws in aircraft and spacecraft materials, has provided an advanced diagnostic instrument that makes possible immediate assessment of burn damage, knowledge that permits improved patient treatment and may even save lives in serious burn cases.

Developed by Westminster Supra Scanner, Inc. (WSS), Orangeburg, New York, and produced under NASA license, the Supra Scanner is the first clinically-tested, commercially available ultrasound system that permits quantitative assessment of burn depth.

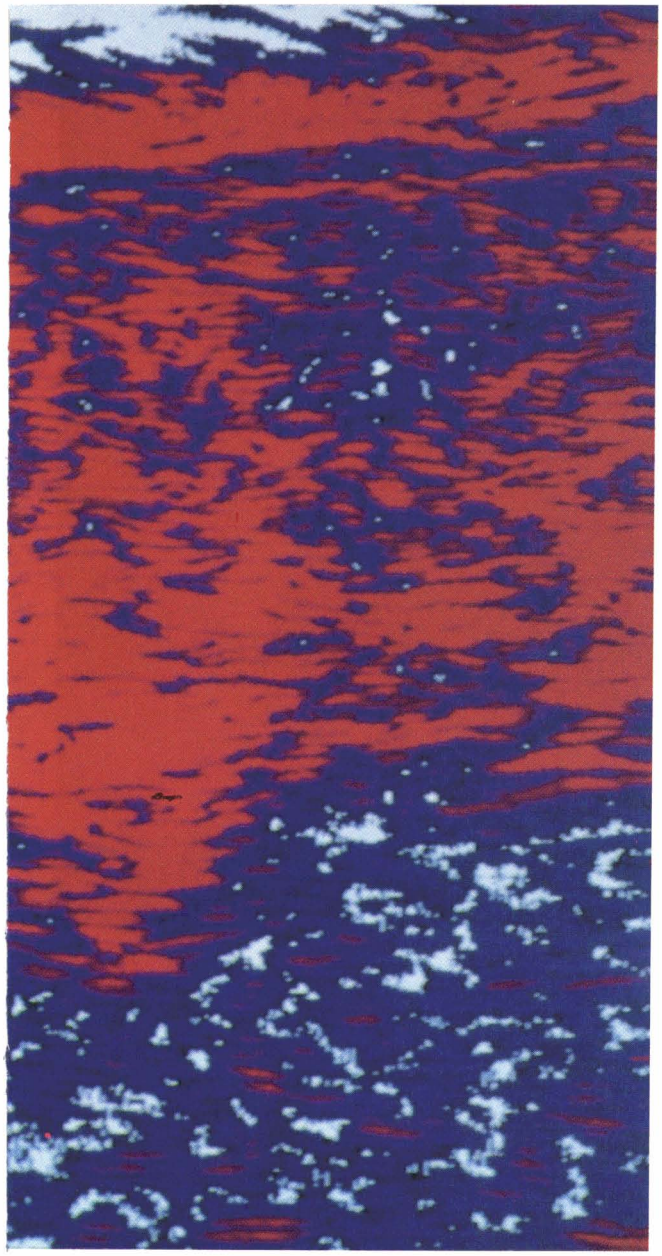
The depth of the burn is the critical factor in burn diagnosis and treatment of second and third degree burns. The customary treatment is to allow natural sloughing of burn-caused necrotic or dead tissue and closing the resulting wounds with skin grafts. Effective treatment, therefore, is dependent upon early recognition of the *extent* of dead tissue and its removal, by chemical or surgical means, to minimize risk of infection and hasten healing. The key is accurate information on the depth of the burn. Earlier methods were subjective and thus prone to error.



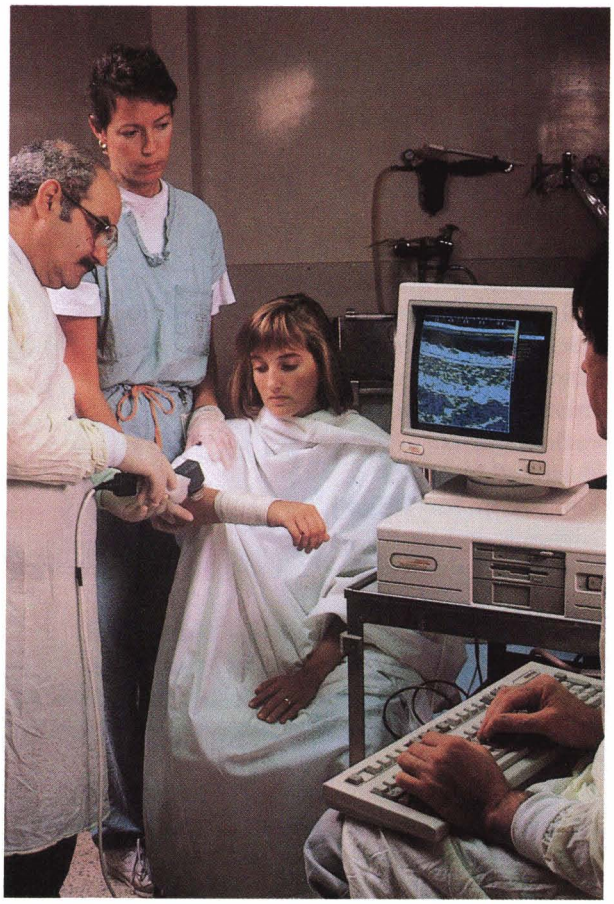
Shown below is the Westminster Supra Scanner, an instrument for measuring burn depth, a key factor in diagnosis and treatment of burns. The system includes the keyboard and display console at left and the ultrasonic scanner held by Westminster chairman Jack Cantwell. At right is William Gregory, president of Westminster Technology Group, Inc.



To meet the need for precise determination of burn depth, Langley Research Center initiated — in 1983 — an applications engineering project (an instrument of NASA's Technology Utilization Program, an applications engineering effort is one involving use of NASA expertise to redesign and reengineer existing aerospace technology for the solution of national problems). The Langley project was spearheaded by Dr. John H. Cantrell and Dr. William T. Yost, both physicists with Langley's Nondestructive Measurement Science Branch, which conducts research on ultrasonic and other techniques for evaluating quality and fatigue of aerospace materials.



A typical false-color image created by the Westminster Supra Scanner. To the skilled eye, it provides information on skin surface and subsurface features that can be applied not only to burn diagnosis but to other skin disorders.



Dr. Anthony Marmarou of the Medical College of Virginia (MCV) uses the Supra Scanner to measure the depth of a patient's burn. MCV conducted clinical evaluations on both the NASA prototype and the commercial instrument.

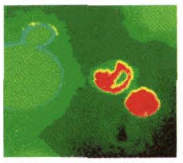
Other organizations cooperating on the project include the Medical College of Virginia (MCV), Richmond, Virginia; the University of Aberdeen, Scotland; and the NASA Technology Applications Team, Research Triangle Institute (RTI), North Carolina, which coordinated the project and directed the commercialization of the technology.

Langley developed a prototype instrument capable of determining the level where burned tissue ends and healthy tissue begins. It is possible to do so because of the fact that, when skin is burned, the protein collagen that makes up some 40 percent of skin becomes more dense. The Langley technique involved directing ultrasonic waves at the burned area; the difference in density between damaged and healthy tissue causes sound waves to reflect at the point of interface.

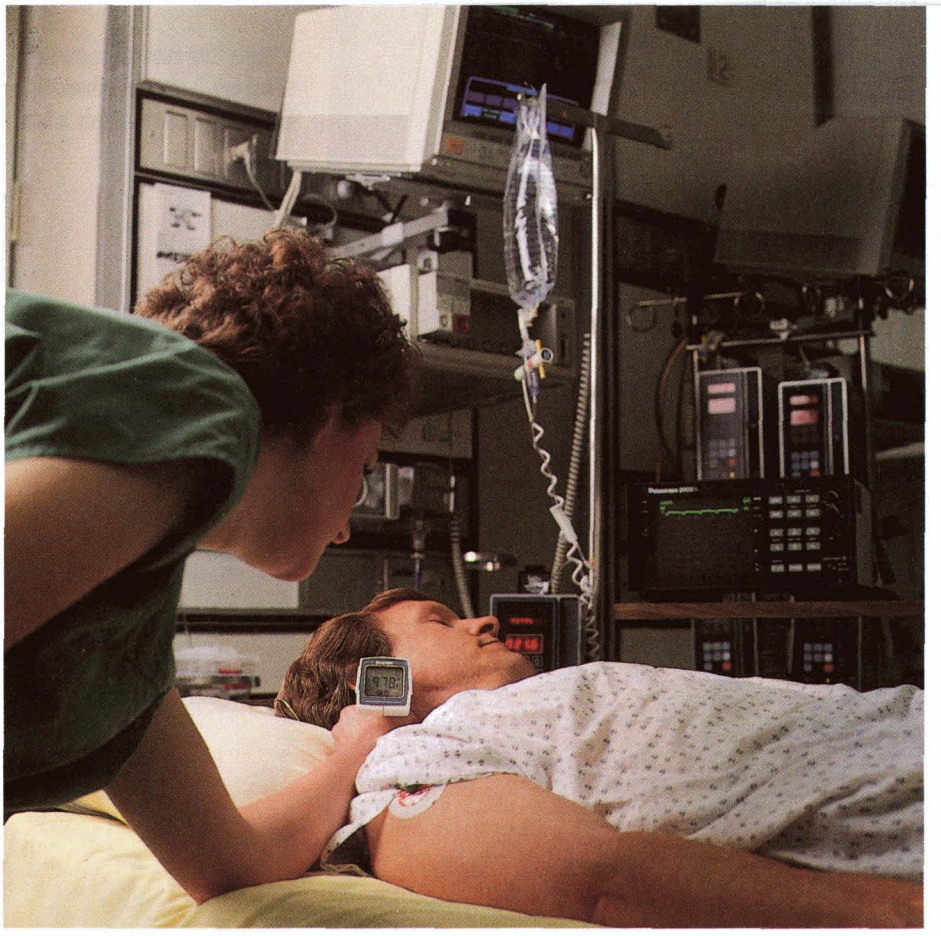
After successful completion of preliminary clinical tests by MCV on patients with different types and different degrees of burn, NASA's RTI technology team negotiated an agreement — in 1990 — with Jack Cantwell, Inc. (now WSS) for commercialization of the technology. Following additional clinical tests of the commercial version by MCV and the University of Aberdeen, the Supra Scanner was granted Food and Drug Administration approval in December 1990.

The Supra Scanner uses the NASA depth measurement technology by combining a scanning transducer and computer in a single instrument that may be used at a patient's bedside. The patented system produces high resolution color images of up to 14 millimeters of human tissue, generates cross-sectional images of the skin and provides information regarding skin surface and subsurface and features.

The Westminster Supra Scanner has additional applicability in diagnosis of skin cancer and other skin disorders, plastic surgery and diagnosis of lymphatic disorders.



Infrared Thermometer



At right, a nurse is taking a patient's temperature with the Diatek Model 7000 aural thermometer, which completed clinical testing in 1990 and was introduced to the commercial market in 1991. The thermometer, which employs infrared technology to get an almost instantaneous reading, was co-developed by Diatek Corporation, San Diego, California, and Jet Propulsion Laboratory (JPL). The development was undertaken as part of NASA's Technology Affiliates Program, which seeks to improve the competitiveness of American industries by facilitating the transfer of government-developed technology to the private sector.

The thermometer employs infrared technology to get an almost instantaneous reading

In the U.S. alone, some two billion clinical temperature readings are taken annually, about half of them in acute care hospital facilities. Because of a national shortage of nursing personnel, Diatek, a world leader in electronic thermometry, saw a need to reduce nursing time by providing a faster thermometer. Company researchers felt that the best developmental route was through use of infrared optical technology, which offered the fastest speed of operation and extreme accuracy. Additionally, it would allow determination of body temperature by measuring the energy emitted from the tympanic membrane (eardrum) into the ear canal; such an approach obviates the need for oral or rectal readings and avoids contact with mucous membranes, virtually eliminating the possibility of cross infection.

Diatek engineers started work on an infrared sensor but found a need for expert guidance. They turned to NASA, since Diatek is a member of the RIMTech entrepreneurial technology program and RIMTech in turn is a member of the JPL Technology Affiliates Program. This gave Diatek access to JPL's expertise, which includes 30 years of experience in remote measurement of the temperatures of stars and planets by reading their emitted infrared radiation.

Diatek and JPL worked closely on development of the infrared sensor that is the heart of the Model 7000 thermometer. The end product weighs only eight ounces, can be operated with one hand and measures temperatures in less than two seconds; this rapid response permits temperature measurement of newborn, critically ill or otherwise incapacitated patients. The saving in nursing time is appreciable because of the great numbers of temperatures taken in the course of a hospital shift. The Model 7000 is also an aid to patient comfort, since the speed of measurement makes frequent temperature taking less bothersome. The device has a disposable probe cover as a further guard against infection.

Diatek estimates the world market for electronic/infrared thermometers at $126 million for acute care hospitals and a roughly similar value for sales to alternate health care facilities, such as clinics, physicians' offices and nursing homes. Diatek's investment in the NASA technology was only the cost of technology transfer. Under the Technology Affiliates Program, a company pays only the cost of adapting or modifying the technology to its current need. For such an investment, the company gets the temporary assistance of a highly skilled staff of NASA technologists and avoids the costs of technologists before and after the company has used their talents. The JPL program is five years old; over that time, 30 companies have joined the program and about 50 transfer tasks have been completed or are being worked.

Heart Research

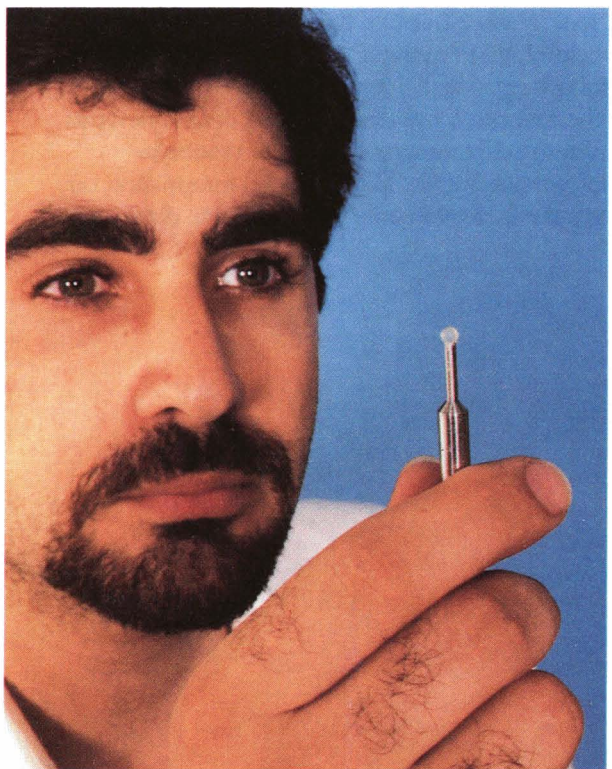
At the University of Pittsburgh School of Medicine, researcher James F. Antaki and colleagues of the Department of Surgery are conducting a study of cardiac biomechanics involving development of a computer model to advance understanding of stress/strain relationships in the heart.

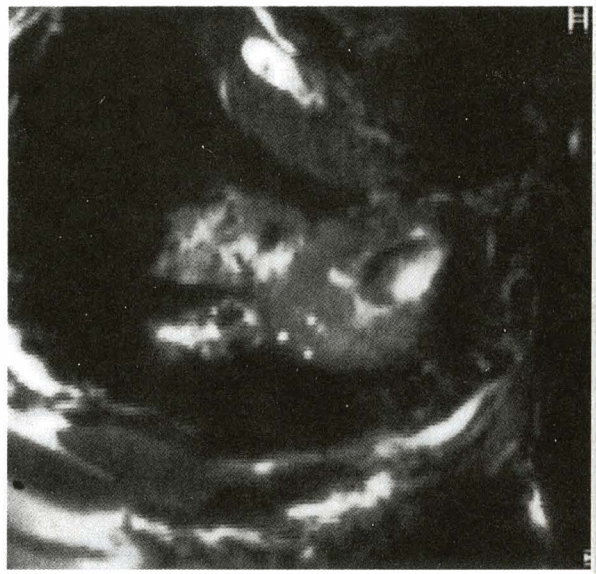
As essential input to the model, it was necessary to supply a full three-dimensional spatial description of the heart surface. The technique of Magnetic Resonance Imaging (MRI) was ideally suited to this task because it is inherently three-dimensional.

In addition to topographic information, the researchers needed a way to visualize and track material points within the heart muscle, some kind of implantable marker that would show up in MRI images as a bright dot against a dark background. Unfortunately, they were unable to find any solid or gel substance that would provide the necessary intensity.

The need, James Antaki explains, was for tiny artificial "eggs" containing a solution of copper sulfate. These heart muscle markers had to be small enough (about two millimeters in diameter) that they would not injure the heart, yet large enough to be seen in the images; they also had to be biocompatible yet tough enough to withstand implantation and the cyclic beating of the muscle.

The group was unable to purchase such a container commercially and efforts to fabricate one failed. Then Antaki read an article in *NASA Tech Briefs,* a publication that describes new technologies available for transfer, about a procedure for making microspheres. Antaki contacted the NASA Industrial Applications Center in Pittsburgh, which in turn put him in touch with Jet Propulsion Laboratory (JPL), the NASA center that had sponsored the technology described in *Tech Briefs*.

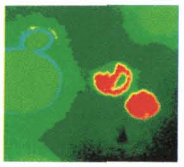




JPL provided Antaki a complete set of NASA reports on every aspect of microencapsulation and in one of them — *Apparatus for Producing Hollow Spheres* — Antaki found the solution to his problem. JPL also directed Antaki to the author of the report, Dr. Taylor Wang of Vanderbilt University, who was persuaded to help the Pittsburgh group construct an apparatus for fabricating myocardial markers.

At left, Antaki is inspecting a marker prior to its implantation in an animal heart; the marker is the tiny sphere atop the implantation tool. **Above** is an MRI image of a beating canine heart, showing three markers (dots circled). The Pittsburgh School of Medicine conducted a series of MRI animal heart imaging tests and is using the information provided by the markers to compute strains and associated stresses. The research is expected to lead to improved understanding of how the heart works and the changes that take place when it fails, perhaps enabling developing of improved techniques for detecting and treating diseases of the heart.

A NASA report sparked development of innovative heart research markers



Balance Function Disorders

Weightlessness investigations prove useful in balance research

Balance disorders affect more than two million Americans annually. In some 20 percent of these cases, the problem is caused by inner ear disease. The balance disorder may manifest itself as vertigo, whirling or dizziness, and it may lead to personal injury, misery and time lost from work and family.

At the Minneapolis (Minnesota) Neuroscience Institute on the Abbott Northwestern Hospital campus, the Balance Function Laboratory and Clinic is a collaborative project of community physicians and LifeSpan hospitals offering diagnosis and treatment of patients with balance function disorders. At the laboratory, physicians and researchers are employing NASA technology originally developed to investigate vestibular (inner ear) function in weightlessness.

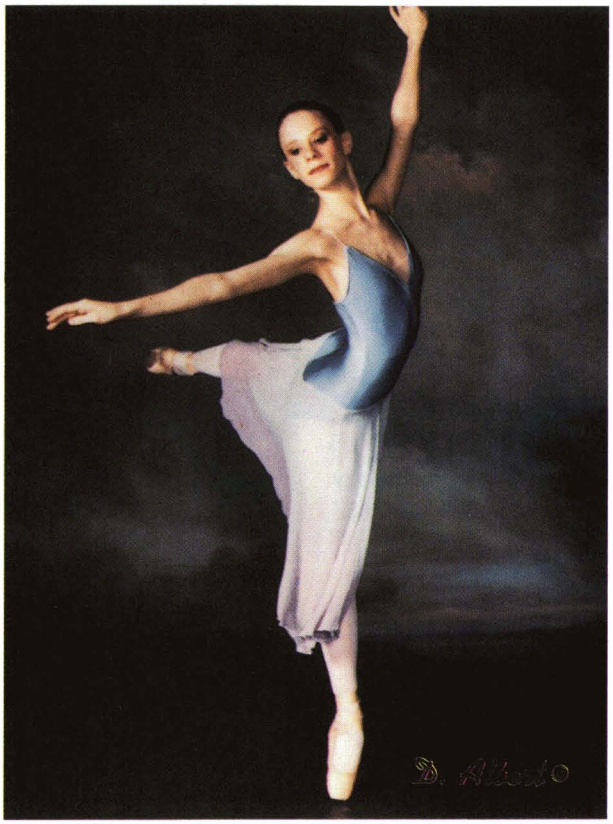
One of the sophisticated tools used in the Balance Function Laboratory is a rotational chair **(left)** technically known as a "sinusoidal harmonic acceleration system." Manufactured by ICS Medical Corporation, Schaumberg, Illinois, the chair system turns a patient and monitors his or her responses to the rotational stimulation. The body's balance is maintained by visual, touch and vestibular information integrated within the brain. The vestibular information is the body's internal monitoring system; vision and touch are environmental monitors.

"The chair technology is invaluable for assessing balance function problems," says Dr. Gene Balzer, audiologist and clinical researcher. "It is particularly helpful in my research with deaf and blind individuals who lack vestibular function, a group that could not adequately be evaluated with previous testing technology. Chair testing can also be used to evaluate children under age two, something that was difficult with other tests."

The chair system is also used by clinical neuro-otologist Dr. Rick L. Nissen to diagnose patients with Meniere's disease (abnormal fluid buildup in the inner ear) and by clinical neurologist Dr. Richard V. Johnson in diagnosis of older patients with unknown loss of vestibular function, also patients with a breakdown in the integration of this information in the central nervous system.

The staff and physicians of Minneapolis Neuroscience Institute have used the chair technology to monitor recovery of balance function following acoustic/vestibular nerve tumor removal. Their research has demonstrated central nervous system adaptation to changes in vestibular information. It has also provided information on treatment to overcome post-operative dizziness.

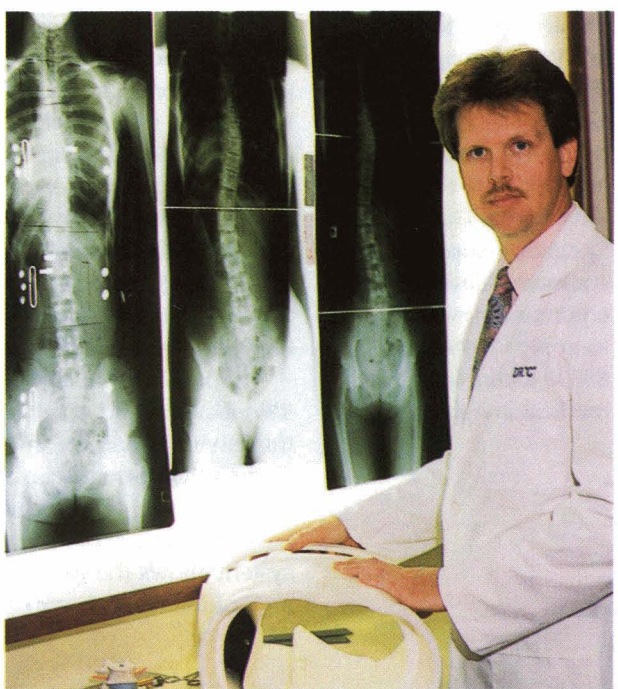
Spinal Bracing



At right is Sandra Wafer, a dancer with the City Ballet of Houston, Texas. A few years ago, this young ballerina's dream of dancing seemed extremely remote; she was a victim of scoliosis, a disease characterized by progressive curvature of the spine. But Sandra Wafer escaped the crippling deformities of scoliosis by means of a new course of treatment that focuses on innovative bracing techniques as an alternative to surgical correction. The key element of the treatment is use of the Copes Scoliosis Brace, developed by orthotist Dr. Arthur L. Copes of the Copes Foundation, Baton Rouge, Louisiana.

The Copes brace, fabricated to a patient's specific need, features a novel pneumatic bladder that exerts corrective pressure on the spinal curve. **Below,** Dr. Copes is shown with a typical brace; one of the pneumatic bladders, which are technically known as force vector pads, is visible inside the brace (dark pouch at the left edge). A brace may employ as many as six pads applying pressure along the deformed spinal curve; each contains a valve system that enables the treating physician to alter the pad pressures as indicated. Through constant corrective force applied to the torso, distortion is slowly reduced or eliminated by periodic air injection into the force vector pad.

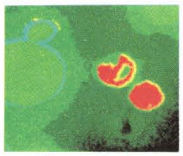
In addition to long term use of the brace, the Copes Scoliosis Program includes a three-phase exercise course, hydrotherapy, bone manipulation and muscle stimulation.



Once a patient achieves maximum correction, he or she is introduced to a retainer brace. The length of a complete program naturally varies with the individual, but usually the patient wears the corrective brace for 14 to 18 months, and correction of some degree is accomplished in more than 80 percent of the cases, according to Dr. Copes. Sandra Wafer began treatment with two 30-plus degree spinal curves; after two years of treatment, the curves were reduced below five degrees.

Dr. Copes credits NASA technology transfer with an assist in his development of the Copes Scoliosis Brace. He was helped by the NASA/Southern University Industrial Applications Center in Baton Rouge, and the Central Industrial Applications Center, Durant, Oklahoma, whose job it is to provide information retrieval services and technical help to industrial and institutional clients. The two centers supplied Dr. Copes with more than 50 technical reports from the NASA databank and other databases; they covered a variety of subjects, such as other types of braces in use, the effects and complications of bracing and surgery, and technology developments in rubber and plastics applicable to both the brace and the pneumatic bladder. Dr. Copes states that roughly 35 percent of these medical reports had a vital degree of utility in his development effort. He adds that the NASA input contributed significantly to the achievement of extraordinary results in hundreds of patients.

The key element of the treatment is use of a special brace developed with NASA databank input



Medical Imaging System

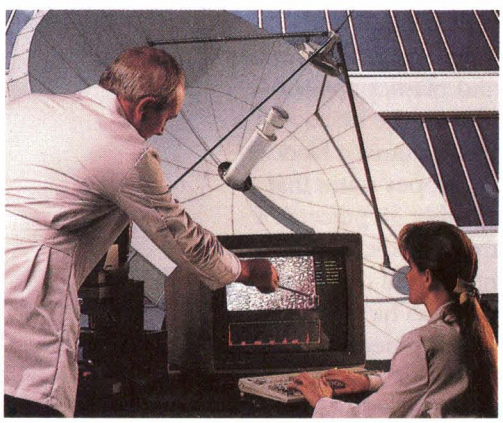
The system incorporates satellite image processing technology

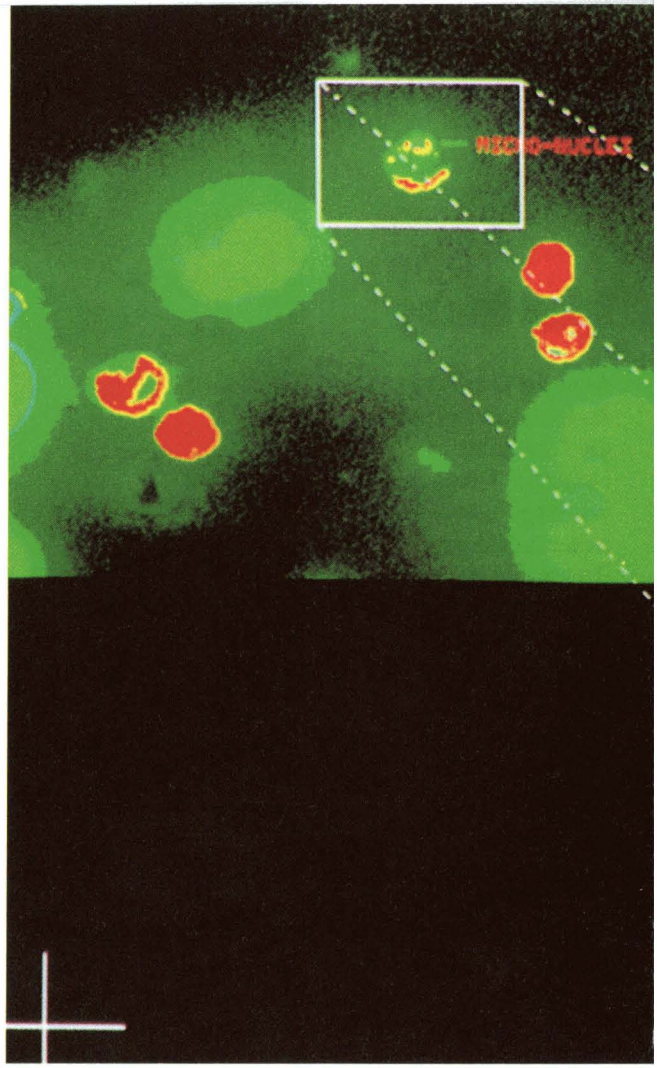
Pictured below is the MD Image System, a true color image processing system that serves as a diagnostic aid and a management tool for storage and distribution of images to hospitals and pathology laboratories. A "spinoff from a spinoff," the system is being developed by Medical Image Management Systems, Huntsville, Alabama, a cooperative venture of three Alabama companies: Crystal Image Technologies and Crystal Data Systems, both of Huntsville, and Delta Technologies, located in Birmingham.

The MD Image System stemmed from an earlier development by Crystal Image Technologies: a general image processing/geographic information system designated GeoStation 88000. This system, now commercially available and in use by government laboratories and imaging firms, includes both hardware and software for remote sensing and image processing.

GeoStation 88000 incorporates enhanced UNIX versions of ELAS, an image processing software package developed by NASA's Earth Resources Laboratory for analysis of Landsat satellite images and now widely used in general purpose image processing. For geographic information applications, ELAS is integrated with the Army Corps of Engineers' GRASS software.

About four months into the development of GeoStation 88000, Crystal Image Technologies officials were introduced to principals from Delta Technologies. The latter company had for several years been conducting research on computer analysis of images digitized from pathology slides. The meeting led to a collaborative effort, involving the two firms plus Crystal Data Systems, a supplier of computer hardware and communications systems, to apply GeoStation 88000 technology to a medical imaging system.

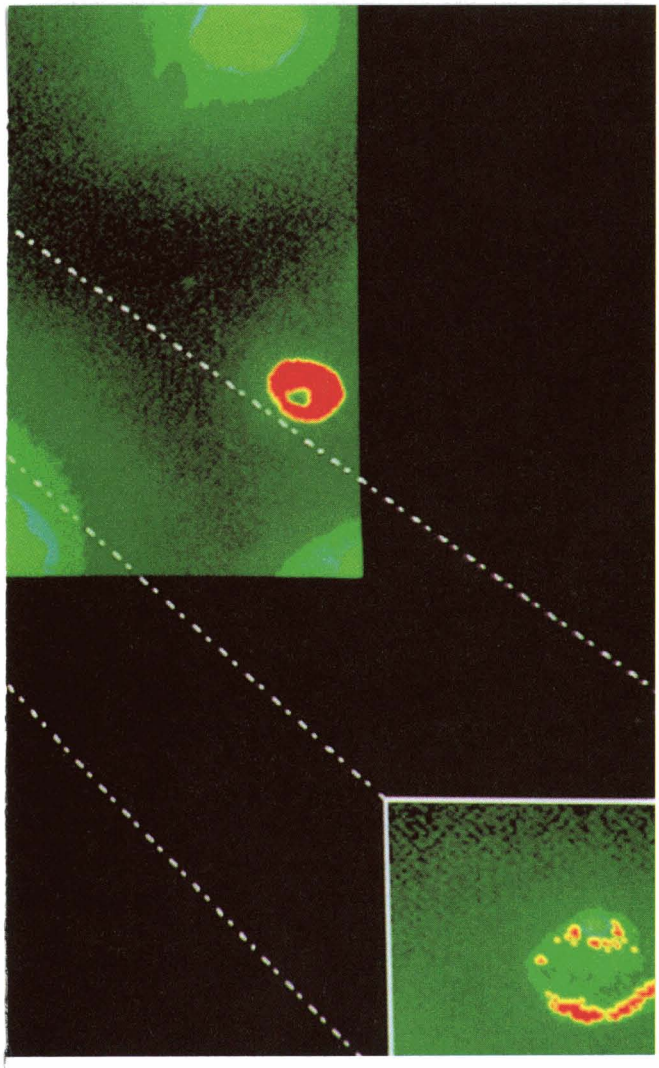


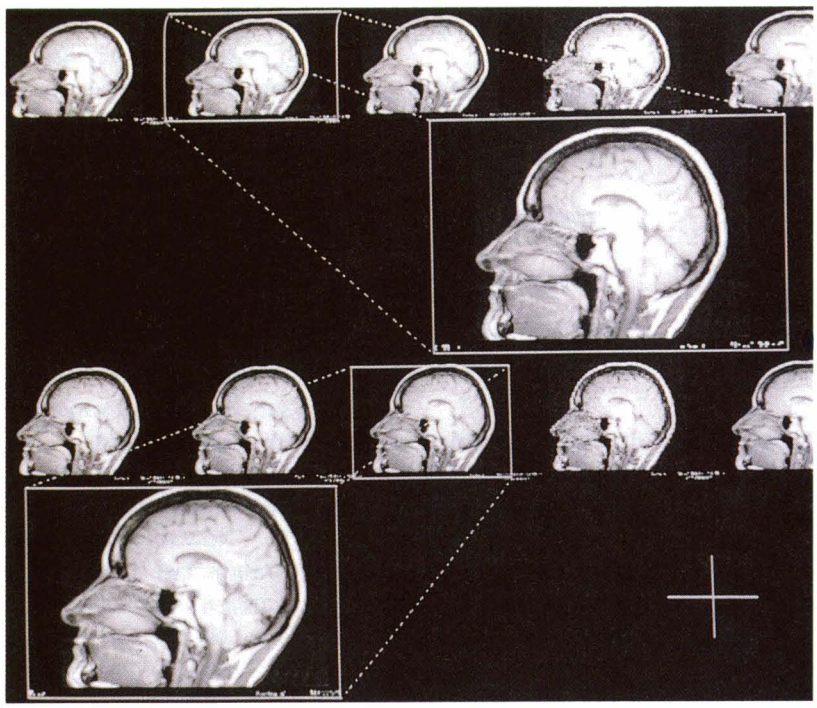


The result was the MD Image System. Externally similar to GeoStation 88000, MD Image includes a microscope, color video camera, a computer and a workstation for image processing, data storage and data communications. The computer software is a proprietary implementation of the NASA ELAS package.

The system is designed to aid in the diagnosis of cancer and other diseases, highlighting specific characteristics to help physicians recognize specific patterns. For immunochemistry applications, MD Image uses its true color capabilities to quantify multiple antibodies simultaneously. For DNA analysis, MD Image complements the flow cytometry technique in the identification of malignant cells. Generally, the system acquires microscope-based images, performs statistical analysis on them, stores them in standard database format, and transmits them to other remote sites for consultation.

A particular area of research interest is the identification and quantification of micronuclei. In this environment, the investigator stains a sample using a fluorescent stain and looks for the existence of micronuclei by searching for those regions that have the same "color density" as the nuclei. The system allows the user to magnify and highlight the area of interest **(above).**

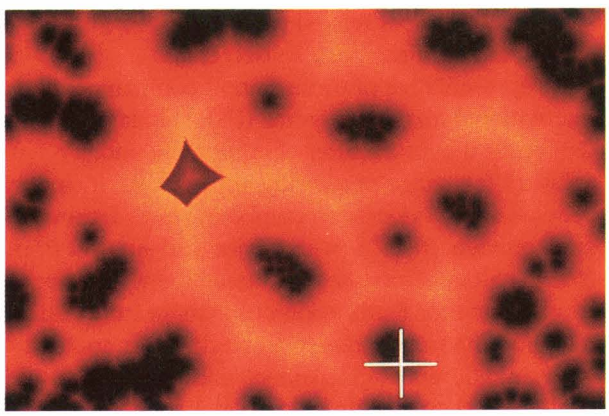




The image **below** illustrates the system's flexibility in classifying an image. In this case the user has specified a classification based on a set of predetermined levels of color intensity and assigned a unique color map for the classification. This flexibility allows a user to highlight graphically minute changes that might otherwise go unnoticed.

The system can accept, store and analyze images from other sources, such as a Magnetic Resonance Imaging system **(above).** These images can be attached as records in the common database format and assimilated to form a complete patient image database that incorporates images from multiple sources such as pathology, radiology and cardiology.

The system is designed to aid in the diagnosis of cancer and other diseases

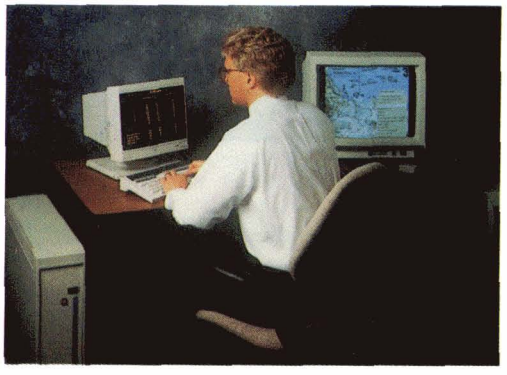


Environment/Resources Management

Landsat Legacy

A flourishing company spawned by NASA remote sensing technology exemplifies spinoffs benefitting environmental protection and resources management

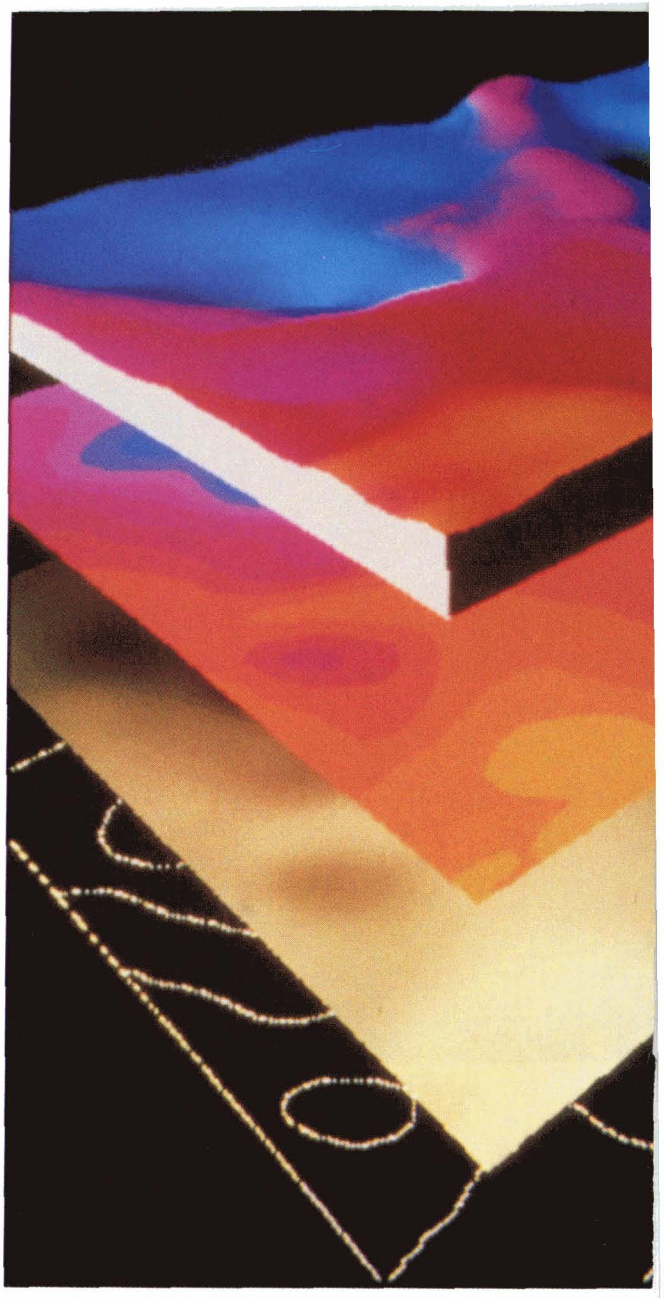
In 1972, NASA introduced the Landsat resources survey system, a series of satellites for observation of changing conditions on Earth's surface. Computer-processed into highly informative tapes and images, Landsat remote sensing data offers a means of differentiating among a broad variety of Earth features, and repetitive coverage allows monitoring Earth processes that change over time — crop growing or land use patterns, for example.



An image processing workstation designed by International Imaging Systems (I^2S), a spinoff company whose product line was developed from experience gained in NASA contract work. The latest I^2S innovation is a high speed digital image-based photogrammetric system and workstation.

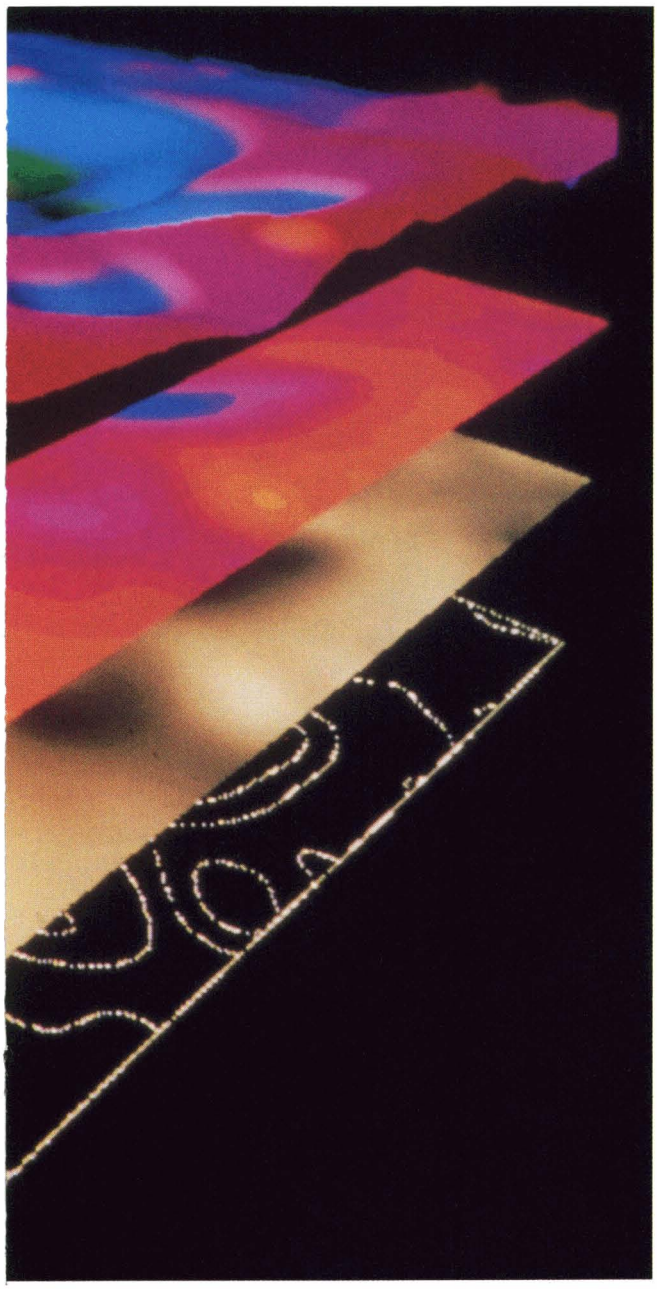
Now operated on a commercial basis, Landsat is approaching the end of its second decade of service. Over the years, the system has provided resource management benefits to thousands of government and private sector users in the U.S. and abroad. Landsat data, combined with data from other sources, offers broad utility in such areas as agricultural inventory, oil and mineral prospecting, charting sources of fresh water, wildlife preservation, monitoring air and water pollution, delineating urban growth patterns, improving the accuracy of maps, studying floods to lessen their devastation potential, and scores of other applications.

The Landsat development has also paid a dividend to the U.S. economy in the form of a small but flourishing Landsat-spawned industry devoted to commercial application of remote sensing technology. Some of this industry's companies expanded from aerial photography into satellite Earthscanning activities; others are firms that were specifically founded to pursue the opportunities afforded by satellite remote sensing. Some manufacture sensor systems for aircraft or spacecraft scanning, others produce hardware or software for image processing, still others offer a variety of specialized services related to analysis and interpretation of remotely sensed data.



Representative of these spinoff companies is International Imaging Systems (I^2S), Milpitas, California, a manufacturer of equipment and software for image processing applications, including systems and workstations combining both hardware and software. In 1975, with advice and support from NASA, I^2S developed its initial equipment to process Landsat data for Earth resources management. Since that time, I^2S has continued to work under contract with six different NASA centers, additionally has sold almost 1,000 systems in 42 countries for processing Landsat data.

The image processing technology I^2S developed to support Landsat provided the basis for development of hardware, software and systems for ground processing of data from Landsat's competitor,



the French SPOT remote sensing satellite, which is also being operated on a commercial basis. I²S provided much of the equipment for the SPOT processing station at Kiruna, Sweden and is providing a complete SPOT ground processing system for Yugoslavia's Rudarski Institute.

Working with Goddard Space Flight Center, I²S branched out into development of meteorological analysis systems. This led to sales of hardware and software to NASA, and additionally to a number of foreign government agencies.

Through continuing research and development, I²S has substantially expanded its product line and the range of applications in which its equipment is used. For example, a number of research hospitals are using I²S systems to develop special software for presenting cross-section and three-dimensional body images for diagnostic use.

I²S products figure in a number of specialized applications. In the Peoples Republic of China, where I²S has sold some 75 systems, one use is biological research using video input from microscopes. The U.S. Bureau of Engraving uses a high resolution scanner and an I²S system for quality control of paper money printing. A major lumber company uses I²S equipment for checking log grades prior to mill operations. And Lockheed Missiles & Space Company uses I²S hardware and software for quality assurance of the heat-shielding tiles on the Space Shuttle Orbiter.

Introduced in 1990, the latest I²S product is an advanced image-based photogrammetric system that employs digital technology — rather than traditional optical or mechanical systems — to generate terrain elevation data and other processing functions. Called PRI²SM, it is a complete system, combining hardware and software into a unique workstation capable of generating highly accurate maps from data supplied by aerial photography or satellite imagery.

An important PRI²SM feature is its ability to compensate automatically for topographic relief displacement, a distortion that occurs in aerial photography and satellite imagery, and to correct other distortions induced by platforms and cameras. The digital image-based photogrammetric system, company literature states, is "less expensive, faster, easier to use and easier to maintain than optical and mechanical systems."

I²S has consistently expanded its customer base and sales have grown to a $12 million a year level. Today, the company's product line embraces four major areas: image processing equipment for Earth resources management; meteorological analysis systems; satellite ground processing systems; and digital photogrammetric and mapping systems. All of the systems involved were developed from the foundation provided by I²S' original work with NASA in support of Landsat image processing.

Typical of images produced by I²S systems are a multilayer magnetic data image used in geophysical research (center) and a three-dimensional thermal image of a hurricane with an overlay showing latitude and longitude of storm features (above).

Environment/Resources Management

Archeological/Environmental Research

Archeologists have been probing the jungles of Mexico's Yucatan Peninsula for 150 years, seeking knowledge of the Maya, a great civilization that flourished in the region from about 2000 B.C. until the Spanish conquest of the 16th century.

As part of a NASA program to demonstrate the broad utility of satellite remote sensing, Ames Research Center has — since 1984 — been engaged in Maya research that employs imagery from NASA's Landsat and Seasat satellites. Satellite remote sensing has often been used in archeological research, but the Ames project takes a novel approach: it seeks to understand the environmental setting of the ancient culture and whether the decline of the Mayan civilization was influenced by environmental change.

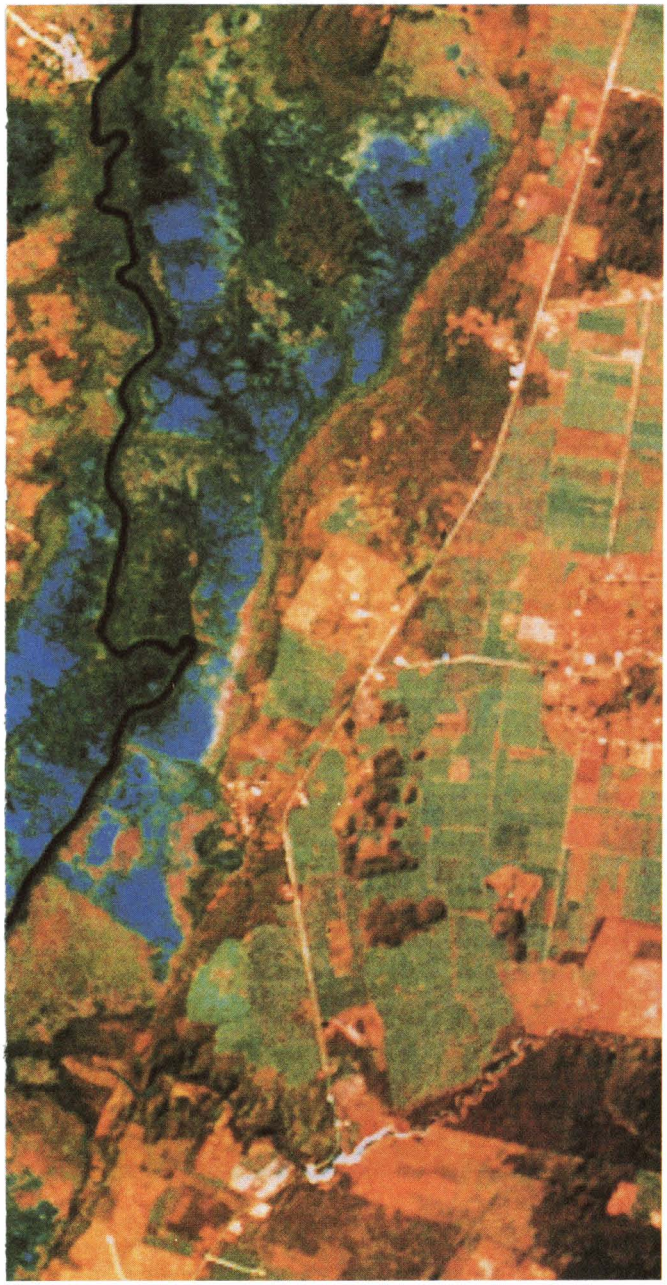
Was the decline of the Mayan civilization influenced by environmental change?

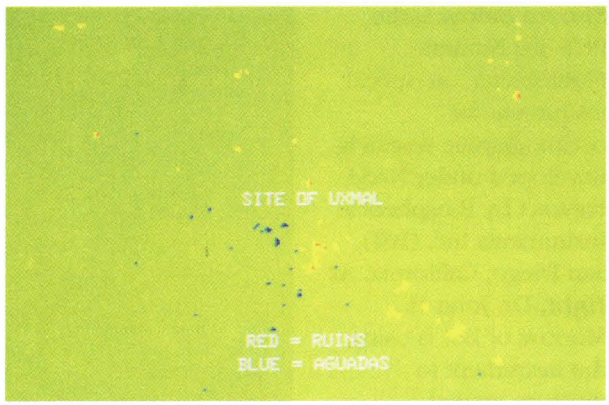
The effort is headed by project chief Charles E. Duller of Ames' Earth System Science Division. Dr. Kevin Pope, formerly an Ames National Research Council Fellow, and more recently with Stanford University; and Dr. Edward Kurjack of Western Illinois University, are principal archeological collaborators. Ten other U.S. and Mexican institutions are represented by collaborative researchers.

More than 35 archeological sites have been imaged. Archeologists have employed the Landsat/Seasat imagery in three extensive site survey expeditions and a large number of individual site mapping projects. Twelve previously unknown sites have been located and mapped by project imagery. This work contributed to development of remote sensing image processing capabilities at three of the collaborating institutions — Western Illinois, Boston and Tulane Universities.

Courtesy Dr. Edward Kurjack, Western Illinois University

The goal of the project is to reconstruct the environmental history of Yucatan's northern plains, with emphasis on the Mayan period. Satellite imagery has provided new discoveries about Maya settlement patterns, environmental settings and the Mayan's use of natural resources. The imagery found additional





Courtesy Dr. Edward Kurjack, Western Illinois University

Satellite imagery shows evidence of ancient coastlines, indications of past changes in sea level, and an ancient river plain extending across lowland Guatemala

utility: it was used by the Government of Mexico and Mexican ecological science officials for developing coastal management plans, establishing two large Biosphere Reserves, and assessing the damage caused by the 1988 Hurricane Gilbert.

The Ames project has focused on the distribution of water resources. Satellite imagery shows evidence of ancient coastlines, indications of past changes in sea level, and an ancient river plain extending across lowland Guatemala. The Yucatan imagery also shows canal systems built by the Maya for agricultural drainage and irrigation. **Above** is a satellite image of canals along Rio Hondo in Belize.

At left is an aerial photo of the ancient Mayan city known as Uxmal (Oosh-mahl), dominated by the Temple of the Magician (pyramid in center photo) and the adjacent quadrangular Nunnery. Archeologists wondered how the large population that must have lived in Uxmal subsisted with so little *known* water availability.

Satellite imagery provided an answer. **At top** is a computer-enhanced Landsat image showing Uxmal structures (yellow) and a number of natural depressions (blue) that became water-filled in seasonal rainfall. The Maya lined these *aguadas* with rock and mortar for year-round water storage.

A rainy season photo flight verified the Landsat imagery. **Shown above** is an aerial view of one of the *aguadas* hidden in the jungle near Uxmal; it proved to be a Maya reservoir and several more were found nearby.

"By studying the Maya," says project chief Duller, "we can better understand human interaction with the Earth system: how they adapted to the environment and its changes, and what changes they may have caused. This project is a pioneering effort combining remote sensing, environmental studies and archeology."

Oceanographic Research

Researchers are looking for new and improved ways of estimating the primary productivity of the world's oceans

Shown below is the PNF-300 Natural Fluorometer, an optical instrument for oceanographic research developed under NASA contract by Biospherical Instruments Inc. (BSI), San Diego, California. **At right,** Dr. John H Morrow of BSI is using the instrument to measure natural fluorescence in coral during The Cousteau Society's 1990 Project Ocean Search off Fiji.

Dr Richard C. Murphy, The Cousteau Society

The instrument is an important innovation for oceanographers, who are looking for new and improved ways of estimating the primary productivity of the world's oceans. They are particularly interested in determining the factors that regulate photosynthesis in phytoplankton, the simple plant forms that are the major sources of sustenance for animal life in the oceans.

The BSI instrument is based on the fact that chlorophyll in phytoplankton emits a natural fluorescence during photosynthesis when exposed to sunlight; this offers a means of estimating phytoplankton production. Where earlier fluorometers use artificial light sources, the PNF-300 uses natural sunlight, offering an advantage because the light source is the same as that which drives photosynthesis: the Sun. Among other advantages, it is less expensive than earlier methods of measuring photosynthetic productivity, it is non-intrusive (does not perturb the sample) and it can be used on site, eliminating the earlier need to remove a sample from its natural surroundings to make a measurement.

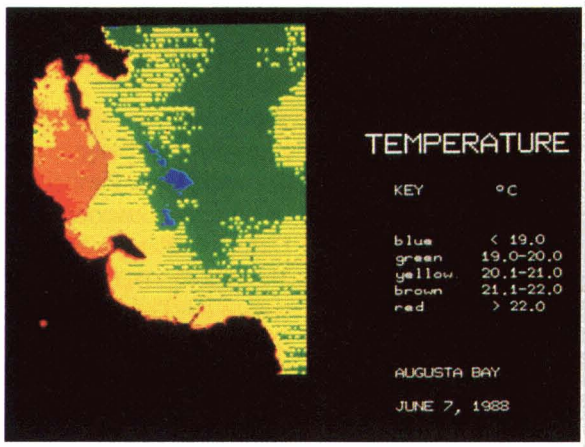
The PNF-300 is a portable, battery-powered, hand-deployed instrument designed specifically to measure profiles of light and natural fluorescence in the oceans. The system includes submersible sensors for measuring fluorescence, irradiance and depth, temperature and water pressure, plus menu-driven software for processing the data. BSI has also developed an INF-300 for long term unattended operation. Among applications are examination of the environmental impacts of coastal installations, including oil terminals, offshore platforms, coastal power plants and recreational harbors. The City of Los Angeles has used a PNF-300 as the heart of a sensor array for monitoring plankton concentrations in a municipal reservoir, a program aimed at eventual reduction of the cost of treating drinking water.

The BSI instruments have been deployed in environments ranging from the poles to the tropical South Pacific by scientists from the University of Southern California, Lamont-Doherty Geophysical Observatory, Jet Propulsion Laboratory, The University of Hawaii, and the Cousteau Society.

Image Processing

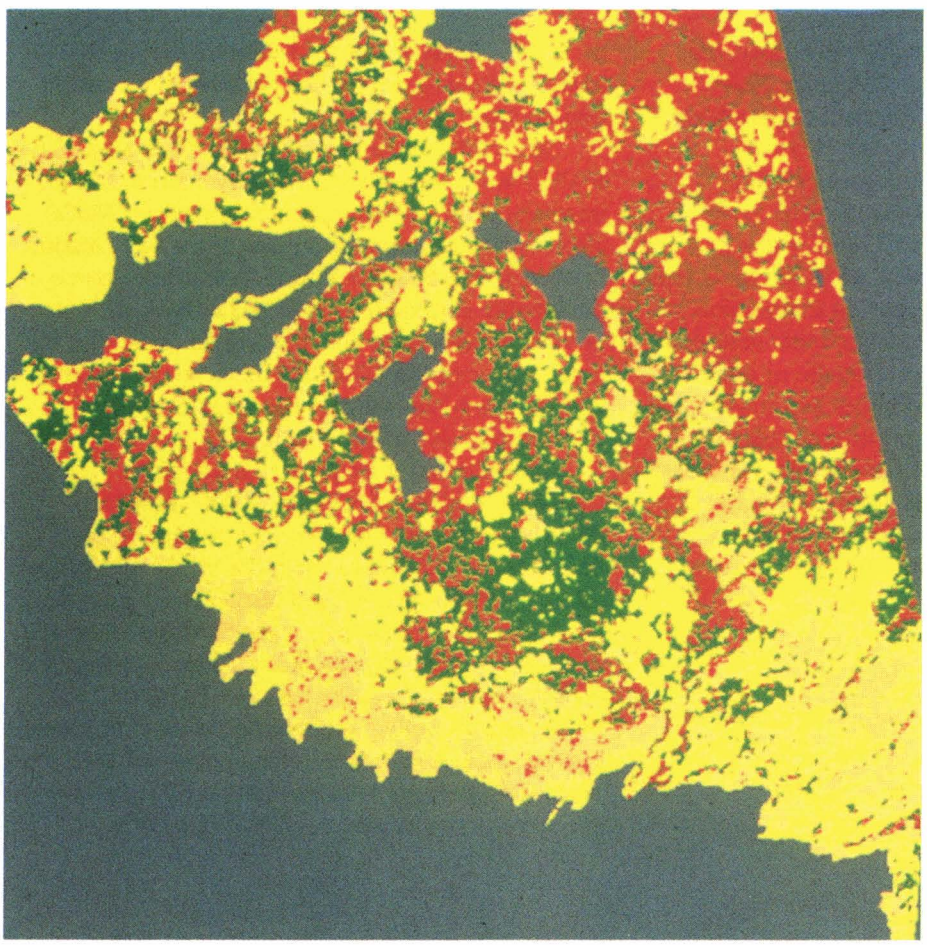
Below is a satellite image of Idaho's Targhee National Forest showing areas of tree mortality caused by the mountain pine beetle; red colored areas have high mortality, yellow represents moderate mortality and green low mortality. **At right** is a composite image of Augusta Bay, Sicily and a portion of the Mediterranean Sea, providing a map of water surface temperatures; the colors indicate temperature ranges: blue, under 20 degrees Centigrade, red over 22 degrees and the other colors representing one degree increments in between.

These images illustrate the use of a NASA computer program — LAS, for Land Analysis System — by the Computer Graphics Center (CGC) of North Carolina State University. CGC analyzes and manipulates raw data from the NASA-developed Landsat and French SPOT remote sensing satellites to produce useful information for land resource application projects of government and private sector organizations. The center uses LAS as its primary image processing package for interpretation of aircraft/satellite data in combination with tabulated data collected by conventional methods.



LAS has enabled researchers to explore new techniques for improving image-based classification accuracies. The program has also been used for training graduate students, technical staff and faculty in remote sensing/image analysis. The system has proved to be sufficiently easy to use that non-professionals can become productive in a relatively short time.

Examples of the program's utility include such applications as forest inventory and management, forest decline modeling, water quality assessments, land use/land cover inventory, groundwater contamination modeling, and wetland/wildlife habitat studies.



LAS was supplied to the Computer Graphic Center by NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia. COSMIC stores government-developed computer programs that can be adapted to secondary uses and makes them available to government and industry users at nominal cost as a special NASA technology utilization service.

A NASA software system has enabled researchers to explore new techniques for improving image-based classification accuracies

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Environment/Resources Management

Earthquake Information System

The principal tool of an earthquake preparedness program is an Integrated Automated Emergency Management Information System

In 1990, Martin Marietta Energy Systems, Inc., USA initiated an earthquake emergency preparedness program at the company's Paducah (Kentucky) Gaseous Diffusion Plant, a Martin Marietta-managed facility within the Department of Energy's Oak Ridge (Tennessee) complex.

The principal tool of the preparedness program is an Integrated Automated Emergency Management Information System (IAEMIS). IAEMIS was developed in a cooperative effort of Martin Marietta and the Mid-America Remote Sensing Center (MARC) of Murray State University, Murray, Kentucky, the state-designated official transfer agent for NASA remote sensing technology. The Paducah application is the IAEMIS prototype; the system is being modified to be integrated into the emergency preparedness programs of Martin Marietta Energy Systems facilities in the eastern United States.

IAEMIS is a two-component set of software, data and procedures designed to provide information enabling management personnel to make informed decisions in the event of an earthquake or other natural disaster. The system doubles as a training aid for instructing plant workers in disaster response procedures. IAEMIS' two components are a database management hazard inventory (dBase III+) and a spatially-oriented information management system (ELAS). The latter is a computer program developed by NASA's Earth Resources Laboratory especially for analysis of data from the NASA-developed Landsat remote sensing satellites.

The IAEMIS system is one of many examples of MARC's work in applying remotely sensed data to improved resources management practices. MARC also conducts continuing studies of the New Madrid Fault in western Kentucky and Tennessee, source of devastating earthquakes in 1811-12. Seismologists predict another large quake along the fault over the next quarter century. MARC studies are aimed at assessing potential earthquake damage and developing ways to cope with it.

Administered through the Murray State University College of Science, MARC provides training, technical assistance and processing of remotely sensed data for both the public and private sectors. Among examples of MARC projects are land use/land cover monitoring, mineral exploration, and studies of wildlife habitat, forests, surface mines, soil erosion and water quality. In addition, MARC develops geographic information systems for specific regions, including data on urban areas, transportation networks, geology, soils, slopes and other resources, plus environmental and socioeconomic data.

Whale Identification

There is sufficient variation in the markings of humpback whale flukes (the lobes of the tail) to allow photo identification of individual whales. By comparing such features as pigment patterns, the location of natural marks and scars, and the size and shape of the notch between the flukes, researchers are able to identify and track individual whales over long periods to determine the distribution and migration of whales.

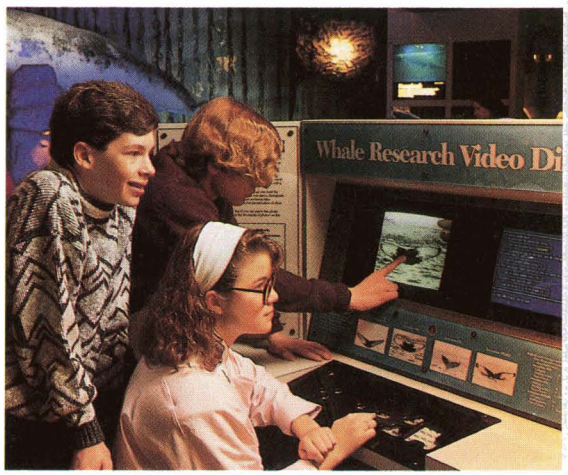
A team of researchers from the National Marine Mammal Laboratory (NMML), Seattle, Washington, with collaboration from the College of the Atlantic, Bar Harbor, Maine and other organizations, has developed an advanced computerized photo matching technique for whale identification. **Below,** NMML's Sally Mizroch, who was active in the development of the photo matching system, is using the system to match whale flukes. **At right,** Seattle high school students get a chance to see how the system works at a traveling exhibit developed by the Pacific Science Center of Seattle with the help of Sally Mizroch and other NMML researchers.

Based on a computer program developed under NASA contract, the new technique employs digitized imagery and a video disc that can store as many as 54,000 single frame images of whale flukes. The software, known as R:BASE for DOS, stores digitized descriptions of the images, compares a new photo with the description, ranks stored photographs on the basis of similarity to the new photo, and presents the ranked images on a video screen in fractions of a second for matching and identification.

The system was tested on NMML's North Pacific humpback whale photo collection, which numbers more than 9,300 photos contributed by 22 research groups working in all areas of the North Pacific. Some 2,400 photos, representing about 790 individual whales, were cross-matched and assigned identification numbers.

The computer program is one of a series of spinoff R:BASE products developed by Microrim®, Inc. Redmond, Washington. Microrim was founded in 1981 by company president Wayne Erickson and other members of a team that had developed for NASA a database management system to store the voluminous data for analyzing heat shielding tiles on the Space Shuttle Orbiter. Called RIM (for Relational Information Manager), the system served as the developmental base for the whole R:BASE line, now the second largest selling line of microcomputer database management software in the world. NMML researchers saw the potential of the R:BASE product for use in the whale identification process, bought the program off the shelf and adapted it to the photo matching technique. Computer assisted matching of humpback whales has made it possible to compare large numbers of whale identification photos from many regions, thus aiding in management of this endangered species.

Spinoff software provided a base for an advanced computerized photo matching technique for whale identification



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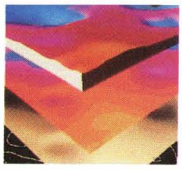


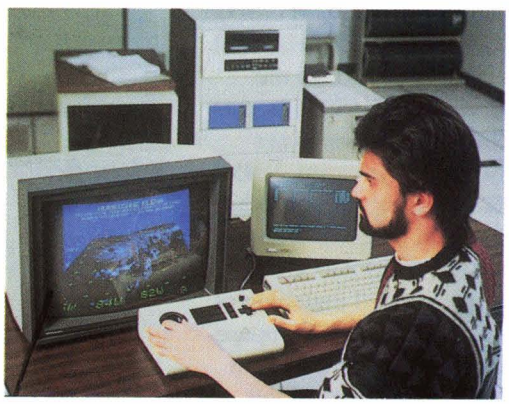
Environment/Resources Management

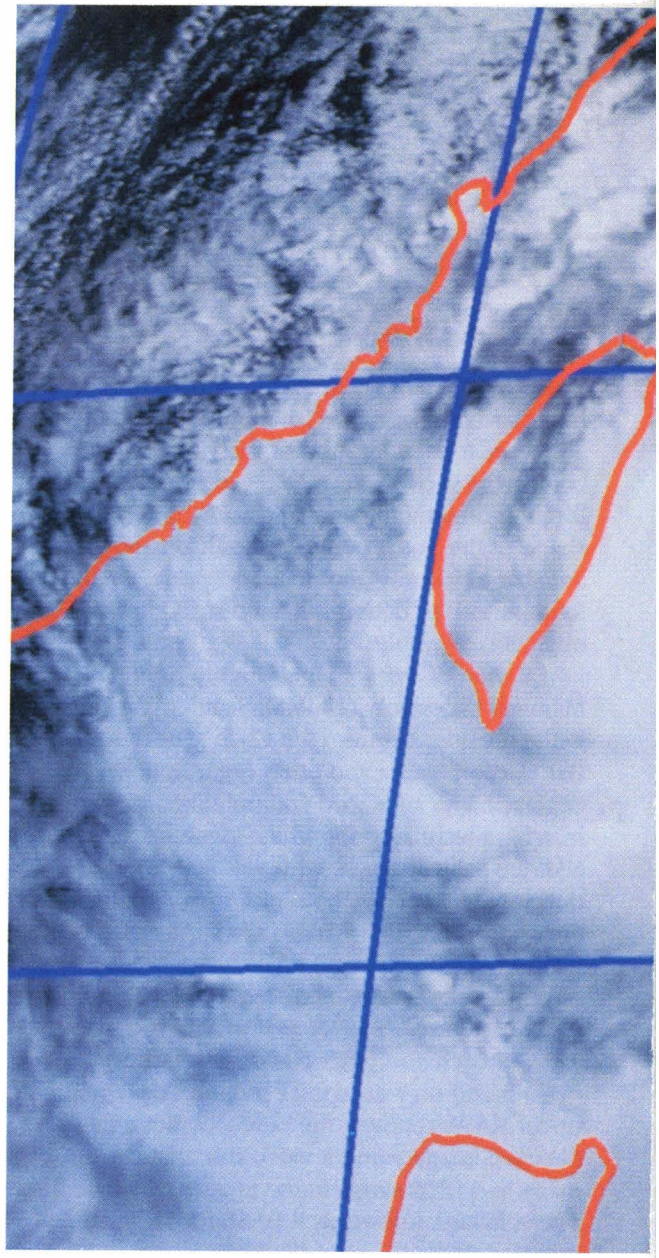
Weather Information Processing

NASA technology spawned an advanced weather forecasting system

On September 11, 1989, Typhoon Sarah hit the east coast of the Republic of China (Taiwan), packing winds of 125 miles per hour. But the people of the island republic were ready for Sarah. The country's Central Weather Bureau was able to issue timely warnings, aided by its brand new METPRO Weather Satellite Reception and Processing Ground Station. METPRO collected data from the Geostationary Meteorological Satellite positioned over the Equator near Australia and converted the data into images showing the size, center and track of the storm as it approached Taiwan.

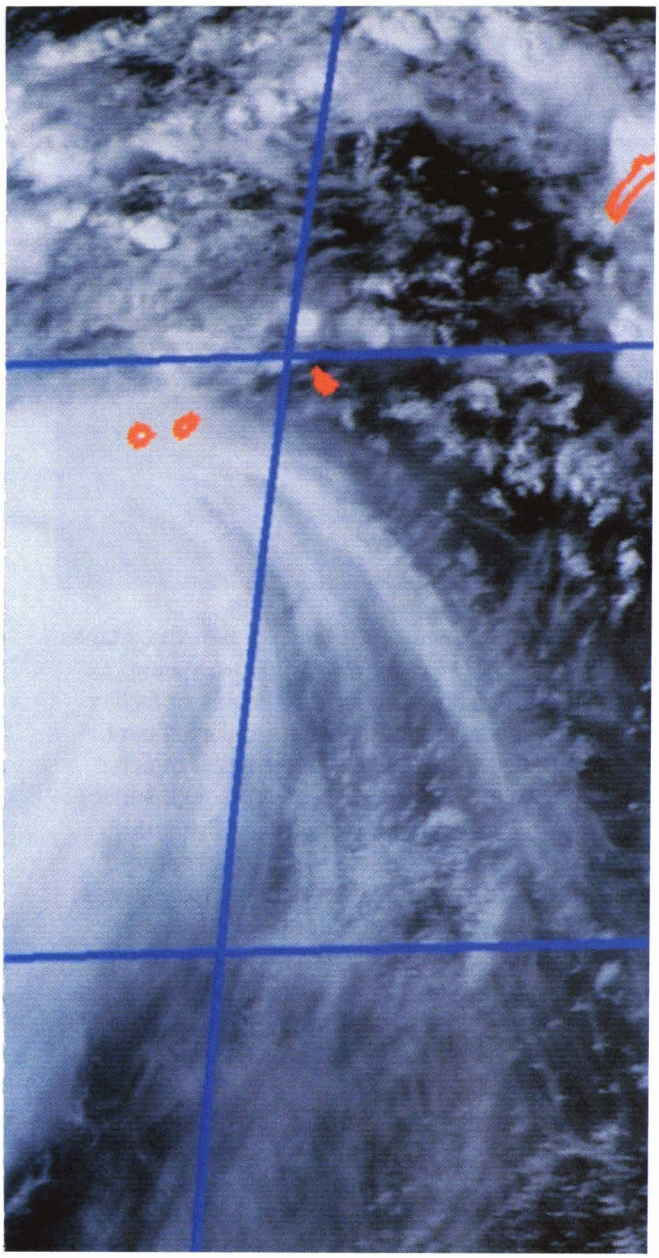
A product of General Sciences Corporation (GSC), Laurel, Maryland, METPRO is a complete meteorological data acquisition and processing system **(left)** designed to meet the full requirements of meteorological research and operational weather forecasting. It consists of off-the-shelf hardware and software components produced by other companies and integrated by GSC, together with GSC-developed METPRO applications software for collecting and processing raw weather data from satellites, remote ground-based observation systems and radio weather broadcasts to generate weather maps and images. In 1990, GSC introduced the METPRO UNIX workstation for production of high quality weather graphics and reports.

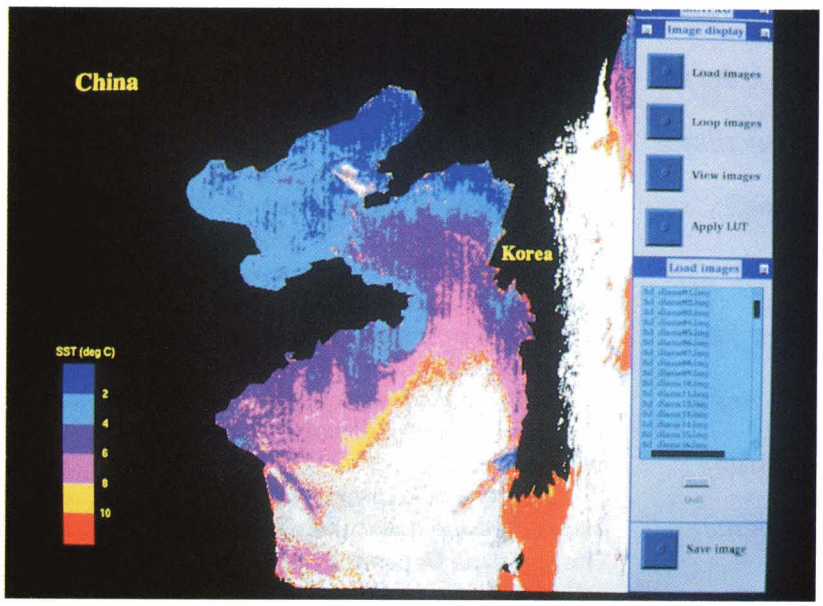




GSC is a high technology consulting firm specializing in scientific and engineering support. The company has developed several commercial products based on experience acquired in contract work for NASA and other government agencies. The company was founded by Drs. Jeffrey C. Chen and Lily C. Chen, president and executive vice president respectively. The Chens emigrated from the Republic of China in the early 1970s and studied at the University of Wisconsin, both earning doctorate degrees in nuclear physics in 1974. Four years later, armed with a $75,000 NASA contract, the Chens started GSC as a basement industry. From that modest beginning, GSC has expanded dramatically; the company now has more than 240 employees, annual sales of about $20 million and is predicting growth of 25-30 percent a year.

At lower left, Drs. Jeffrey and Lily Chen consult with a GSC programmer. On the programmer's console is a METPRO image of Typhoon Sarah,





shown in closeup **above**. Outlined in red in center photo is the island of Taiwan and, to the north, the tip of mainland China; the eye of the storm is clearly visible to the east of Taiwan. **At right** is an example of another METPRO product, a sea surface temperature map of the waters off the coasts of south China and Korea, created by processing data from the TIROS satellite's Advanced Very High Resolution Radiometer; the dark blue color indicates the lowest temperature range (0 to 2 degrees Centigrade), the reddish brown color the highest (10 degrees) and the other colors denote two degree increments in between.

GSC's initial NASA work, for Goddard Space Flight Center's Laboratory of Atmospheric Sciences, involved development of a research system — called METPAK — for processing and analyzing data from weather satellites. Later, GSC produced an enhanced NASA version of METPAK that allowed processing weather observations from radar, surface and satellite sensors, as well as oceanographic data. This Atmospheric and Oceanographic Information Processing System served as the departure point for GSC's development of the commercial METPRO system, introduced in 1989. GSC has sold four METPRO systems (two to the Republic of China, one each to Korea and Thailand) and has prospects for a number of others.

In addition to continuing work for NASA in support of weather, Earth observation, astronomy, oceanography and other areas of research, GSC has performed extensive contract work for such other agencies as the Environmental Protection Agency, the National Institutes of Health, the National Oceanographic and Atmospheric Administration, the Department of Veterans Affairs and the Department of State (GSC supports office automation for more than 250 U.S. embassies).

Besides METPRO, GSC has recently introduced two other commercial products: RISKPRO, an environmental toxic chemical assessment system, and MAPPRO, a geographic information system.

Special applications software generates weather maps and images

Environment/Resources Management

Sewage Treatment

The latest in aquaculture spinoffs: a rock/plant filter system for treating domestic sewage

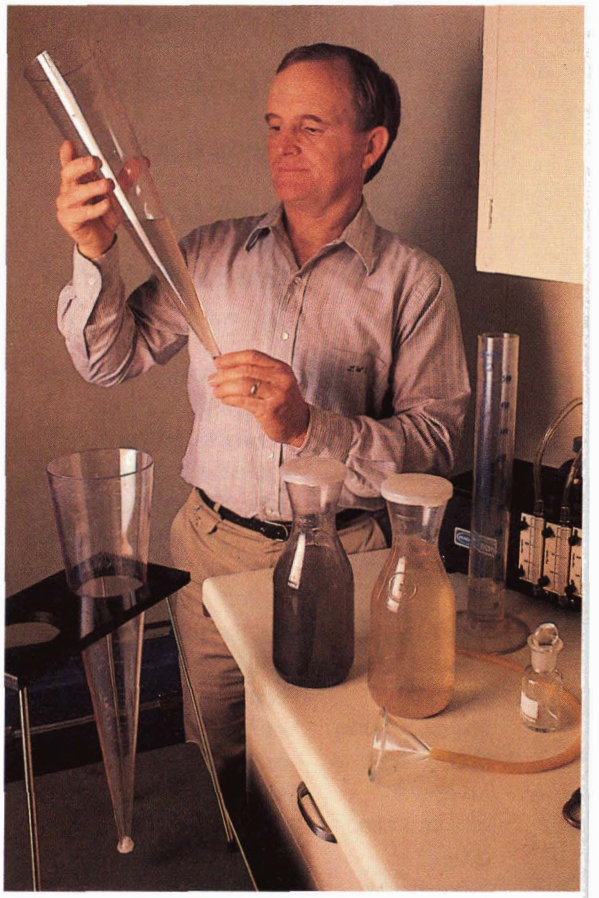
At right is what appears to be — and in fact is — an attractive flower bed at a home in Alexandria, Louisiana. It is, however, more than a floral display; it is part of a functional system that employs plants, rocks and microorganisms as a natural means of treating domestic sewage.

A scaled-down version of a municipal wastewater treatment system, the individual home rock/plant filter system represents one more in a lengthy list of spinoffs from a NASA aquaculture research program conducted by Stennis Space Center (SSC). Since 1974, SSC has been exploring closed systems habitability, edible product growth, water/air reclamation and bioregenerative processes for future spacecraft that may have to spend years in space without resupply from Earth. As part of NASA's Technology Utilization Program, SSC has provided assistance to communities interested in aquaculture as a natural municipal wastewater cleansing technique.

The State of Louisiana has played a pioneering role in applying aquaculture to wastewater treatment. The Louisiana Department of Health and Hospitals, Office of Public Health (DHH-OPH) has experimented with a number of municipal aquaculture systems and published guidelines for their construction and operation. In 1987, the town of Haughton, Louisiana initiated one of the first municipal rock/plant filter sewage treatment facilities. The application of the rock/plant technology to wastewater treatment for individual homes was spearheaded by Larry Amberg, Alexandria-based sanitarian regional manager for Louisiana's DHH-OPH.

A typical home use system consists of a two or three-compartment septic tank (or two/three tanks working in series) for initial sewage processing, together with a natural secondary treatment facility for further processing of the septic tanks' effluent. The latter facility is a shallow, rectangular trench containing marsh plants and rocks (the rock surfaces provide a place for microorganisms to live and grow). The plants and microorganisms work in concert to absorb and digest — and thereby cleanse — the partially processed wastewater. The rock/plant filter bed has no objectionable odors and the system meets Environmental Protection Agency standards for secondary treatment, allowing legal discharge of the cleaned effluent into a stream or drainage canal.

The photo **at left** shows the first step in construction of a rock/plant filter: digging the trench and lining its walls with polyethylene. After that, marsh plants — such as cattails, canna lilies, calla lilies, bulrushes and elephant ears — are planted in



the trench. The next step is illustrated **at left**: the trench is filled with gravel. The "influent" — the wastewater partially processed by the septic tanks — comes into the level trench through a pipe. Particulate matter is forced through the rock bed and is absorbed by the roots of the plants; microbes digest nutrients and minerals from the sewage, further cleaning it. **Above** is a completed, working rock/plant filter being shown to visiting sanitarians and municipal officials. The system has been installed in a score of homes in central Louisiana and it has excited considerable interest among officials from other states.

At right, project leader Larry Amberg of DHH-OPH is testing samples of influent (taken from the septic tank outlet) and effluent (taken from the exit port of the rock/plant filter). The darker liquid in the foreground is the tank-processed influent, the lighter liquid the completely processed effluent, visible evidence that the secondary treatment facility removes a great deal of pollutant material. There is also a significant reduction in odor levels.

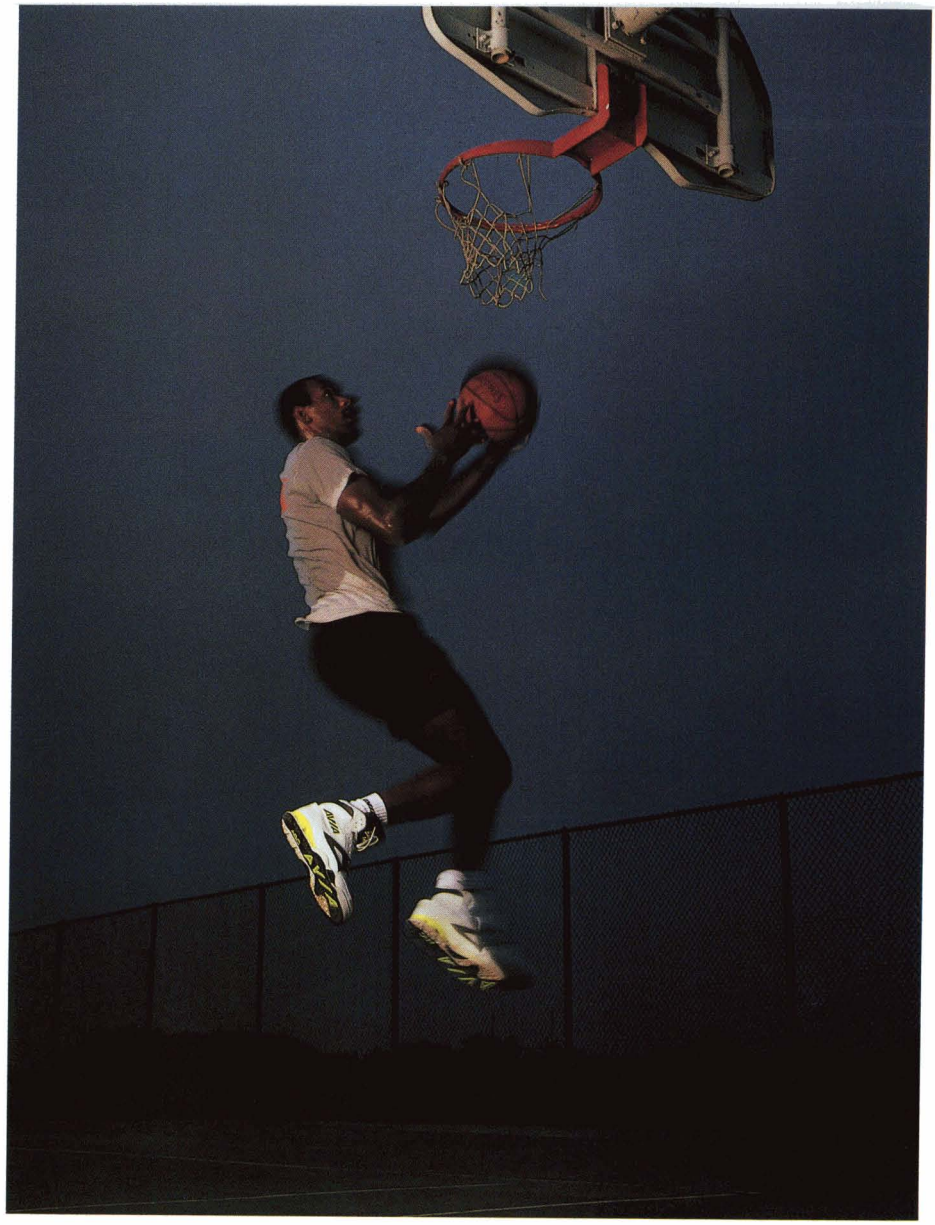
The rock/plant filter is useful in rural areas where conventional septic tanks and drainfields have failed. The natural filter system, with its companion septic tank, costs somewhat more (average $1,800 - 1,950) than the conventional tank and soil absorption system ($1,300 - 1,400). Its advantages are its attractiveness and considerably less maintenance than is required by mechanical systems; the only maintenance needed is removal of dead leaves and grass from the floral bed.

The rock/ plant filter is useful in rural areas

Consumer/Home/Recreation

Spinoff from a Moon Suit

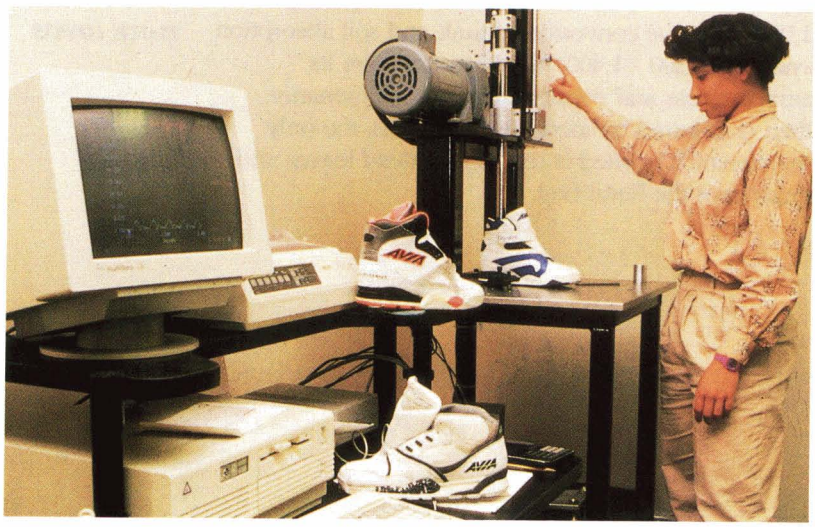
An advancement in athletic shoes heads a selection of technology transfers for consumer, home and recreational use



National Basketball Association star Clyde Drexler puts AVIA Compression Chamber shoes through a workout. The shoe, designed to retain its performance properties over a longer life span, is an adaptation of NASA space suit technology.

Manufacture of athletic footwear is a big business and an extremely competitive one. Shoe producers spend millions annually on research and development, searching for the innovation that will give them a competitive edge in style or performance, for example, superior shock absorption or extended durability under stress.

One company—AVIA Group International, Inc., Portland, Oregon, a subsidiary of Reebok International Ltd.—created a major shoe advancement through application of space technology. The resulting product component, known as the AVIA Compression Chamber™ midsole, was introduced to the market in October 1990.



Compression Chamber shoes get extensive testing under conditions simulating actual use. Below, an AVIA research technician is impact-testing shoe components and completed products to determine performance characteristics, such as cushioning and resilience.

In the latter 1980s, AVIA initiated a project to eliminate the unwanted compression or breakdown that occurs in athletic shoes and causes loss of cushioning. AVIA contracted with Alexander L. "Al" Gross of Lunar Tech, Inc., Aspen, Colorado to design an advanced shoe that would retain its shock absorption, stability and flexibility properties over a substantially longer lifetime.

Al Gross turned to space technology, as well he might, being an aerospace engineer who has won a number of awards and citations for his work in space suit design, including NASA's Apollo Achievement Award for his contribution to man's first exploration of the Moon. Gross worked with ILC Industries, Dover, Delaware, during and after NASA's Apollo lunar landing program, eventually becoming lead design engineer. ILC was then — and still is — the NASA prime contractor for design and manufacture

of all extravehicular space suits worn in the Apollo, Skylab, Apollo/Soyuz and Space Shuttle programs.

Al Gross' basic approach to designing the advanced shoe was to eliminate foam materials from the midsole, because such materials are subject to cushioning loss due to the repeated vertical force of body weight. Gross explains:

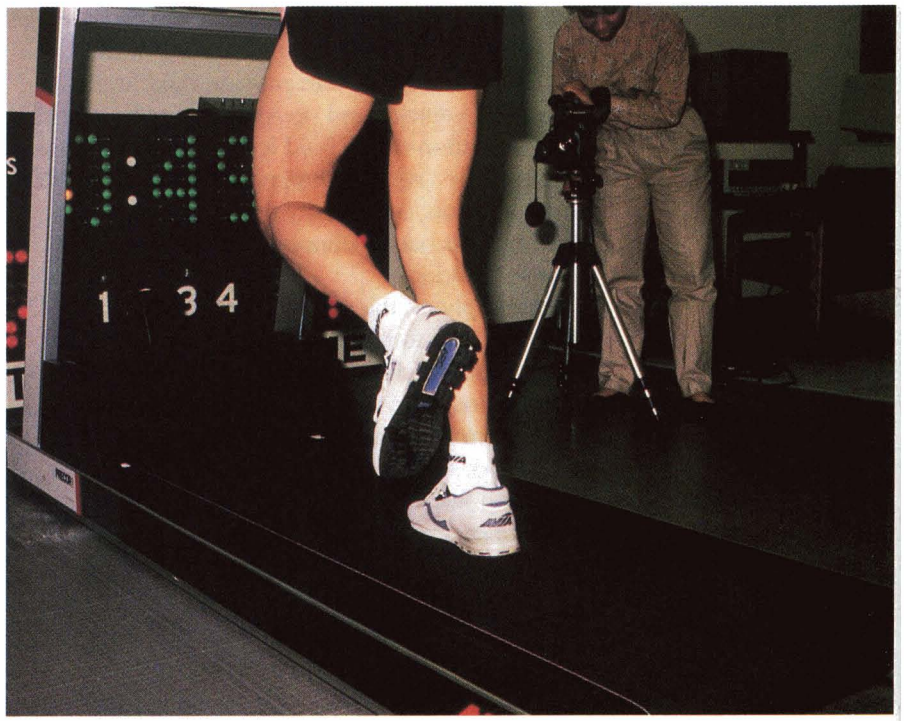
"During use, athletic shoes will experience forces up to six times body weight. These forces begin to reduce the performance benefits of shoes after only one use and result in a loss of designed function. Structural walls of foam materials will become damaged from repeated excessive loading, resulting in a completely rigid system that will no longer compress when loaded and will thereby lose cushioning capability." Elimination of foam in favor of a fatigue-free mechanical system, Gross decided, was the answer to the superdurable shoe AVIA wanted.

A task force composed of Al Gross supported by AVIA research, design and development personnel agreed upon a solution: a "rigid/flexible" system similar to a pressurized space suit.

Being pressurized, the space suit is rigid — but it must have sufficient flexibility to allow the astronaut to move. The big challenge is to provide astronaut mobility at the joints. The answer, in the Apollo Moon suit and later suits, was the "convolute system," a series of bellows in the joint areas that expand and contract (compress) every time a motion is made. By layering or combining materials, and varying the shape, size and the number of bellows, space suit designers can vary joint flexibility.

The space suit technology was applied to the AVIA shoe project. The task force created an external pressurized shell, with horizontal bellows for cushioning and vertical columns for stability; by varying the shape, number and thicknesses of shell materials, and the styling lines within the shell, the designers were able to "tune" the stiffness and cushioning properties of the midsole.

Creating a stress-free environment to ensure durability demanded a single-piece part, without weld lines or cement seams. To meet that requirement, AVIA and Gross adapted another NASA technology — a stress-free "blow molding" process originally employed to get superior impact resistance for the Apollo lunar helmet and visor. The Compression Chamber task force was not able to eliminate foam entirely. Made of duPont's strong but lightweight Hytrel® plastic, the shell is filled — for stability — with a low density polyurethane foam, but the foam provides little of the cushioning function. The lower density foam offers a weight saving up to 10 percent of a shoe's weight.



Above, a running subject is filmed by high speed photography for studies of foot motion.

In durability tests at Penn State Center, the Compression Chamber midsole was subjected to stresses equivalent to 400 miles of running and it showed no visible signs of wear or structural fatigue. Compression Chamber footwear was initially available in basketball and cross training shoes, but AVIA plans 1991 additions to the line.

The blow molding process, never before used in the footwear industry, allows AVIA to configure the Compression Chamber differently for each specific sport. Mechanical cushioning is also an industry first and AVIA plans to take it further. The Compression Chamber, company officials say, is a "first step" toward a completely foamless, non-fatiguing, mechanical midsole that will not wear out.

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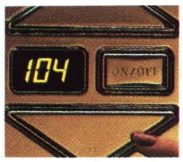
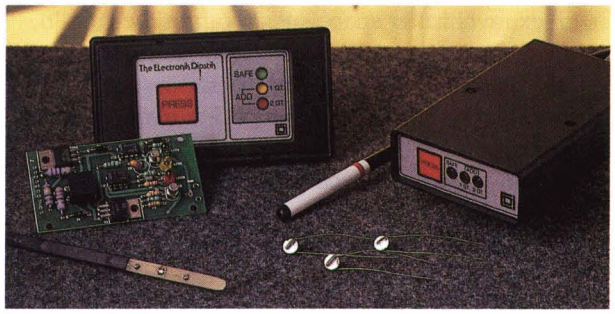
®Hytrel is a registered trademark of E. I. duPont de Nemours and Company.



Electronic Dipstick



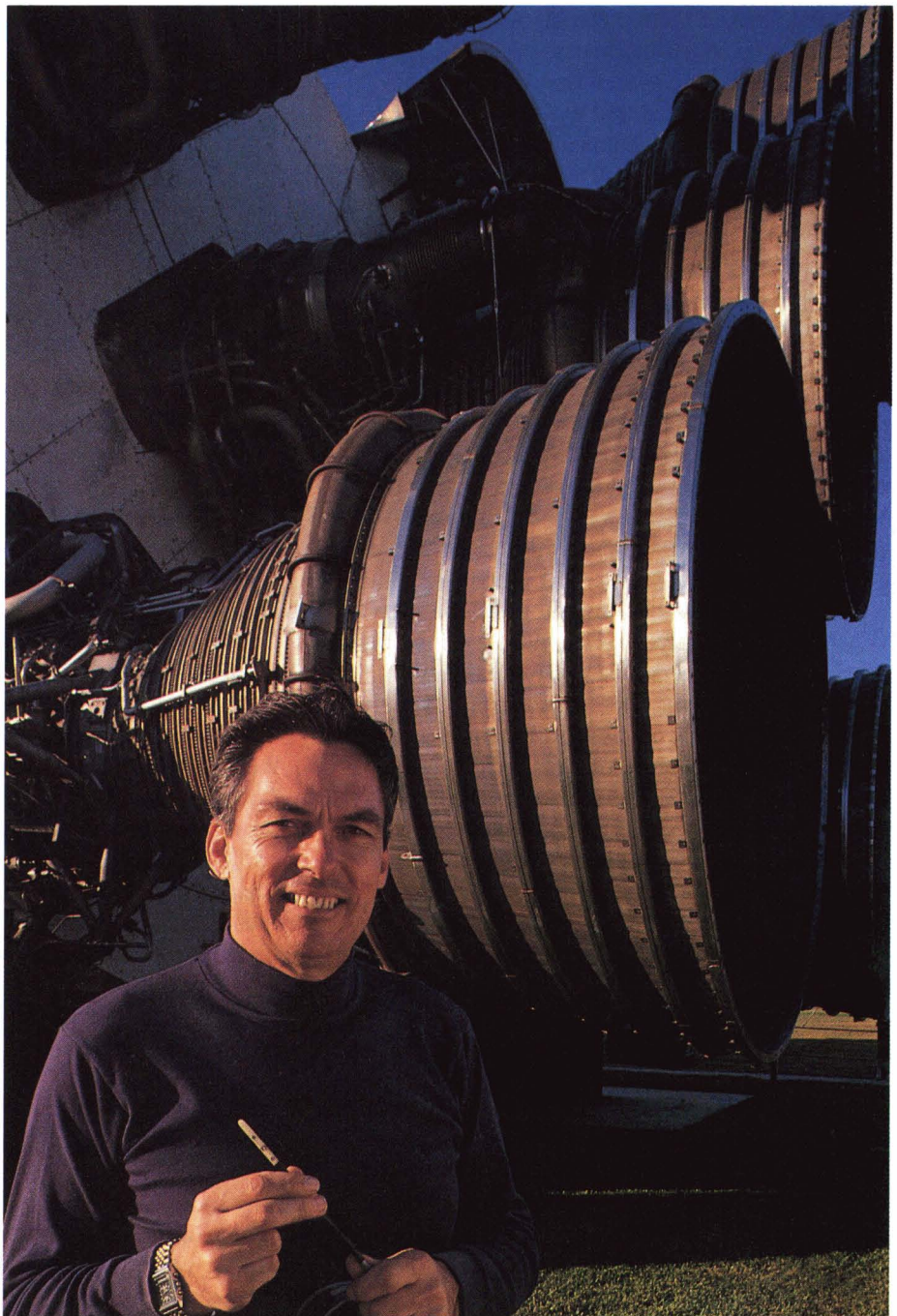
At right is a space-derived innovation known as the Electronik Dipstik, a device that automatically monitors crankcase or transmission fluid levels in automotive vehicles and presents the motorist with a visual indication of the fluid level. The Dipstik was developed by Creative Designs and Inventions (CDI), Houston, Texas, a company that specializes in adapting aerospace technology to consumer and industrial products.

In the photo, the product on the left is the dashboard unit for recreational vehicles, trucks or boats; on the right is a smaller model for under-dash installation in autos. The tubelike fiberglass wands are the dipsticks, one with its sheath removed to show the sensors; the sensors are pictured separately in the foreground.

A new device automatically monitors crankcase or transmission fluid levels in automotive vehicles

The Electronik Dipstik employs NTCs (Negative Thermistor Coefficients), tiny components that experience a change of resistance with a change in temperature; that characteristic is the basis for fluid level measurement.

NTCs play an important role in a Space Shuttle launch. The power of the Shuttle Orbiter's three liquid-fueled main engines tends to swing the engine nozzles from side to side, changing the thrust line. However, the change is prevented by NTCs in a hydraulic cylinder; they sense a resistance change that, analyzed by a microprocessor, indicates the swing of



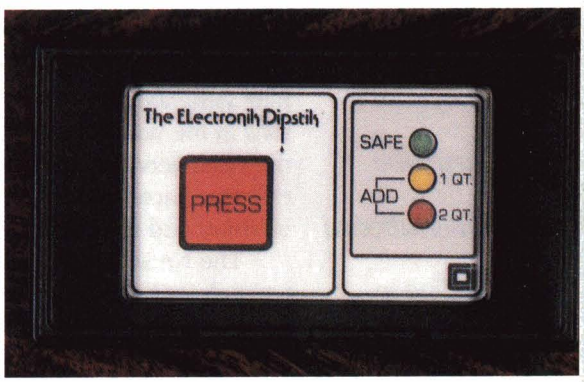
the nozzle. The microprocessor immediately sends a signal to a servo-motor, which repositions the nozzle so that the engine's thrust is properly delivered through the centerline. **At left,** CDI president Ron Doak poses with the rocket engines whose technology was adapted to the Electronik Dipstik.

CDI markets the device, but it is produced by Lake-Tronics, Corvallis, Oregon. The NTCs are supplied to CDI by Katema, Rodan Division, Anaheim, California. The Space Shuttle system from which the NTC technology was adapted is known as the Rotary Variable Differential Transformer. Developed by HR Textron, a subsidiary of Textron, Inc., this system keeps the rotary motion of the Orbiter's engines under control by maintaining the proper thrust line.

In automotive use, NTCs are placed at predetermined levels in the tubular dipstick — for example, full, one quart low or two quarts low — and electrically heated to a predetermined temperature. When anything — such as the oil or transmission fluid — touches the NTC, it will dissipate heat and create a resistance change; microprocessor analysis of the resistance change indicates the fluid level. The dipstick is installed in an auto simply by placing the old dipstick within the tube, as pictured **above,** and wiring the dipstick to the microprocessor/display component. At the press of a button, the dashboard unit **(below)** shows the appropriate level.

Four major auto manufacturers, two U.S. and two foreign, are testing the device for possible application to their cars. The applicability of the device goes well beyond vehicular use, CDI officials say. They are contemplating development of special units to monitor fluid levels in underground and remote storage tanks. They add that the device will work for any non-solid commodity and thus can be applied to measurement of such products as wheat, flour, sugar and sand.

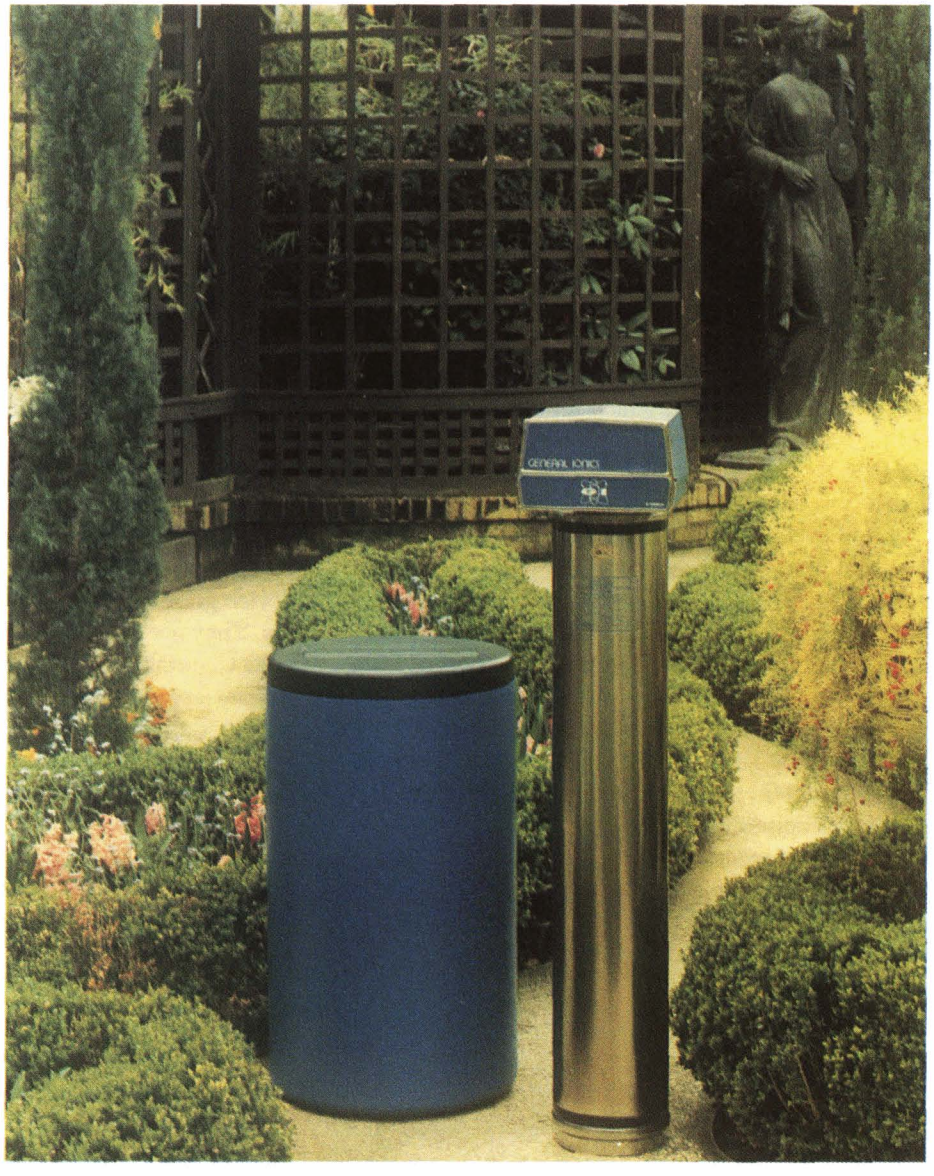
The device will work for any non-solid commodity



Water Conditioner

A home-use water treatment system incorporates technology developed to purify the water aboard the Space Shuttle Orbiters

At right is the General Ionics Model IQ Bacteriostatic Water Softener, a home use system that not only softens municipally treated water but also inhibits the growth of bacteria within the filtering unit. It was developed by Ionics, Incorporated, Bridgeville, Pennsylvania, international water consultants and manufacturer of water treatment equipment for municipal, industrial and consumer use.



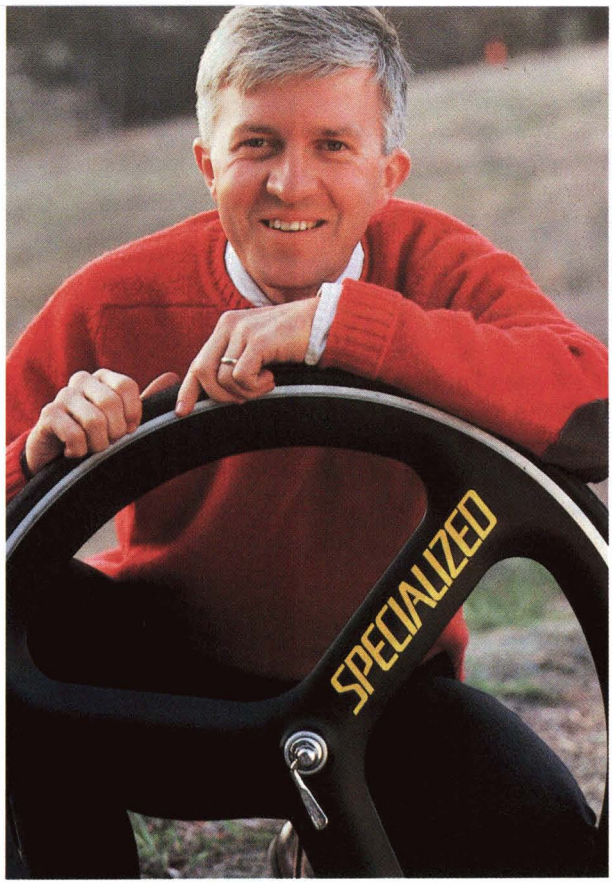
The bacteria growth arresting feature of the Model IQ is based on NASA silver ion technology developed to purify the water aboard the Space Shuttle Orbiters. In Shuttle use, an electrolytic water filter generates silver ions in the water flow; the silver serves as an effective bacteria inhibiter and deodorizer.

The NASA technology has been used in several water purification products, among them a line of home water filters developed by Ray Ward, president of Bon Del, Chula Vista, California. Ward was assisted in his development effort by Ionics, Incorporated. The latter company helped him design his equipment to make the most efficient usage of silver impregnated carbon (activated carbon helps remove objectionable tastes and odors).

Some time later, Ionics vice president Walter J. Poulens learned that some countries in Europe were considering a ban on water softeners that breed bacteria. It occurred to Poulens that the silver ion technology, on which he had worked with Ward, might be the answer to a water softener that would not breed bacteria.

Ionics used the NASA technology as a departure point for company development of a silver carbon of such density that it would remain on top of the water softening resin bed where, Ionics' research indicated, the greatest bacterial growth occurs. After extensive company testing, the Environmental Protection Agency evaluated the process and found Ionics' silver carbon to be an effective bacterial growth inhibiter.

Bicycle Wheel



At right, Mark W. Hopkins displays the new aerodynamic wheel for racing bicycles he designed with colleague Frank S. Principe. Both engineers are members of a "Wheel Team" organized by the Advanced Composites Division of E. I. duPont de Nemours and Company, Wilmington, Delaware. The team developed the wheel in conjunction with Specialized Bicycle Components, Inc., Morgan Hill, California, employing duPont composites technology with NASA aerodynamic and computer modeling technology.

At racing speeds (25-35 miles per hour), multispoked wire wheels create considerable speed-trimming drag. Newer disc wheels offer less but still significant drag and their large surface areas make them difficult to control in crosswinds. To obtain even lower aerodynamic drag, Principe and Hopkins decided that the design should be as thin as possible and should have the fewest spokes that would support the loads the wheel would encounter. The design effort was a complicated task because the thinner the wheel and spokes, the more difficult it becomes to obtain adequate lateral stiffness.

The duPont engineers conducted extensive research on the latest data available relative to drag coefficients for NASA airfoils and determined an optimum profile to balance aerodynamic and structural needs. The basic design they selected is a three spoke wheel, each spoke in effect an airfoil, with a blunt leading edge and a thin trailing edge to maximize aerodynamic efficiency as the spoke moves through the air like a helicopter's rotary wing. To get the requisite stiffness, they employed a composite material of epoxy resin reinforced by fibers of carbon, glass and Kevlar®.

After establishing the basic geometry, the team used sophisticated computer modeling techniques to engineer the material to the target weight and stiffness. Modeling was accomplished by use of PATRAN® and MSC/NASTRAN® computer programs (NASTRAN is an acronym for NASA Structural Analysis; MSC/NASTRAN is an enhanced proprietary version by MacNeal-Schwendler Corporation).

The final product met its targeted performance goals and has a retail price of $750. Introduced in the spring of 1990, the wheel is manufactured by duPont's Pencader Composite Part Fabrication Plant, Newark, Delaware. Specialized Bicycle Components handles promotion and marketing.

The basic design is a three spoke wheel, each spoke in effect an airfoil

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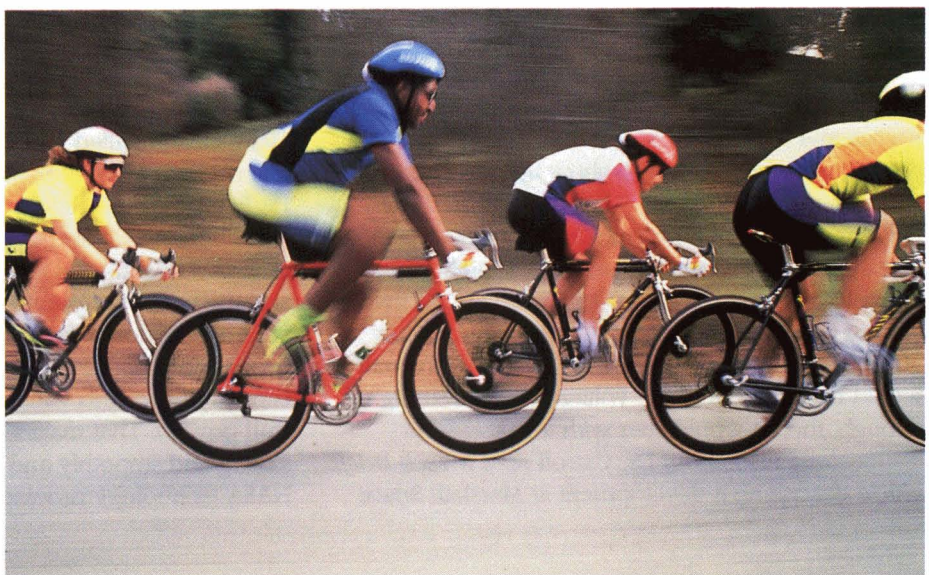
®PATRAN is a registered trademark of PDA Engineering.

®NASTRAN is a registered trademark of the National Aeronautics and Space Administration.

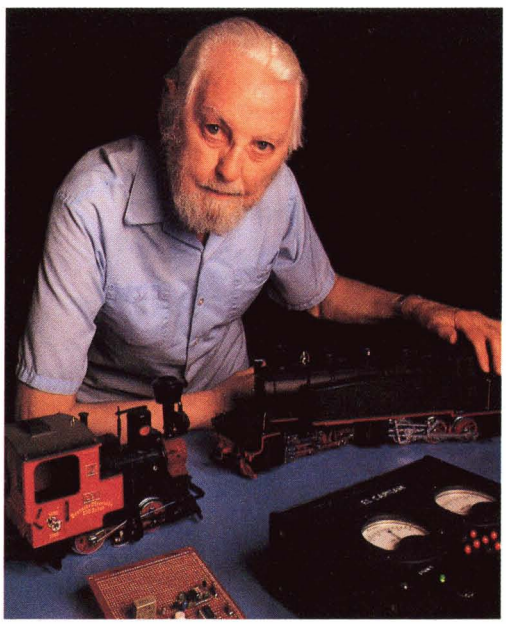


Museum Exhibit

A NASA technical report provided a solution to a museum's problem

NASA Tech Briefs is a publication intended to tell what new technologies are available to potential users. Sometimes a *Tech Briefs* notice provides a lead that eventually produces a spinoff product or service of considerable economic value. In many other cases the publication serves as a current awareness medium or problem solving tool. Such uses may individually provide only small economic gain but they offer better ways of doing things and in the aggregate — with 120,000 follow-up requests annually — they represent a very significant benefit.

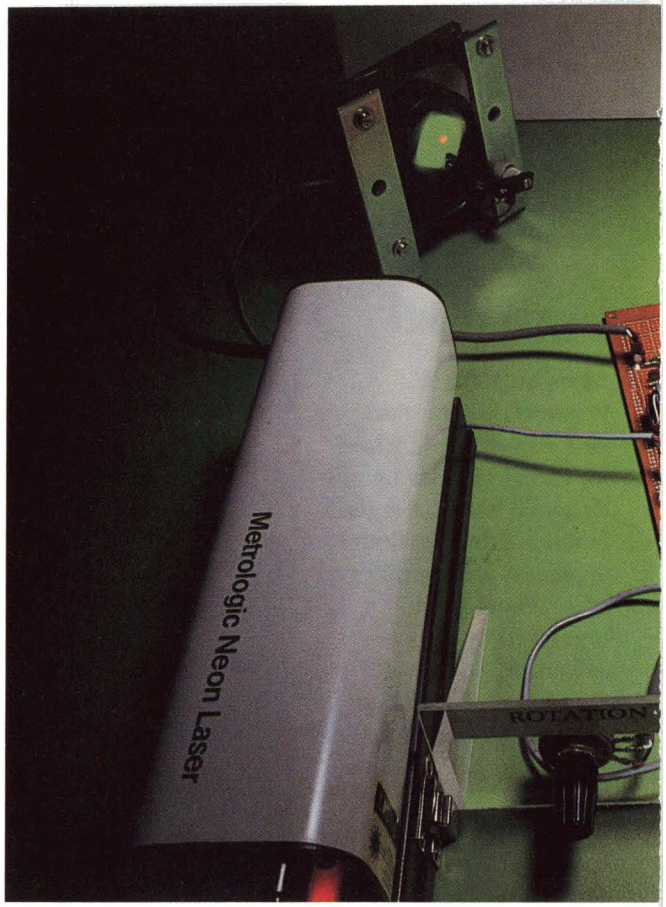
An example of a problem solved through a *Tech Briefs* lead is the experience of the Miami (Florida) Museum of Science and Space Transit Planetarium. Supported by private and corporate donations, the Museum is a private non-profit institution dedicated to promoting scientific literacy by providing an interesting, non-threatening environment for science, learning and exploration.

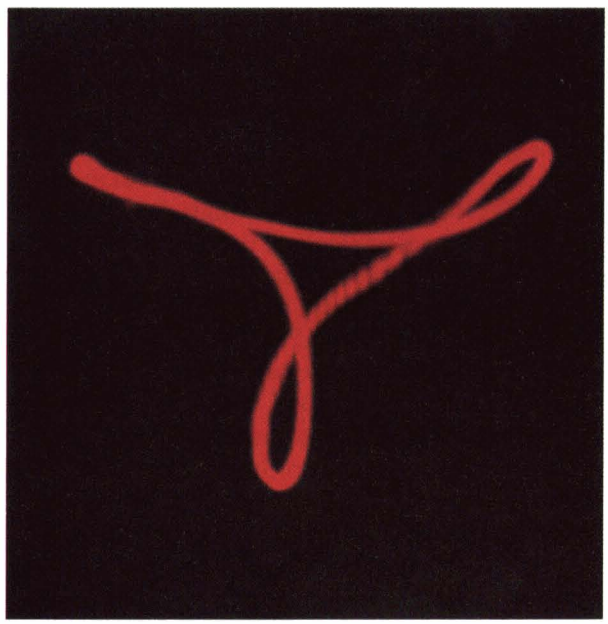


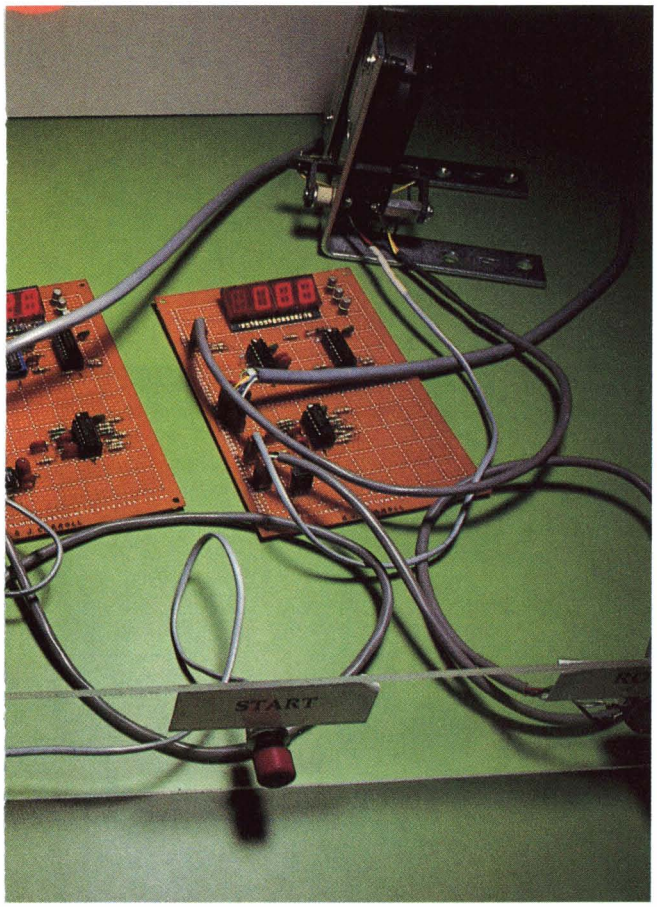
Most Christmas seasons since 1985, the Museum has set up an exhibition of model trains "for youngsters from four to fourscore," to quote Edward J. Carroll, M.D., Head of the Electronics Lab, and Victor J. Vincent, Director of Exhibits, who jointly reported the successful problem solution. The exhibition consists of three large scale trains, each with its own hands-on, child operated control panel. Each panel contains stop and start buttons, a speed control knob and meters to show the volts and amperes used.

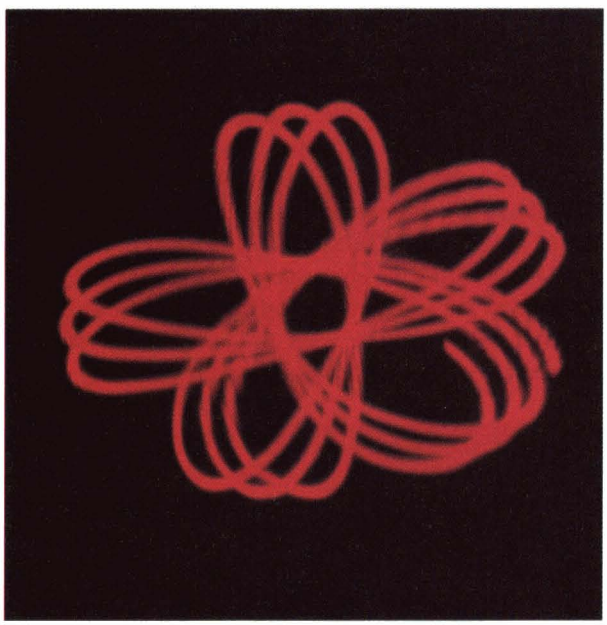
The Museum's problem stemmed from the fact that the original system employed a straight direct current voltage control, zero to 20 volts. With that type of control, the motor had little torque at low voltage; when the operator tried to start it, the train would not move until the voltage was raised high enough, then it would start with a jerk.

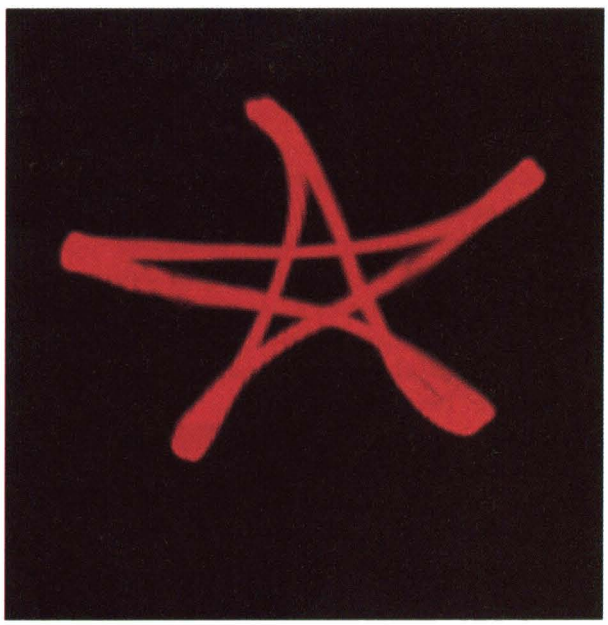
Seeking a solution, Dr. Carroll read a *Tech Briefs* article describing a development at Marshall Space Flight Center called a Pulse Width Control (PWC) that seemed to be the answer to the train problem. He borrowed the circuit blueprinted in *Tech Briefs* and duplicated it for the train exhibition; Dr. Carroll is shown **at left** with the PWC board (foreground) and the train control unit (black). The Museum's control box now uses a full 20 volts at all times, divided into about 1000 pulses a second. The pulses can vary from zero width (no power) to full width (full power). That makes it possible to start a train slowly and smoothly and to run it at low speed. The NASA technology provided two other advantages:











NASA technology offered advantages in lower exhibit construction cost and reduced maintenance

the PWC is less expensive to construct and is easier on train motors, reducing maintenance costs.

Another hands-on exhibit uses the NASA Pulse Width Control technology. A touch of a button starts a laser beam, which reflects from one rotating mirror to another, then to a screen. The operator can produce an assortment of geometric and Lissajous figures, determined by the offset of each mirror and by the relative speed of the mirrors. Each mirror has its own control knob and a three-digit speed indicator; a PWC circuit provides low speed control of the mirrors. In **the upper photo** are the PWC controls; **the lower photos** show examples of the infinite number of shapes that can be created by changing the speed of one rotating mirror, then the other.

Dr. Carroll and Vincent reported that the Museum will be using a great deal more NASA technology: "Our files now hold 11 Technical Support Packages (detailed amplifications of *Tech Briefs* reports) waiting to be used in future exhibits. The information we obtain from NASA helps us create effective, reliable teaching tools for science."

Memory Metals

Shape Memory Effect, or SME, is a term for the ability of certain metal alloys to change from one shape to another in response to temperature change, a direct result of a transformation of the alloy's crystal structure. SME technology was developed in the 1960s and NASA renewed interest in it in the 1980s. Among companies awarded contracts for advanced SME investigations was Memry Technologies, Inc., a subsidiary of Memry Corporation, Norwalk, Connecticut which, since 1985, has been working on SME alloys for advanced composite structures and space station applications. That work inspired company development of a spinoff line of civil use products.

Certain metal alloys change from one shape to another in response to temperature change

An SME device can be made to expand when cooled or contract when heated; it may have one-way or two-way "memories." A one-way SME alloy can be deformed, then recover and permanently retain its original shape when heated to a certain temperature. Two-way alloys hold their original shape at one temperature and another shape at a different temperature.

Under its NASA contracts, Memry produced alloys over a wide range of transformation temperatures in sheet, wire, rod and tube form. The company developed several types of one-way memory quick connect/disconnect joints for space station structures and two-way actuators for the disconnect feature.

Adapting its expertise in shape memory characterization and behavior, Memry Technologies moved into the civil market by applying two-way SME alloys to commercial safety products known as MEMRYSAFE® and FIRECHEK®.

MEMRYSAFE products provide protection against scalding in the home; they instantly restrict the flow of water in the shower, bath and sink before scalding temperatures are reached, a feature particularly important for protection of children. The technology developed under NASA contract gave Memry a competitive edge because the special SME alloy used in MEMRYSAFE allows low consumer prices ($15 to $30).

A related consumer product is ULTRAVALVE™, a computer-controlled shower and bath valve **(above)** that allows the user to preselect a preferred bathing temperature. The temperature is

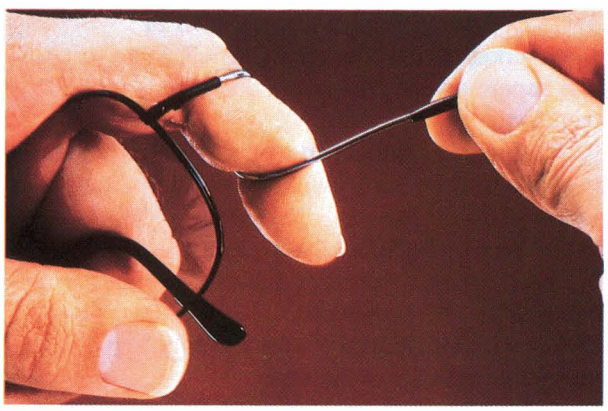
A "smart" eyeglass frame remembers its shape and its wearer's fit

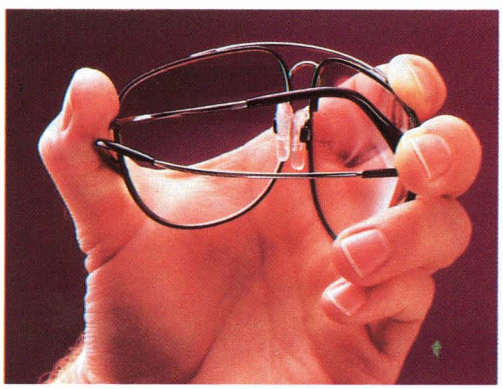
maintained by an automatic electronic control and confirmed by a digital readout **(above)**. A MEMRYSAFE device similar to the anti-scalding unit serves as a mechanical backup to the electronics. This again allows a lower price to the consumer by eliminating the need for more expensive electronic backup circuitry.

The FIRECHEK product that emerged from Memry's SME research is a fire control safety valve **(top right)** for semiconductor industrial process lines containing hazardous gases or fluids; it detects unsafe temperatures and automatically shuts off the pneumatic pressure that operates the control valve. The SME element accomplishes detection and actuation simultaneously and requires no outside power source. Memry Technologies is continuing research toward applying its SME knowhow to a wide range of other commercial products.

Another company — Marchon® Eyewear, Inc., Melville, New York — has applied the memory metal technology in a different manner. Using the NASA technology as a departure point, Marchon is using a patented version of the material in a "smart" eyeglass frame **(bottom, opposite page)** that remembers its shape and its wearer's fit. Frames made with Flexon™ can snap back to their original shape after being wrapped around a finger **(lower left),** bent in half **(below)** or twisted like a pretzel.

Marchon's advancement is a patented "memory encoding process" that gives the special titanium alloy used in the frames its flexible memory: it works at room temperature and does not require heat to return to shape. Flexon frames are marketed under two brands, Autoflex® by Marchon and Accuflex™ by an affiliated company, Marcolin® S.p.A. Marchon sees a large market among some 115 million U.S. wearers of eyeglasses, whose frames will maintain replacement cost of frames smashed or twisted out of shape.





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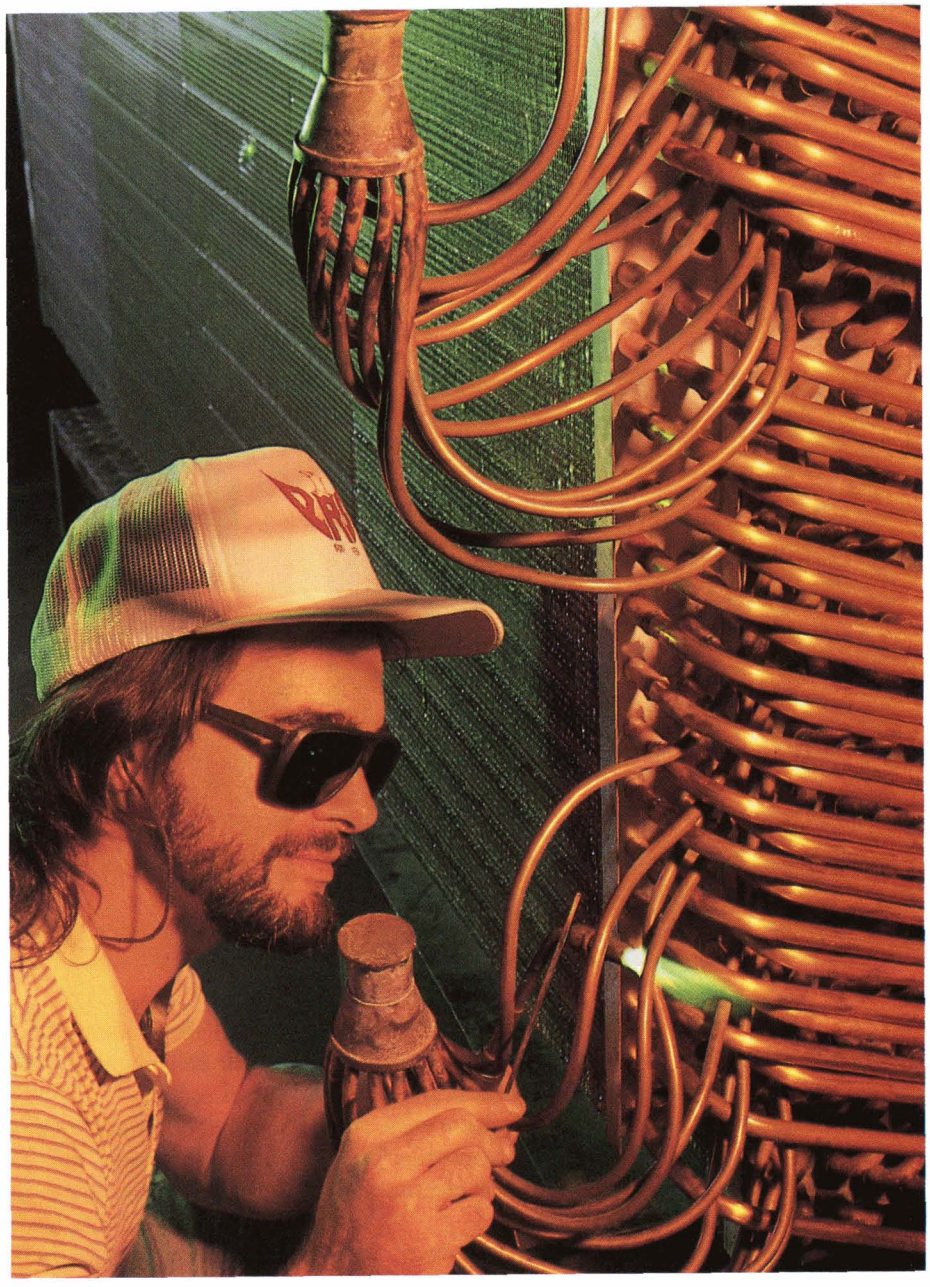
Consumer/Home/Recreation

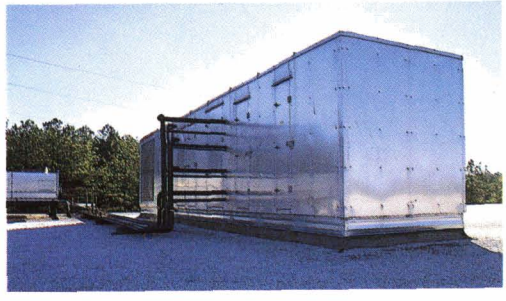
Heat Pipes



NASA - developed heat pipes control supermarket humidity and provide bonus energy savings

Shown below is a Phoenix 2000 rooftop refrigeration/air conditioning system for supermarkets, manufactured by Phoenix Refrigeration Systems, Inc. (PRS), Conyers, Georgia. **At right,** a PRS craftsman is applying the finishing touches to a heat pipe unit; heat pipes are an optional feature of the Phoenix 2000 designed to control humidity in the supermarket and afford energy savings in the process.

An application of NASA space technology, the heat pipe addition to the Phoenix 2000 stemmed from PRS participation in an ongoing large scale field test of heat pipes as enhancements of air conditioning systems. The objective is to evaluate the heat pipe as a high efficiency alternative for humidity control in supermarkets, which require greater dehumidification capacity than most commercial facilities, therefore can realize the most significant savings in energy consumption and improved frozen product marketability due to lower frost formation. Georgia Power Company is spearheading the demonstration/ performance verification program; other participants, in addition to PRS, include Alabama Power Company, Florida Power Corporation, Mississippi Power Company and Wisconsin Electric Power Company, along with a number of supermarket chains. The sponsors will share results with supermarkets, equipment designers and manufacturers.



The top center photo shows one of frequent meetings held by participants; second from left is project manager Dennis L. Keebaugh of Georgia Power. **At top right,** Keebaugh is conferring with Professor James M. Akridge, Georgia Institute of Technology, who conducted a study of heat pipe applications for Georgia Power and who serves as a consulting member of the team.

Originally developed by NASA for temperature control of sensitive space electronic systems, the heat pipe is a simple but highly effective heat transfer system. The individual heat pipe is a sealed tube containing a small amount of liquid refrigerant. In a multitube heat pipe system, each tube is inclined so that the refrigerant can flow to the lower

Heat pipes provide a simple, low cost alternative to complex and expensive desiccant systems and mechanical dehumid-ification systems

end by gravity.

The low end is an evaporator, the high end a condenser. When the refrigerant flows to the low end, it evaporates and absorbs heat in the process. The low density vapor then rises to the other end, where it releases heat and condenses into a liquid to repeat the cycle. This provides a system that alternately cools and heats without significant use of energy or any moving parts.

Its potential is described in this report from Georgia Power:

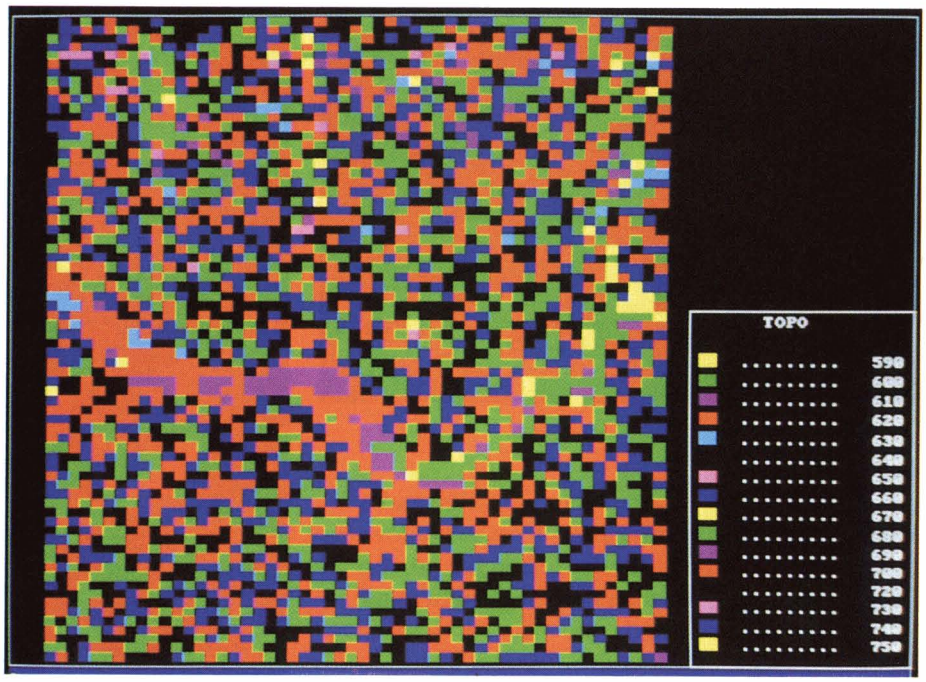
"Typical air conditioning systems often lack the moisture removal capacity to cope with high-moisture cooling loads. ...Heat pipes provide a simple, low cost alternative to complex and expensive desiccant systems and mechanical dehumidification systems. Heat pipes are ideal in situations where low humidity must be maintained, where moisture gains are unusually high, or for drying materials or products. They have already been used successfully in libraries, candy storage facilities and now, supermarkets. Heat pipes have also proven effective for moisture control in indoor spa and pool buildings and in residences in humid climates."

Georgia Power kicked off the program in July 1989 with an installation at a Winn Dixie supermarket in Lithonia, Georgia. PRS supplied a standard rooftop refrigeration/air conditioning system modified to include a 144-tube heat pipe system. The heat pipes' job is to ease the load on the air conditioner and provide more effective humidity control at reduced energy expenditure. Normally, the air conditioner alone could lower humidity, but to do so its cooling coil would have to operate longer and use more energy. Then, in the process of lowering humidity, it would overcool the air, necessitating reheating the air to a comfortable temperature with more energy expenditure. The heat pipes precool the air before it reaches the cooling coil. After the coil removes the remaining heat and humidity, the heat pipes reheat the overcooled air to the proper temperature. Thus the heat pipes dehumidify more efficiently and provide significant energy savings.

Since the first installation, the project has expanded to include supermarkets in Wisconsin, Florida, Virginia, Texas, New York and Maryland. An interim report on the findings at the Winn Dixie supermarket indicated that the system performed well and did in fact effect consumption reductions, but more data was required to fully quantify the energy savings and the impact of the heat pipes on the air conditioning system.

NASA's Software Bank

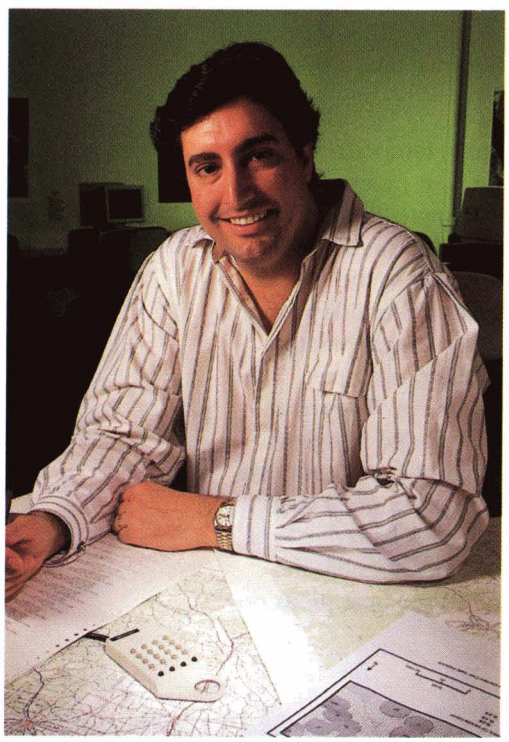
A special NASA service aids national productivity by providing low cost computer programs to public and private sector clients



At Ohio University, assistant geography professor James Lein (left) has adapted a NASA computer program to a novel use: simplifying the evaluation and selection of landfill sites for solid waste disposal. An expert system developed with the CLIPS program uses details about a candidate site, such as topography *(above)* or adjacent water sources *(upper right)* to determine whether the site meets requirements.

In an era of heightened environmental awareness, finding sites to dispose of solid waste is a difficult, complicated and tedious process, often a tug-of-war between state and local community officials.

Each candidate landfill site must meet a series of rigorous criteria, for example, slope, distance to cultural features, surface and subsurface hydrology, soil erosion potential and land ownership; in addition, the site must be sufficiently distant from residential areas, schools, airports, population centers and endangered species habitats.

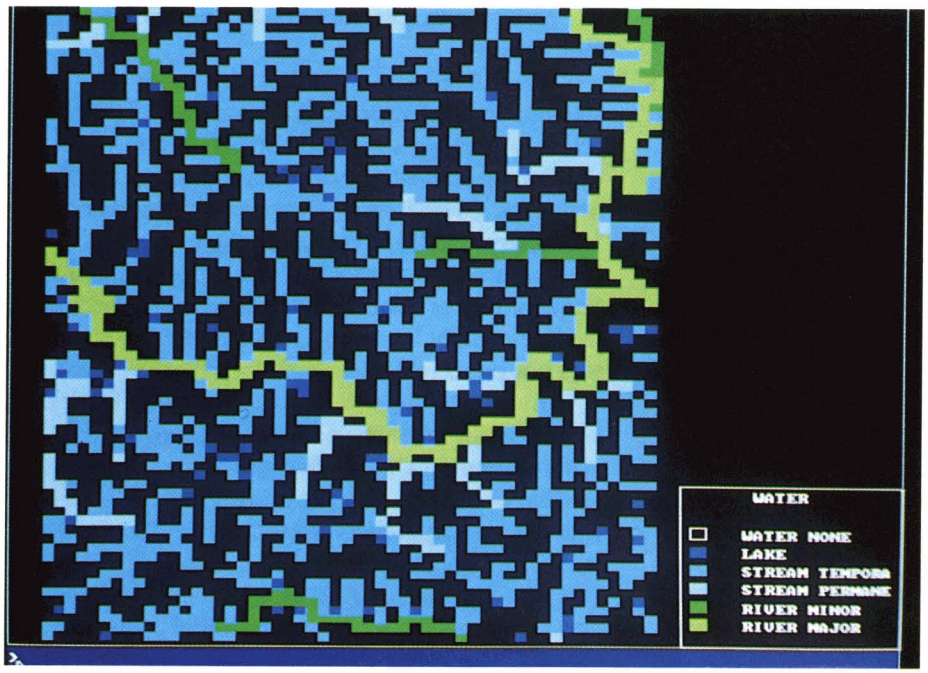


Researchers at Ohio University, Athens, Ohio, are trying to make site selection less complex by programming computer software to help evaluate a candidate site. Their tool is a NASA-developed program called CLIPS, a software shell for developing expert systems. Originally developed by Johnson Space Center, CLIPS is designed to allow research and development of artificial intelligence on conventional computers.

Says Dr. James Lein, assistant professor of Ohio University's Geography Department:

"We structure the rules and parameters surrounding the decision-making process and CLIPS provides an estimate of whether a particular site fulfills the siting requirements." With an expert system, the reasoning mechanisms influencing site selection can be defined more clearly and the system can be modified to reflect changes in legislation or new information. With an expert system the site selection process is less difficult, reducing the time and costs involved. CLIPS was supplied to Ohio University by the Computer Software Management and Information Center (COSMIC)®, NASA's mechanism for helping industrial, government and institutional organizations to effect significant reduction of automation costs.

Information processing by computer is still experiencing explosive growth in the United States.



Thousands of organizations are joining the ranks of computer users annually, while longtime users are regularly finding new ways to improve their operations through greater automation. NASA's way of helping them cut costs is providing them, at low cost, previously developed computer programs that have secondary utility.

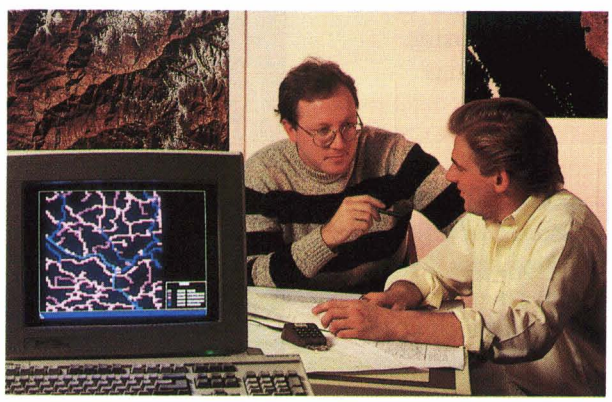
Development of an entirely new program is time consuming and expensive. Frequently, however, a program developed for one purpose can be adapted to an entirely different application. Thus, software users can save time and money by taking advantage of COSMIC's service; they can purchase a program for a fraction of its original cost and get a return many times the investment, even when the cost of adapting the program to a new use is considered.

The CLIPS program has proved a valuable research tool for a wide variety of applications. At Ohio University, researchers are also exploring use of CLIPS to assist in historic preservation, which involves identification, inventory and selection of structures — or entire areas — that have special cultural or historic significance.

Other examples of CLIPS' versatility include its use to monitor product quality and quantity at a chemical plant; its employment by an attorney to help him decide which facts from a casefile are most pertinent; and its use as the core of an advanced software system that gives a user engineer instant expertise in disciplines in which he is not skilled. Another use of CLIPS is its inclusion in a text book — *Expert Systems: Principles and Programming,* by Joe Giarratano and Gary D. Riley — in use at 40 colleges and universities. CLIPS serves as the prime example of an expert system development tool in the book; sample CLIPS applications are included on a disc bound with the text book, enabling students to design and develop their own expert systems.

Widely used in business and government, CLIPS represents only one of thousands of examples wherein users have benefited from COSMIC's service.

(Continued)



Ohio University graduate students use the CLIPS program to develop an expert system for historic preservation, which involves evaluation of structures or areas that have special cultural or historic significance.

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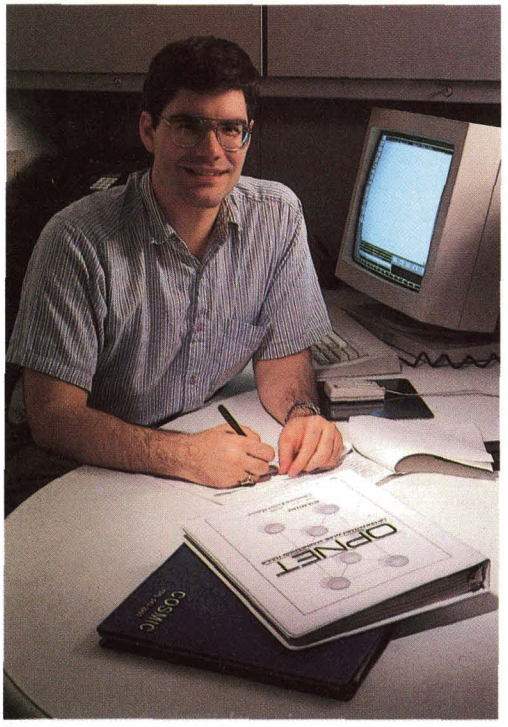
NASA's Software Bank (Continued)



Steve Baraniuk of MIL 3, Inc. uses a COSMIC computer program in his company's OPNET software package, which develops computer simulations of satellite communications networks.

Located at the University of Georgia, Athens, Georgia, NASA's Computer Software Management and Information Center (COSMIC) is custodian of the large "bank" of computer programs developed in the course of work sponsored by NASA, the Department of Defense and other technology generating agencies of the government.

COSMIC gets a continual flow of these government-developed software packages and identifies those that can be adapted to secondary usage. The center stores and maintains the programs and informs potential customers of their availability through a catalog and through notices in the publication *NASA Tech Briefs*.

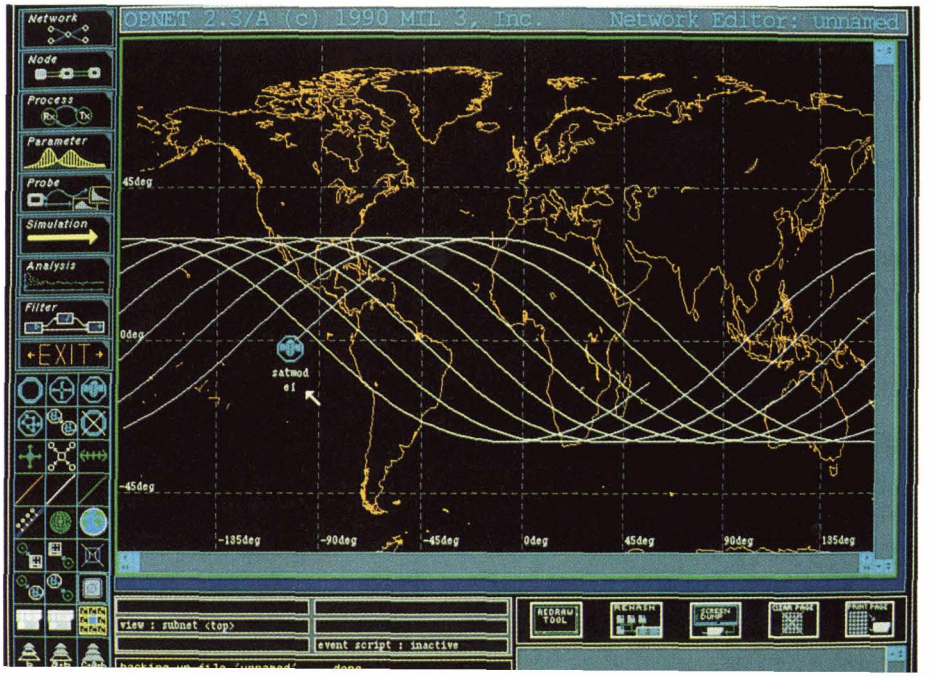
COSMIC's library contains more than 1,200 programs for such purposes as structural analysis, artificial intelligence, computational fluid dynamics, thermal analysis, image processing, project management and a great variety of other functions. The center has distributed thousands of programs, some of which have made possible savings amounting to millions of dollars. Thus, COSMIC's service represents one of the broadest areas of economic benefit resulting from secondary use of government developed technology.

Among examples of COSMIC program uses by industry are:

MIL 3, Washington, D.C., a developer of software for the communications industry, supplies a software package — called OPNET — for developing simulations of communications satellite networks. OPNET easily supports geosynchronous or "stationary" satellites. However, the movement of low Earth orbit satellites was not supported and the frequent loss of communications when Earth blocks the line-of-sight between satellite and Earth station was not predictable.

In order to support predictions of low Earth orbit as an interim measure, pending a planned advancement of OPNET that will allow predicting satellite occlusion, MIL 3 is using a COSMIC program called ASAP (Artificial Satellite Analysis Program) as an OPNET enhancement. MIL 3 translated the ASAP program from the original FORTRAN to C language and integrated the modified version of ASAP into OPNET. The ability to directly utilize ASAP code has enabled MIL 3 to offer low Earth orbit satellite modeling capability much sooner. A planned OPNET advancement involves development of a customized second-generation orbital mechanics program based on ASAP.

Heath Tecna Aerospace Company, Kent, Washington, a major supplier of composite structures, designed and built the first full scale composite hybrid rocket motorcase. Looking for a computer program that would predict stresses in the



An OPNET image showing a satellite track against a world map background.

Photo copyright AMROC, used by permission

The first test firing of an AMROC rocket motor employing a new composite motorcase developed by Heath Tecna Aerospace with the help of COSMIC software.

motorcase walls and calculate the ideal geometry for the domes at either end of the filament-wound pressure vessel, company researchers discovered and used a COSMIC program descriptively titled "Analysis of Filament Reinforced Metal Shell Pressure Vessels."

The test motor was built under contract to American Rocket Company (AMROC), builder of privately-developed rocket launch vehicles. Heath Tecna confirmed the predictions of the COSMIC program by testing a subscale motorcase to failure. A full-scale 22-foot motorcase was then fabricated and successfully test fired by AMROC.

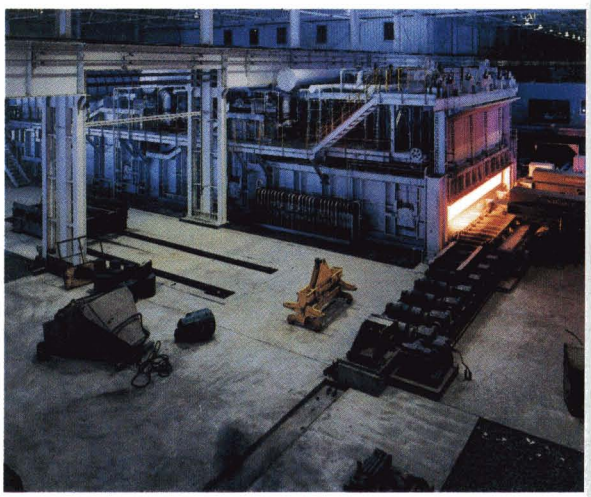
Scientific-Atlanta Inc., Atlanta, Georgia, is an internationally known leader in cable television electronics and satellite communications networks. Company engineers were assigned the task of designing a new Cassegrain antenna, which consists of a primary radiator, a multimode horn to receive signals, a main reflector and a subreflector.

Researchers found — and purchased — the COSMIC program "Machine Design of Cassegrain Feed System," which seemed uniquely formulated to design this special type of antenna. The program allowed for computer simulations of the antenna's performance, allowing engineers to change the design before any hardware was actually built. The program saved time and money in the design process, and additionally enabled engineers to build a vertex tuning plate intended to redirect scattered energy, which provided for greater operational economy.

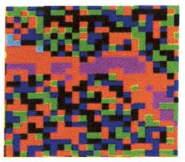
Salem Automation, Pittsburgh, Pennsylvania, conducted research on methods whereby increases in energy efficiency and quality might be achieved in reheat furnaces. The reheat furnace is an energy intensive stage of steel processing, used to raise the temperature of steel slabs, blooms or billets to the point where they can be formed by rolling.

Along with other software, the company used a COSMIC program to evaluate technology intended to increase productivity and reduce energy usage in the reheat process. The COSMIC program — the General Thermal Analyzer Program — solves steady state and transient thermal problems using desk top computers. Salem Automation used it in modeling reheat furnaces; for example, the program can simulate how slabs in a proposed furnace will heat during operation.

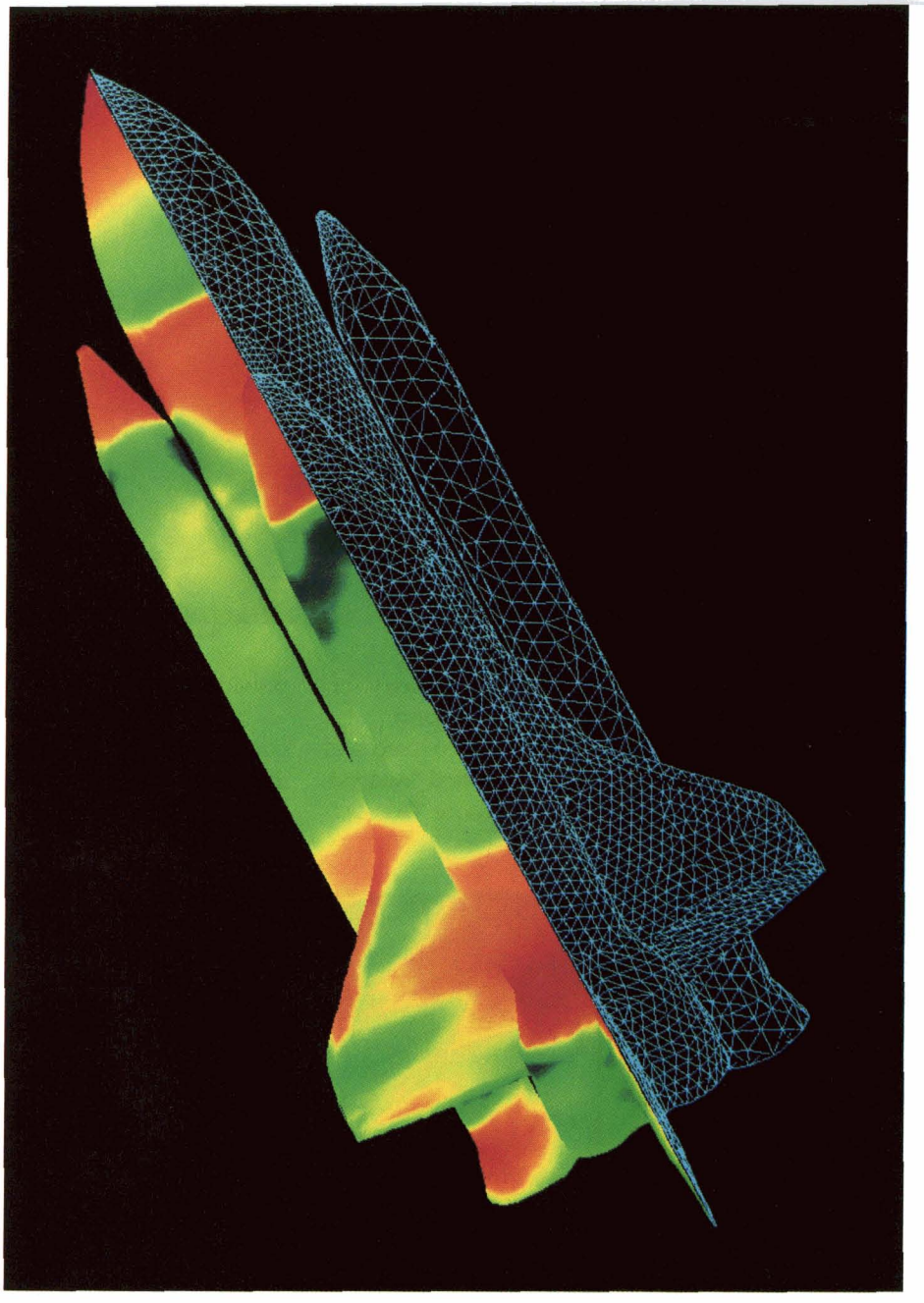
A COSMIC program contributed time and monetary savings in the design of a new type Cassegrain antenna developed by Scientific-Atlanta Inc.



A reheat furnace used in steel processing. Salem Automation used a COSMIC computer program in a research project intended to increase productivity and reduce energy usage in the reheat process.



Design Software

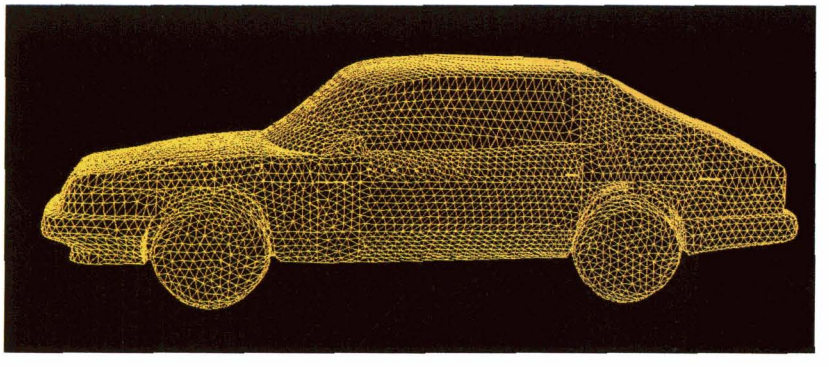


Spinoff software products have found application in auto design, structural analysis and other non-aerospace applications

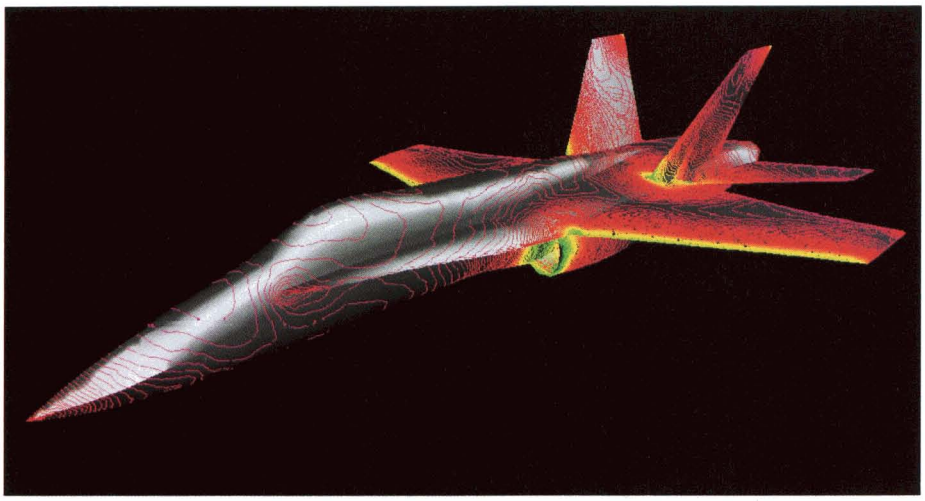
One of the objectives of the Small Business Administration's Small Business Innovation Research (SBIR) program is to encourage contractors to pursue research on innovative concepts and to seek commercialization of the end product.

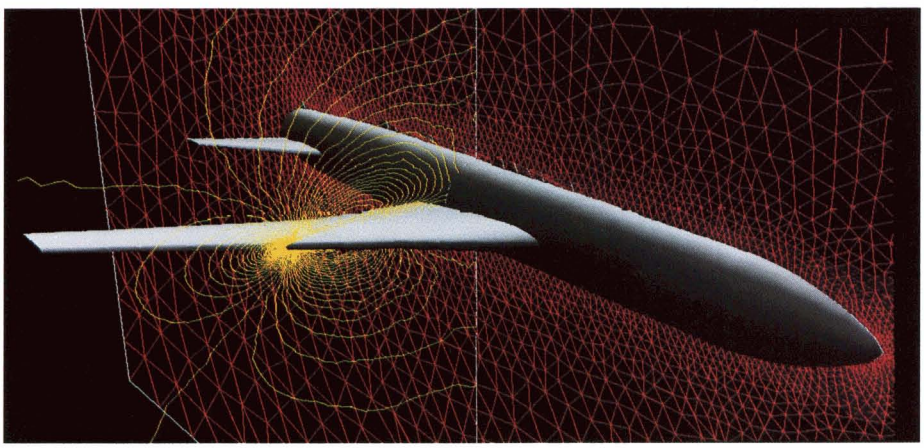
An example of a company that has successfully attained that end is ViGYAN Inc., Hampton, Virginia. ViGYAN is a small minority business firm providing aerospace, environmental and data processing services. Founded in 1979, the company received its first contract from NASA's Langley Research Center. Langley subsequently sponsored SBIR awards to ViGYAN for research and development of advanced software for computer simulation of flight vehicle configurations.

ViGYAN has converted the results of its NASA research into commercial software products known as VGRID3D and VPLOT3D. Both are employed in the aerospace design technique called computational fluid dynamics (CFD) and they have also found application in automobile design, structural analysis and other non-aerospace applications.



In aeronautical research, design engineers create mathematical models of flight vehicles and "fly" them by computer simulation. One of the disciplines extensively used is CFD, wherein the flow over a complex three-dimensional configuration is simulated using mathematical equations. The body of the configuration and the space surrounding it is represented by clusters of points, lines and surfaces; equations are numerically solved at these points. The set of lines and surfaces is called a





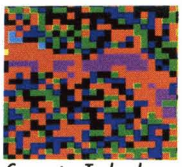
computational grid; the accuracy of the final result depends in great measure on the quality of the grid.

Since the early days of CFD, scientists have used "structured" grids — a structured set of lines in three coordinate directions. In recent years, availability of supercomputers has made it possible to calculate flow fields around very complex shapes in a matter of hours. However, grid generation, using the structured grid method, still takes a large part of the typical computational cycle.

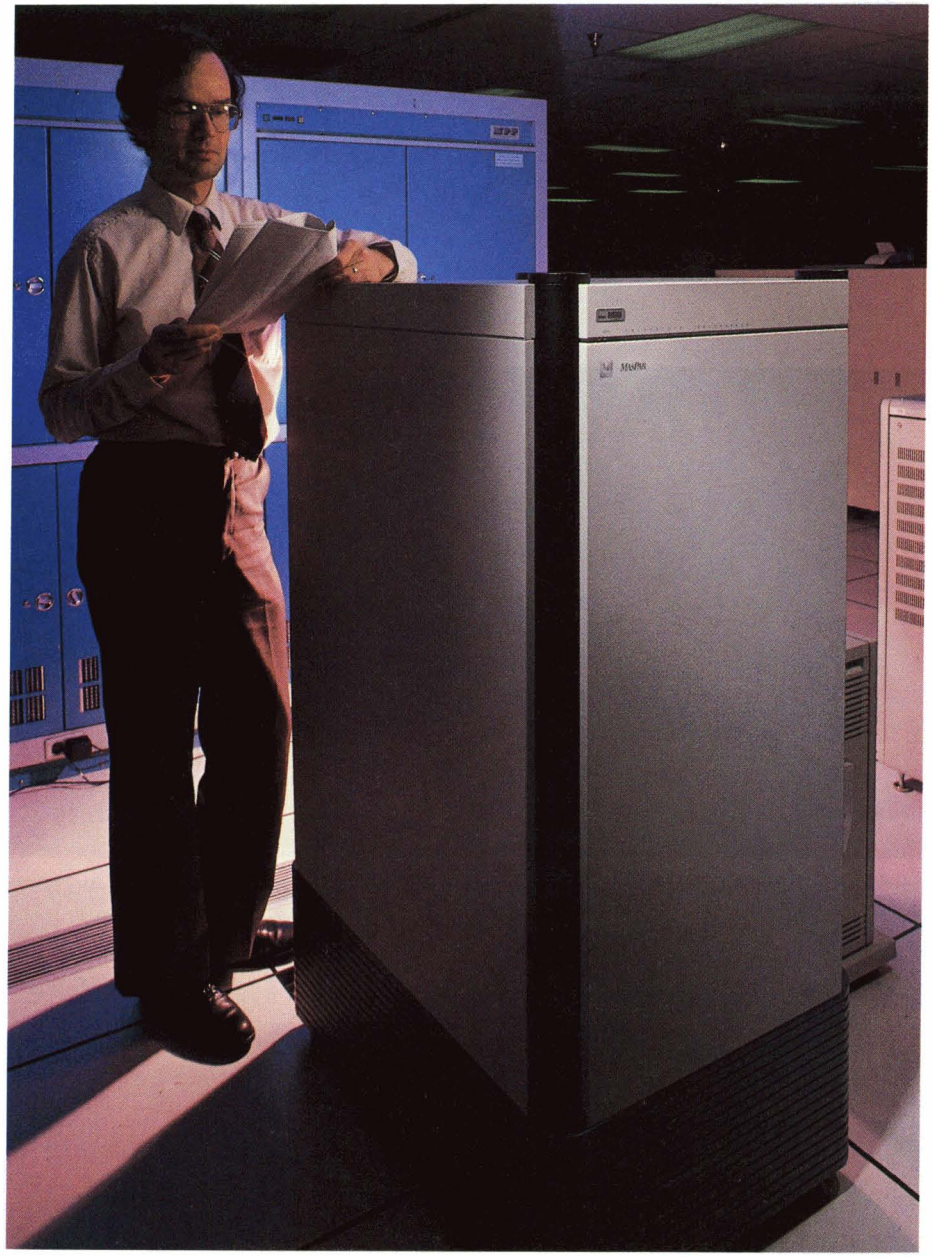
An alternative grid generation technique — "unstructured" grids — has received a lot of research attention in recent years. In addition to an inherent ability to handle complex configurations with ease, unstructured grids are apt to efficiently incorporate adaptive refinement and moving boundaries and offer better control over the grid size and point clustering. It is in these areas that ViGYAN has been working for NASA and the company has created — with VGRID3D and VPLOT3D — what company officials term "an easier alternative to the use of conventional structured grids for fluid dynamic calculations."

VGRID3D is a robust, interactive program for generation of unstructured grids around complex 3D configurations. Examples of the types of grids it produces are shown **at far left** (a SAAB auto) and **left center** (a Space Shuttle study). VPLOT3D is an interactive, menu driven post-processing graphics program for manipulation and display of fluid dynamic data on unstructured grids. VPLOT3D examples are pictured in **the top photo** (which shows Mach number contours on an F-18 military aircraft) and **above** (a composite picture of a generic aircraft design).

Availability of supercomputers has made it possible to calculate flow fields around very complex shapes in a matter of hours



Parallel Processing System



Parallel processing involves simultaneous processing of image picture elements rather than step-by-step serial processing

In the latter 1970s, NASA saw a need for computing power orders of magnitude beyond anything then available for satellite image analysis. Already operating at that time were satellites relaying voluminous information to Earth at high transmission rates, such as NASA's Earth-scanning Landsat resources survey satellite sending digital data to ground stations at the rate of 15 million bits per second. On the developmental horizon were satellites of far greater data gathering and transmission capacities.

To provide a capability for processing very high resolution image data from spacecraft sensors, Goddard Space Flight Center commissioned development of a unique type of computer based on the concept of parallel processing — meaning simultaneous processing of image picture elements (pixels) rather than step-by-step serial processing. Designed and built by Goodyear Aerospace Corporation, the resulting prototype was known as the Massively Parallel Processor (MPP). It was delivered to Goddard in 1983 and it was soon found to have utility in a far broader range of applications than just image processing.

The MPP architecture — known as SIMD for single instruction stream, multiple data stream — offers enormous computational power at lower cost than other architectures. The speed of the prototype derived from a network of 16,384 simple processors, which allowed dividing up a task so that each processor performed the same operation on different pieces of data at the same time.

For example, in tests involving analysis of Landsat data, the MPP would individually study each of the million pixels in a typical image and decide whether each dot represented land or water, forest or farmland, or whatever else. In other words, in massively parallel processing an entire image is processed at once, where in serial processing an image is processed one pixel at a time; the latter takes hours to analyze and classify an image, MPP about 20 seconds.

NASA research led to a new generation massively parallel computing system

In order to measure and document the advantages and disadvantages of parallel processing, and to learn the capabilities and limitations of the MPP, NASA organized a working group of 40 scientists who were provided opportunities to test their computational algorithms on the MPP beginning in the fall of 1985.

A year later, sufficient results had been acquired to warrant convening — at Goddard — the first symposium on massively parallel scientific computation. The MPP investigators described a broad variety of applications, including signal and image processing, Earth science, physical science, computer science and graphics. The performance of many of these applications was found to be in the supercomputer range, and for certain tasks MPP was found to be faster than traditional vector supercomputers. Subsequently, Goddard funded the Microelectronics Center of North Carolina's development of a second generation MPP called the Blitzen Project to demonstrate that the size and weight of the MPP could be reduced enough to allow its use in spacecraft.

Based in part on technology developed in the two NASA MPP projects, MasPar Computer Corporation, Sunnyvale, California, has produced a new generation massively parallel computing system. The MasPar MP-1 product family ranges upward from a unit with 1,024 processors that can deliver 1,600 MIPS (millions of instructions per second) and 82 MFLOPS (millions of floating operations per second). At the upper end of the scale, with 16,384 processors, the MP-1 can deliver 26,000 MIPS and 1,300 MFLOPS. MP-1 users, including NASA, are attacking computationally-intensive problems in such areas as image processing and understanding, signal processing, database management query systems, neural-net algorithms, computational fluid dynamics, content-sensitive text retrieval and seismic data reduction.

At far left, James R. Fischer, head of Goddard's image analysis facility, is shown with the MasPar MP-1 (foreground) and the earlier MPP prototype (blue unit in background); the photo emphasizes the compactness of the new system as compared with its predecessor. Fischer (white shirt) and a colleague are shown **at left** checking out one of the MP-1's circuit boards.

Help for the Steel Industry

Among spinoffs that aid industrial productivity and manufacturing technology are advances in steelmaking techniques

Until the 1960s, the United States led the world in steel production. In the years since, however, the American steel industry has fallen behind Japanese and European companies in the fiercely competitive international market.

Today, American steelmakers are seeking to regain lost ground by modernizing their facilities and production techniques. Among recent improvements is the use of more efficient equipment in the steelmaking process known as continuous casting, which accounts for some 60 percent of the 100 million tons of steel produced annually in the U.S. NASA contributed to this effort by adapting aerospace high temperature metal technology to the continuous casting process.

NASA's help came from a collaboration between Lewis Research Center and Gladwin Engineering, East Palestine, Ohio, a manufacturer of equipment used by steelmakers in continuous casting of steel slabs and billets (steel bars).

Continuous casting is generally more efficient than conventional ingot casting because it takes less time and labor. Gladwin is one of the few U.S. companies producing continuous casting equipment. Improvements in this area of steel production equipment are particularly important to the competitive status of the U.S. industry. Seeking such improvements, Gladwin approached NASA to see if aerospace technologies might be applied to steelmaking processes. Says Gladwin Chief Engineer, George J. Wagner:

"Our equipment was as good as or better than anyone else's, but we didn't want to play 'me too.' We wanted to be the best in the world.

"We had a list of about 20 technology items that we feel are holding back the ability of the U.S.A. to produce more steel and better quality semi-finished products. We knew we wouldn't be able to tackle all of these areas at once, so we focused on a couple of things we

Gladwin Engineering's George J. Wagner and Lewis Research Center materials expert William J. Waters examine steel-processing rollers cracked by thermal stress. A Lewis team solved Gladwin's cracking problem by applying space technology.

Wagner checks newly machined rollers that incorporate the NASA technology, which allowed a threefold improvement in roller lifetime.

really wanted to improve — mold life and roller life."

In the continuous casting process, equipment is subjected to an extremely hostile environment. Thick multi-ton sheets of semi-molten metal slide rapidly across metal mold surfaces, causing wear and failure on the contact surfaces. Chemical fluxes used in the casting process form acids that attach and corrode the metal mold. After exiting the mold area, the hot steel slabs are transported over a series of metal rollers that reach 1800 degrees Fahrenheit on the top contact surface, while the bottom surface is cooled by water mist.

These operating conditions caused cracking of the rollers due to thermal fatigue. Erosion of the mold surface plates was caused by friction, high temperature and acids. Improving roller and mold life were considered the two main factors in keeping the casting line running, the key to more efficient, less costly steel production. A continuous casting line costs upwards of $100 million and down time results in production losses ranging from $10,000 to $150,000 per hour.

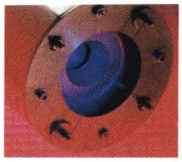
Materials engineers of Lewis Research Center's Technology Utilization Office tackled the problems. A period of extensive experimentation led to a breakthrough involving application of materials originally developed for aerospace systems to continuous casting hardware.

Specifically, Lewis offered as a solution to the roller-cracking problem: use of a high temperature material once used on the X-15 research plane. Applied to the rollers by a special spraying technique developed at Lewis, a thin layer of the material would provide resistance to thermal shock and cracking. To reduce wear on the mold surfaces while maintaining a high heat transfer capability, Lewis supplied mold prototypes of metal composites that reduced erosion and promoted the desired thermal conductivity in the critical initial solidification area.

Both measures proved successful. Roller life has improved dramatically. Where the average roller used to last for about 300,000 tons of steel, the improved roller can handle a million tons or more. Improvements of two to three times over previous mold life were also realized.

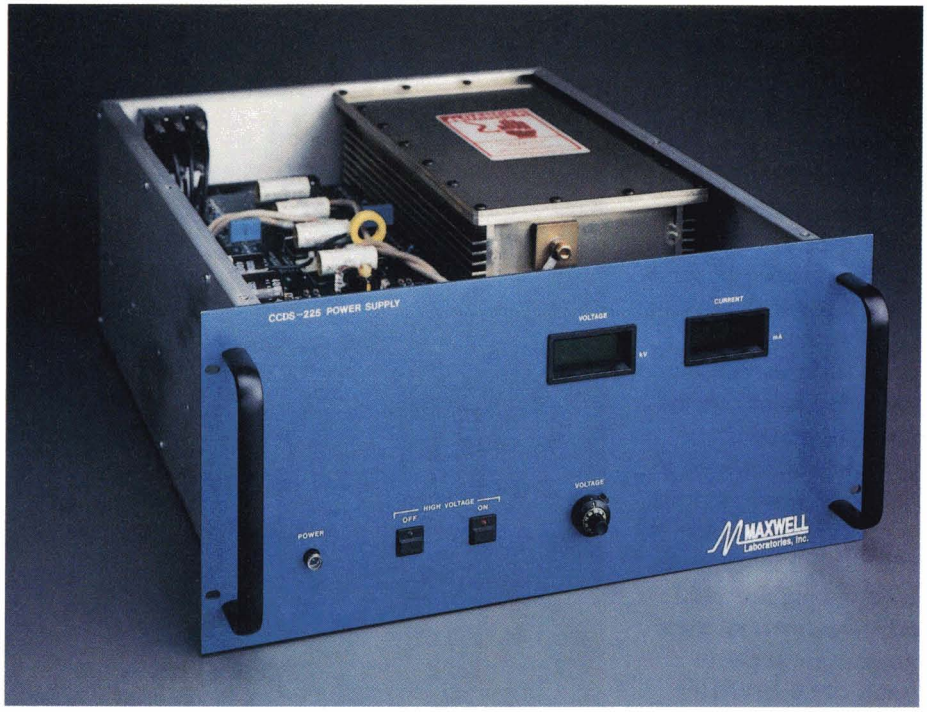
Only a few months after introducing the improved components, Gladwin posted large sales increases, helping the company to keep its share of the continuous casting equipment and maintenance market despite intense foreign competition. The company anticipates additional improvements through continued NASA cooperation.

"I have to say that NASA technology has definitely helped us," says Chief Engineer Wagner, "but it goes much further than that. The real benefit goes to the U.S. steel industry — an industry that needs help."



Power Supply

The power supplies are the first commercial spinoff from the CCDS program



At right is a Maxwell Model CCDS-225 Capacitor Charging Power Supply, one of 63 models in the commercial CCDS series produced by Maxwell Laboratories, Inc., San Diego, California. The series is named for NASA's Centers for the Commercial Development of Space, which are competitively selected consortia of industrial firms, universities and government organizations established to accelerate development of technology for both ground-based and space-based commercial applications.

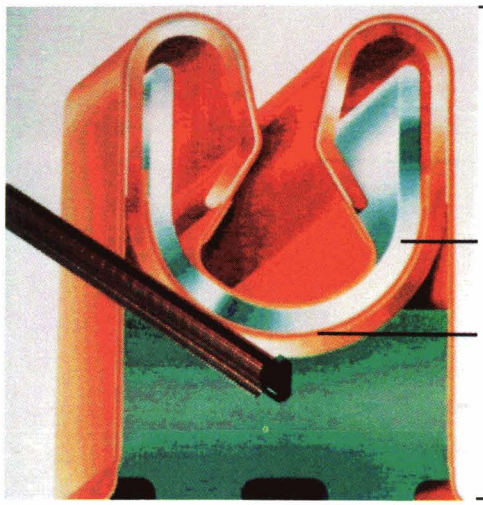
The CCDS series was co-developed by Maxwell Laboratories and one of the 16 CCDS, the Center for Commercial Development of Space Power, Auburn University, Alabama. Maxwell will share with the Auburn center revenues from sales of the CCDS series.

The first commercial spinoff from the CCDS program, the power supplies are rectangular units about the size of a stereo receiver. Their job is to transform and condition large voltages (up to 50 kilovolts) to charge capacitors used in such devices as x-ray sources, medical accelerators, radar and microwave communications equipment, and industrial lasers used for marking, cutting and welding operations. The system is lighter, more reliable, more compact and more efficient than existing systems that do the same job, its developers say; these features are critical to industrial, medical and space applications.

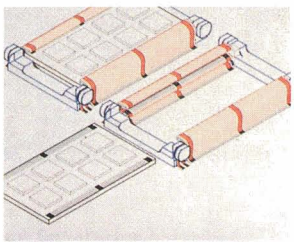
Work began on the system in 1988, originally conceived as a lightweight high voltage power supply to charge capacitors used mainly in NASA space lasers, which perform guidance, communications and weather monitoring functions. Early in the program it was recognized that there was a need and a market for an efficient capacitor charging power supply in terrestrial applications. By the fall of 1988, the Maxwell/Auburn team had developed several prototype designs for the commercial unit. The design was finalized in February 1989 and in May of that year an engineering prototype confirmed product performance. Production for the commercial market began in 1990.

Electrical Connectors

Electrical connectors are the single greatest limiting factor facing designers of high performance digital systems, according to John Krumme, President of Beta Phase, Inc., Menlo Park, California. Beta Phase, a pioneer in innovative connector technology since its founding in 1984, is offering designers what it calls "a new tool to help them do more in less space at less cost." The tool is a line of BetaFlex™ connectors/sockets that connect multichip modules and high density ceramic packages to printed circuit boards.



The new connectors do more in less space at less cost



Aimed at computer, telecommunication, avionics and military markets, the BetaFlex line will enable designers to gain up to 40 percent more board space and provide 100 signal lines to the inch, according to Beta Phase. This is expected to lead to higher levels of miniaturization and a significant reduction in the cost of large scale integrated packages.

BetaFlex is a new technology for connectors, but actually it combines two well-proven technologies: photolithography and shape memory alloy. Beta Phase uses precision photolithography techniques to etch the contacts onto flexible circuits, thereby allowing a greater number of contacts in a given area, eliminating pins and sockets that might break, and reducing signal distortion.

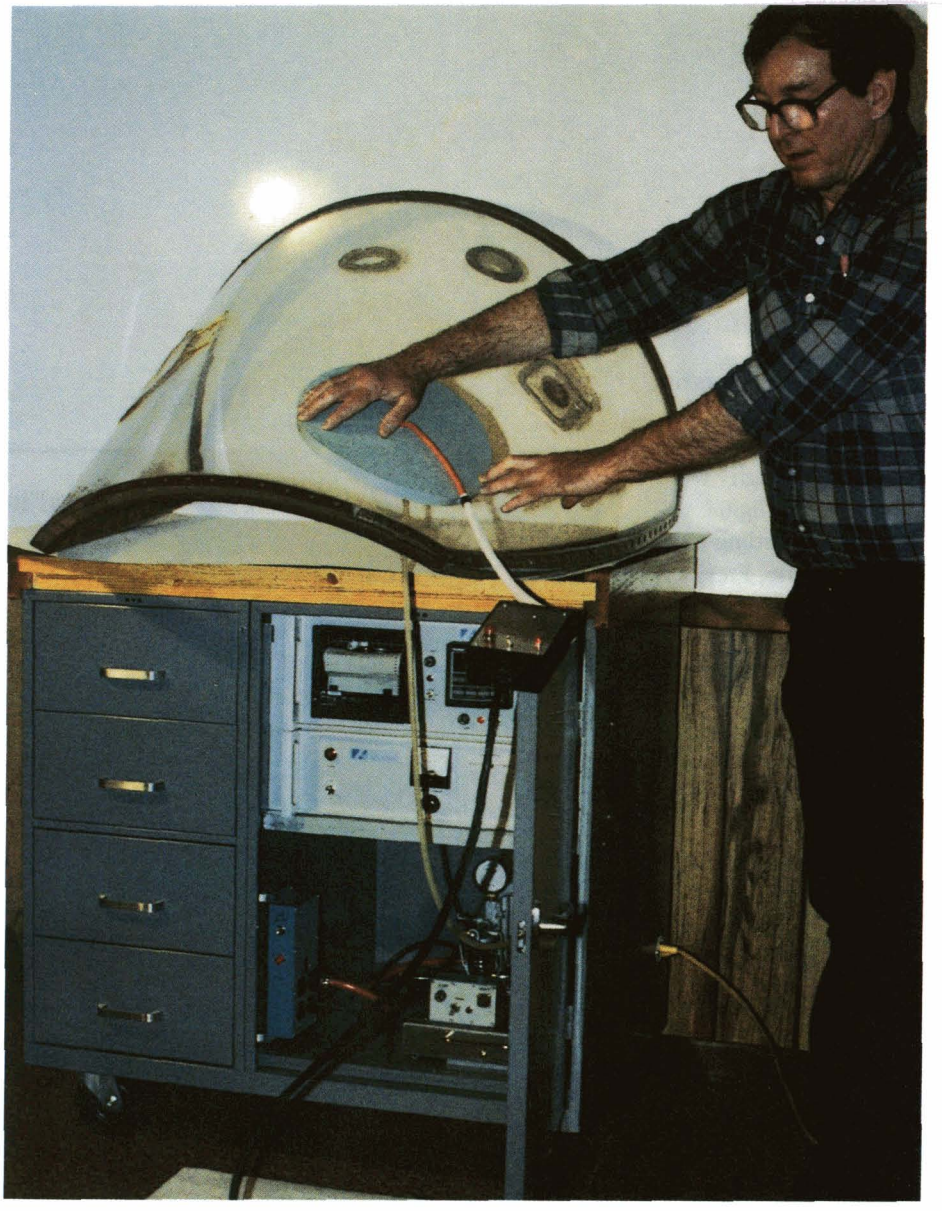
Shape memory alloy technology is represented by a nickel-titanium element within the connector. When a low voltage power supply heats the alloy, it opens the connector's spring, allowing the mating printed circuit board to be inserted with zero force. This, says the company, provides the additional benefits of easier assembly and greater reliability than pin-and-socket connectors.

The spinoff connection is the shape memory alloy technology. The shape memory effect of nickel-titanium (whereby the metal can be severely deformed yet spring back to its original shape upon heating) was discovered in 1962 by the Naval Ordnance Laboratory. Although the discovery inspired a lot of industrial experiments, few practical applications emerged. In the 1970s and 1980s, NASA revived interest in the technology with a series of in-house and contractual projects involving further research on the shape memory properties of nickel-titanium, on procedures for processing the alloy, and on practical applications. NASA's work prompted wider adoption of the technology and brought about a number of practical applications.

In 1990, Beta Phase and Molex, Incorporated, a leading manufacturer of electronic connectors located in Lisle, Illinois, signed an agreement whereby Molex purchased a minority interest in Beta Phase and acquired the right to become an alternative source for Beta Phase connectors.

™BetaFlex is a trademark of Beta Phase, Inc.

Induction Heating Systems



Induction heating systems enable spot and seam bonding of many plastics, composites and metals

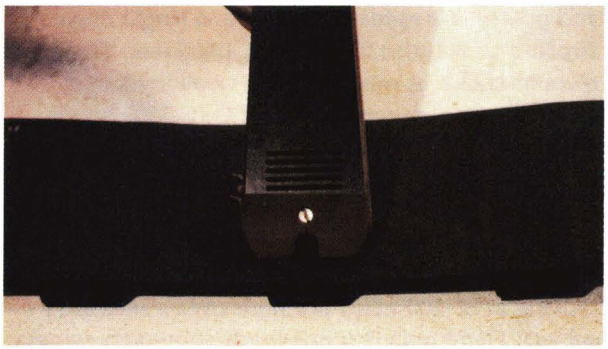
More than a decade ago, Langley Research Center conducted research on a new method for in-space joining of plastic and composite components of space structures. A new method was needed because plastics and composites are difficult to join in the airless environment of space by conventional methods. Adhesive bonding, for example, is not reliable in a vacuum, riveting techniques often deform the material, and mechanical fasteners require hole preparation and special hardware.

Langley researchers decided the best approach was induction heating, or magnetic heating, which causes little or no deformation and can be used with any type of thermoplastic material. They developed and patented a prototype system that had applicability not only in space structure assembly but also offered advantages in a variety of terrestrial applications in the automotive, appliance, aerospace and construction industries, plus military utility as a battlefield repair tool.

In 1981, Inductron Corporation, Grafton, Virginia, obtained an exclusive NASA license to use the induction heating technology in commercial applications.

Inductron initiated its own program to develop equipment and technology specifically for aircraft manufacture and repair. From that beginning, the company produced a series of induction heating systems and associated equipment — such as heating heads and joining tools — with applicability not only in aircraft manufacture/repair but also in a number of industrial and military applications. According to company literature, Inductron induction heating systems enable spot and seam bonding of many plastics, composites and metals in a fraction of the time required by conventional joining methods. A sampling of applications includes battlefield repair of aircraft windscreens, skins, hydraulic lines and rotor blades; rapid attachment of strain gauges; laboratory testing of adhesives; and manufacture and repair of composite assemblies.

Inductron produces several models of the Torobonder low-powered, self-tuning, portable induction bonding systems. Generally similar in size



and weight (24-27 pounds), they differ primarily in output wattage. They come with a number of interchangeable heads such as the Torobonder Flex Head shown in closeup **(lower left, opposite page)** and in use **(left)** for repair of an aircraft windscreen. In the latter photo, the Flex Head is being fitted over a patch on the windscreen; the power supply delivers bonding heat and distributes it — on flat or curved surfaces — evenly throughout patch area.

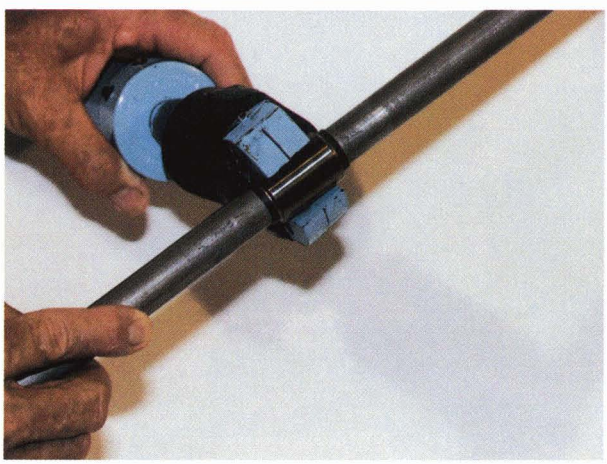
Another Inductron development is the E Heating Head **(above)**. Earlier methods for inductively heating two separate areas (spots or seams) require two separate heating operations. Inductron's E head can perform inductive heating of two spots or seams in a single operation. The unit offers advantages in aircraft manufacture/repair for attaching stiffeners to aircraft panels, and in automobile manufacture for attaching stiffener legs for strengthening door, trunk and hood panels.

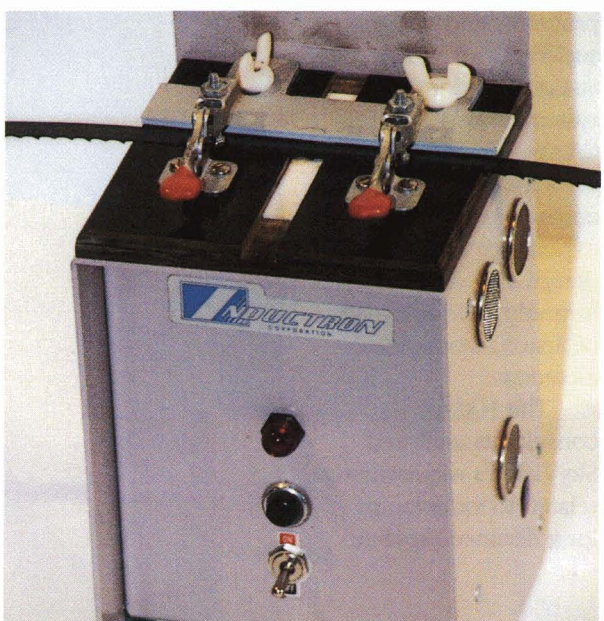
Inductron has developed a Toroid Joining Gun applicable to heating a variety of conductive materials. One version of the gun is reconfigured for a special type of job important in military and industrial maintenance; heating metal heat-to-shrink couplings and fittings, typically for repair of hydraulic, air or plumbing lines. These shrink fittings are heated to a high temperature at which they shrink and bond to the line. In this application, the Inductron device offers advantages over earlier heat-to-shrink methods in that it has no open flame and is non-hazardous; generates focused and controllable heat; does not adversely affect surrounding objects, such as wire harnesses or fuel lines; and has a long shelf life. **At lower left,** the tool is shown heating a coupling; the heating head comes in several sizes to accommodate a range of fitting and coupling diameters.

Shown below is still another Inductron system, the Torobrazer, which offers a new and advantageous method of brazing and annealing sawblade joints employing the induction heating process. Advantages cited include lightweight portability, low cost, low power, safety and ease of operation, even for inexperienced personnel.

All of these devices and others in the Inductron line stemmed from the original Langley induction heating research. In 1990, Inductron negotiated an agreement with NASA to patent all induction heating-related inventions in NASA's name, with Inductron granted exclusive rights to practice the technology.

All of these devices stemmed from the original Langley induction heating research





Aerial Video Imaging

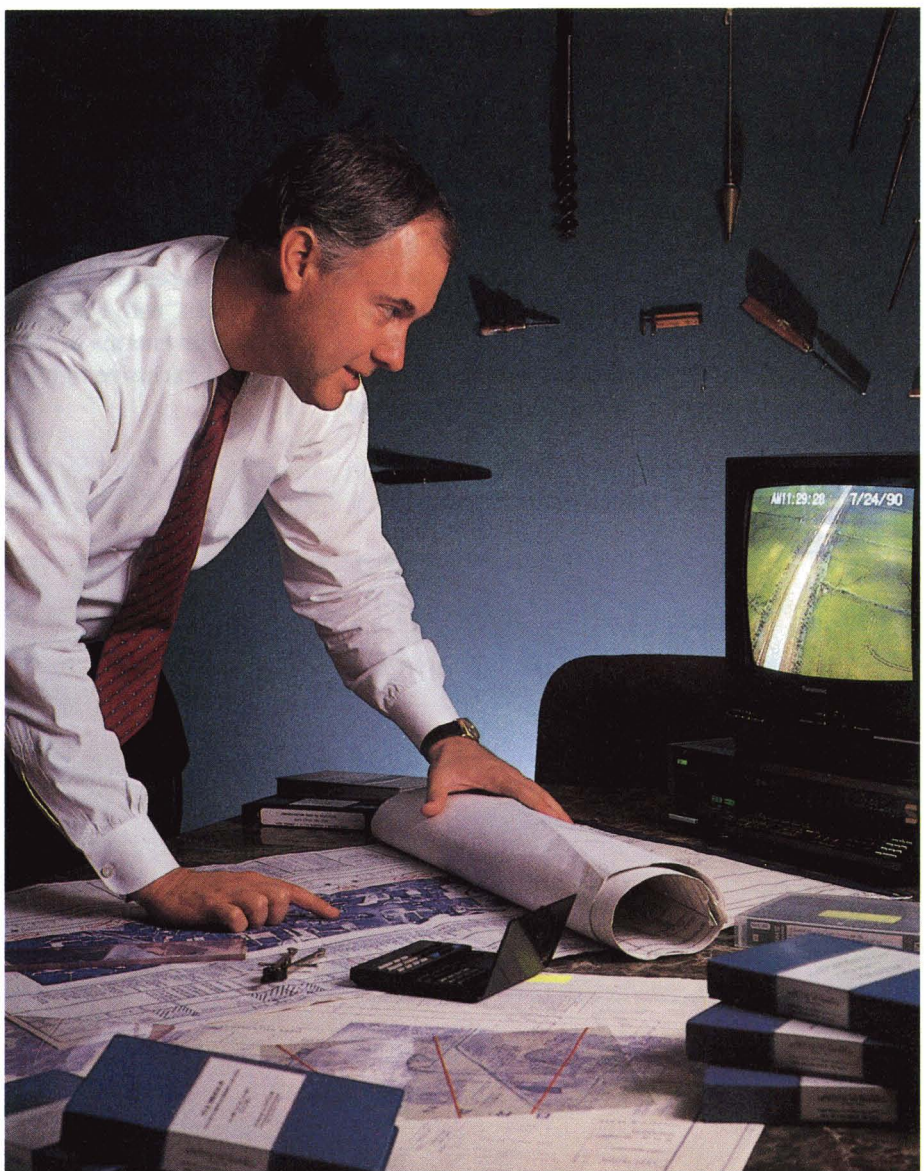
Below, Michael E. Henry, president of SkyVision, Inc., Houston, Texas, examines a videotape taken by his company's Cessna 182 airplane. A recently formed affiliate of Barr Air Patrol, Inc., an aerial pipeline and utility patrol company, SkyVision provides aerial video service to operators of pipelines, power lines, and other rights-of-way. The videotape supplements visual inspection with a high resolution permanent record useful in planning, construction and maintenance of pipeline/power line rights-of-way, or in environmental data collection.

In 1989, Henry and his partner in both companies, Ron Hyde, saw a need for the aerial video service in such applications as planning and routing rights-of-way, environmental studies, documentation and reference, and before/after evidence in liability issues. With no knowledge of how to build and operate such a system, they sought guidance from Johnson Space Center (JSC) and were introduced to two NASA engineers who agreed to serve as consultants: Olin Graham, principal engineer responsible for the design and development of TV systems used in the Apollo, Skylab, Apollo-Soyuz and Space Shuttle programs and design supervisor of Space Station Freedom's video system; and W. K. "Bill" Creasy, a private pilot, aeronautical/mechanical engineer with long experience in aircraft design and modification, formerly JSC's manager of Space Station flight elements.

The NASA consultants analyzed SkyVision's requirements related to videotaping long distance pipeline and power line rights-of-way from a single engine airplane at altitudes from 200 to 1,500 feet. Their first recommendation was for a high quality yet cost effective video system: the Sony DXC-750 camera with a small, lightweight head that would create less wind resistance and load when mounted under the Cessna 182's wing.

A key requirement was to reduce the effect of the "smear factor" that occurs when the camera is moving at 80-100 miles per hour over a stationary subject. Flight tests determined the optimum camera speed for stopping motion (1/2000th of a second); that shutter speed provides a clear image of the right-of-way, which can be observed more closely by stopping the video and inspecting the subject area frame by frame.

A key requirement was to reduce the effect of the "smear factor" that occurs when the camera is moving at 80-100 miles per hour



The consultants designed and fabricated a wing-mounted fiberglass camera pod **(above left)**. The camera head can be actuated in pitch and yaw and the video team can adjust the camera angle in flight to get the desired field of vision. The camera pod is aerodynamically shaped to reduce vibration, and vibration is further mitigated by a shock absorbing foam specifically selected after tests of the aircraft's vibration frequency.

A solo pilot can operate the entire video system alone. The camera control unit, video recorder and TV color monitor are installed in a rack on the cabin floor in place of the right front seat. The controls are conveniently located so that the pilot can start and stop recording, operate the zoom lens and maneuver the pod without compromising safety. The type of view the system provides is illustrated by the image **at left,** taken on a demonstration flight over Texas' Barrier Islands at 1,500 feet. Zoom capability is shown in the **bottom left** image, which shows an oil drum washed up on the shoreline. An important feature is illustrated in the **bottom right** image, in which the video is following a pipeline to a group of storage tanks.

At the bottom of the image is a microprocessor readout showing the latitude and longitude, and the bearing of the airplane (along with the time, cut off in this frame). A Global Positioning System (GPS) receiver provides the position data, accurate to within 15 meters; it gets the data from the USAF's network of GPS satellites, which provide precise position information to receiver-equipped military and civil aircraft, ships and surface vehicles. The GPS information enables matching the location of the video image with coordinates on a map, providing a document that could prove useful as a reference, for example, in a legal case such as encroachment.

SkyVision's video service proved highly successful in its first 16 months of operation, completing 29 projects involving about 6,000 miles of videotaped right-of-way. Examples include work related to railroads, pipelines and power lines, state and federal highways, rights-of-way, coastlines, offshore environmental surveys, and real estate sales and appraisals. The company plans to add aircraft and expand the capabilities and applications of its equipment.

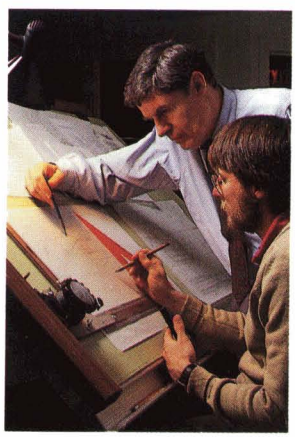
A solo pilot can operate the entire video system alone

Wireless Communications

A NASA industry team adapted Space Shuttle technology to local area networking

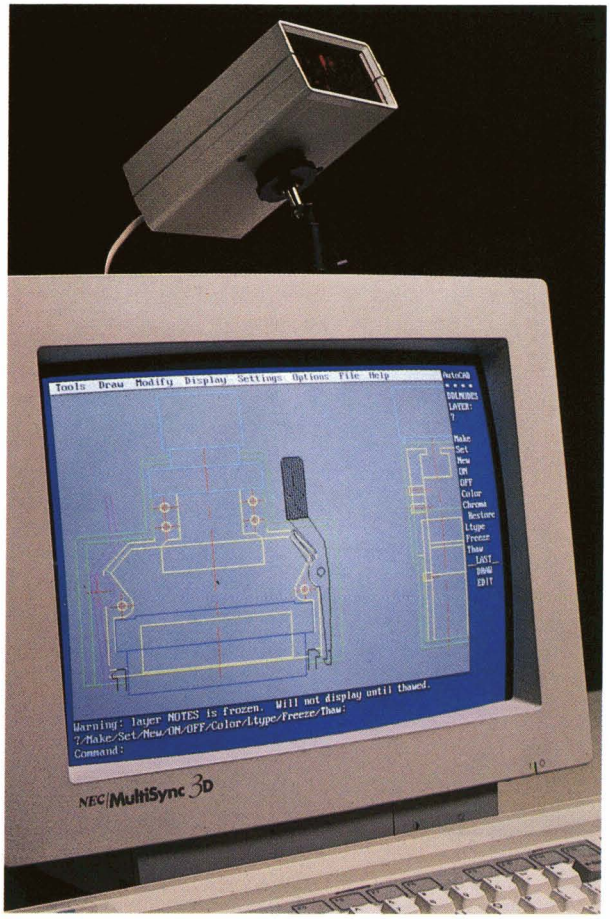
To eliminate entanglement of free-floating cables in the crew compartment of the Space Shuttle Orbiter, Johnson Space Center (JSC) developed a wireless infrared (IR) voice communications system in which signals are impressed on IR light beams and relayed through a series of boxes from one astronaut to another. First demonstrated on a 1988 Shuttle flight, the technology may also find application in multichannel wireless communication for mission control and other ground support operations.

Since such a system has obvious applicability in business and industry, NASA sponsored a technology utilization project to adapt the technology to local area networking, in which large numbers of microcomputers are tied together into wireless integrated networks. The project involved a collaboration among JSC's Tracking and Communications Division; JSC's Technology Utilization Office; the NASA Technology Application Team at Research Triangle Institute (RTI), Research Triangle Park, North Carolina; and Wilton Industries, Danbury, Connecticut.



JSC contributed its extensive systems engineering and design capability to assist in development of a commercially viable wireless infrared data acquisition system. RTI served as liaison between JSC and Wilton Industries and helped Wilton focus on a primary commercial application; Wilton brought to the project its proprietary infrared communications technology. Wilton was awarded a contract to provide engineering design and fabrication of a prototype "cable eliminator" commercial system based on JSC's wireless infrared communications technology. Now in production at Wilton Industries, the commercial derivatives that emerged from the collaboration provide the wireless equivalent of an RS232 link for industrial signal transmission and data communications applications.

The advantages of a cable-free system are evident in the industrial rule of thumb which estimates that the average cost of a foot of cable is only one dollar, but the average cost of installing or

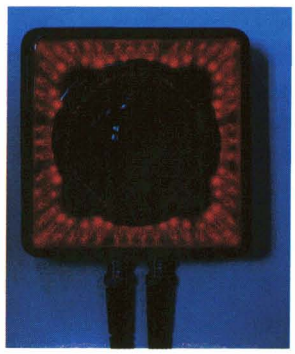


relocating cable is $15 a foot — and therefore connecting equipment in temporary installations (such as an industrial trade show) or installations likely to change (such as office floor plans) can be expensive. In addition, running cable is often impractical in factories, as is cable connection for data communications equipment in motion (such as portable computers).

At far left, Wilton Industries president Jim Crimmins works with a product designer on a new unit for the company's IRplex Wireless RS232 Cable Eliminator line. **At left center** are some of the small and compact products of the Wilton line: clockwise from left, an IRplex 6000 hub and transceiver, an IRplex 1000 transceiver, and the IRplex 3100 unit.

A substantial number of applications require the simple wireless connection of two equipments without need for channel switching. For such installations, Wilton Industries offers the IRplex 1000 Series RS232 Cable Eliminator, which can, for example, send data to a printer 200 feet away or receive data from a remote data acquisition module. An IR transceiver can be located anywhere that is convenient because line-of-sight transmission is not necessary; the IR pattern is omnidirectional, so the unit does not have to be pointed at another unit. In the photo **above** an IRplex 1000 transceiver is mounted atop a computer terminal.

Wilton Industries provides IRplex 3000 series units for extended area coverage requiring continuous communications between two equipments as they move over a large area that may include multiple large rooms. The extended area IR system consists of mobile transceivers which move under the IR field of view of a number of ceiling mounted IR heads, or R/T Modules (**at right** is a ceiling mounted IR head for use with the IRplex 6000 system). The IRplex 6000 provides wireless local area network coverage up to 44,000 square feet and can be connected to the Ethernet, ARCNET® or Token Ring networks.



Running cable is often impractical in factories, as is cable connection for data communications equipment in motion

Among local area network applications for wireless IR communications cited in a survey by Transaction Marketing, Inc., Greenwich, Connecticut, are stock exchange communications between floor traders and their back offices; exposition/trade show communications; improved quality control through sampling data at loading/discharge points; telepresence location of bar-coded parts in inventories or warehouses; improved process control through expanded measurement points; emergency communications in earthquake zone buildings; and voice/data communications for "roving" workers, such as nurses, factory foremen and guards. Among Wilton Industries' initial commercial applications were instrument panel testers at the Ford Thunderbird/Cougar assembly plant in Lorain, Ohio; wireless voice communications on the trim/paint inspection lines at a number of Ford's final assembly plants; and wireless RS232 data transfer systems for substation monitoring at Florida Power and Light.

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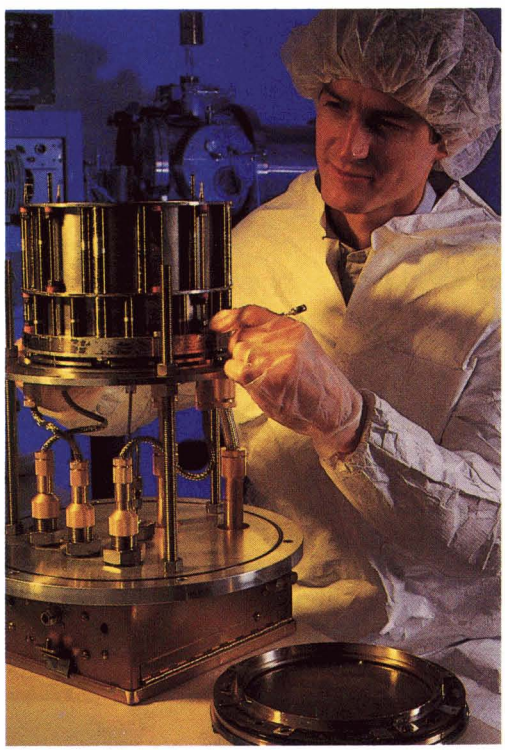
Ion Generators

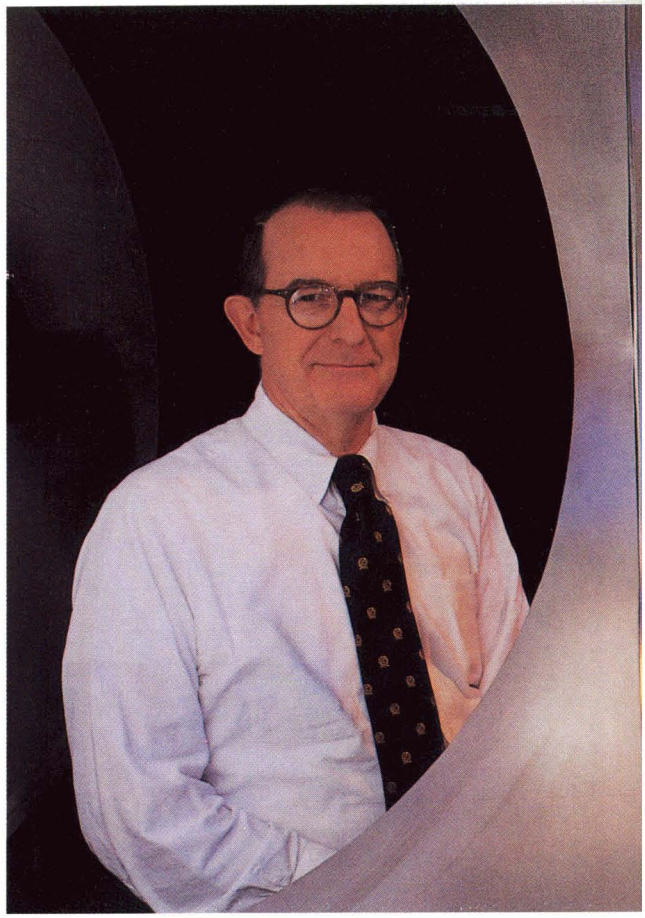
An ion engine could theoretically accelerate a spacecraft to a velocity approaching the speed of light

In 1959-60, the first electron bombardment thruster was conceived, developed and tested by Lewis Research Center engineer Dr. Harold R. Kaufman. This and later "Kaufman thrusters" and "Kaufman sources", as they came to be known, were intended for use in a spacecraft electric propulsion technique known as ion propulsion.

Ions are atoms or molecules that have lost one or more of their electrons — and therefore are electrically charged. One method of generating ions for propulsion is by electron bombardment of a gas in a discharge chamber — any gas, but most often mercury or cesium in early work, argon and xenon in most recent applications. The bombardment causes atoms to lose electrons. The ions thus created are accelerated and ejected from the chamber as ion beams. Mixed with an equal number of electrons, the ion beam becomes a thrusting force similar in function to the hot gas exhaust of a chemical rocket, but with a major difference: where the chemical rocket creates high thrust values for short periods, the ion propulsion system generates very low thrust for extremely long periods with very high exhaust velocity.



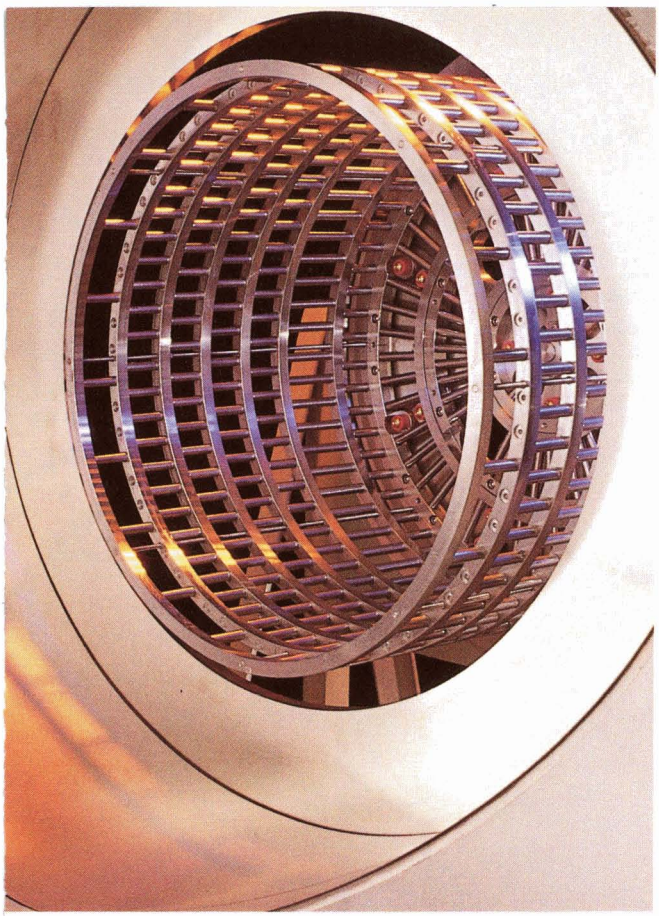
As a primary space propulsion system, an ion engine could theoretically accelerate a spacecraft to a velocity approaching the speed of light for voyages beyond the solar system. It also has utility as an auxiliary propulsion system for spacecraft stationkeeping and attitude control functions.

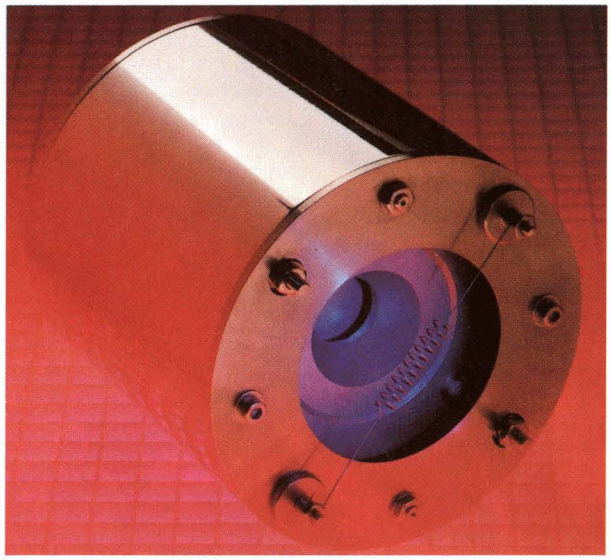


Dr. Kaufman continued his electron bombardment ion thruster work at Lewis until 1974, when he joined Colorado State University as Professor of Physics and Mechanical Engineering. Now with Front Range Research, Fort Collins, Colorado, he is a foremost expert on broad beam ion sources for both space and terrestrial applications.

Dr. Kaufman's ion propulsion devices were used in some space projects, beginning in the mid-1960s, but their potential as a primary propulsion system lies in the future. However, the technology developed for space use resulted in development — starting about 1970 — of a variety of industrial ion beam sources. Several other techniques for ion generation have been developed in the U.S. and abroad, but most broad beam electron bombardment ion sources now in use trace their origins to Dr. Kaufman's work at Lewis Research Center. (Dr. Kaufman developed the 38-centimeter ion source for large capacity, broad beam production applications; in addition to its high processing capability, it offers reliability and ease of maintenance in an industrial environment.)

The principal industrial applications of ion beam technology are in etching microcircuits for electronic systems and deposition of thin films used, for example, as coatings on solar cells or optical





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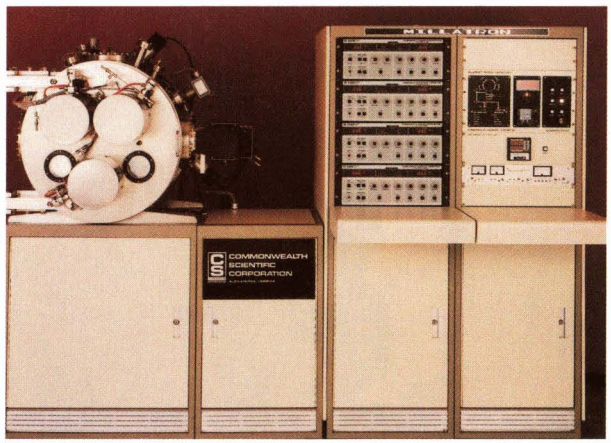
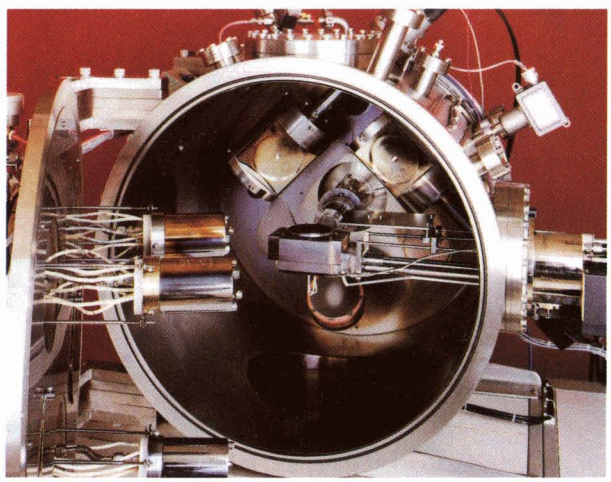
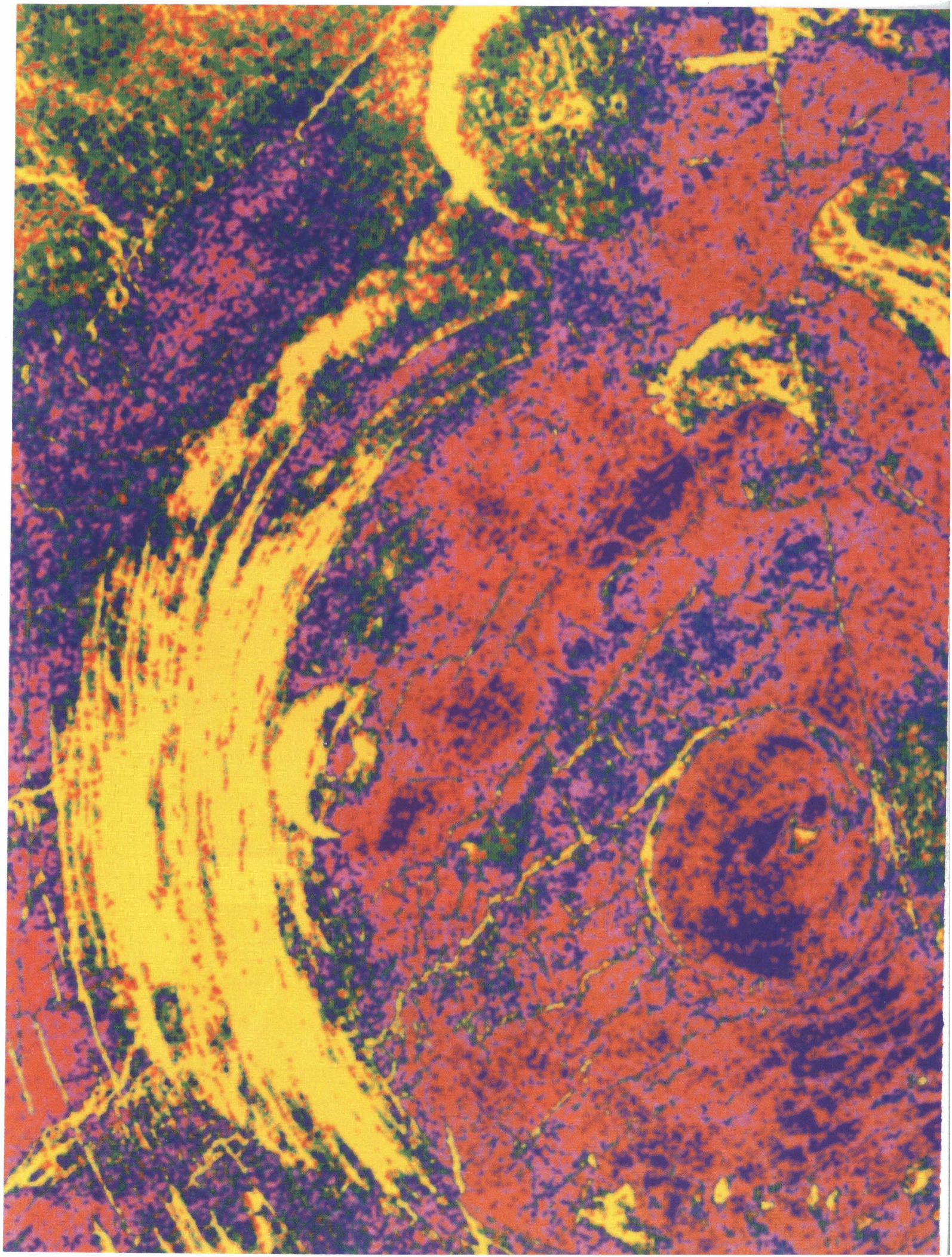




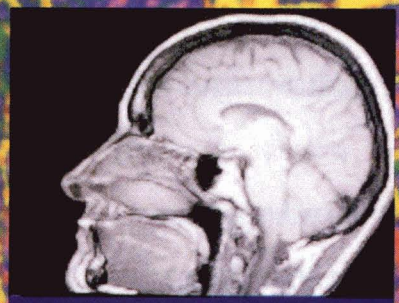
equipment. Recently there has been growing use of ion sources for modifying or controlling the properties of thin films. In a property modification application, the target material is bombarded by an ion beam before, during or after the film deposition process to improve certain properties of the end products, such as adhesion or corrosion resistance.

A company whose product line derives largely from Dr. Kaufman's ion beam technology is Commonwealth Scientific Corporation (CSC), Alexandria, Virginia. Dr. Kaufman serves as a vice president-research and a member of the board; CSC president is George R. Thompson, shown in the **center photo. At far left,** a research engineer is working on assembly of a CSC ion source. **At top right** is a closeup view of a CSC Mark II Gridless Ion Source. The photo **at right** shows a complete CSC etching/deposition system with the ion source chamber at left photo; the chamber is shown in closeup **at bottom right.**

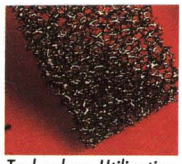
Founded in 1966, Commonwealth Scientific Corporation is a leader in engineering research for the ion beam technology industry and a leading producer of ion beam equipment. The company's product line includes more than a dozen types of ion sources for various applications, power supplies for the sources, surface analysis equipment, thin film coating equipment and a number of related systems.



Technology Utilization



A description of the mechanisms employed to encourage and facilitate practical application of new technologies developed in the course of NASA activities



Putting Technology to Work

A nationwide technology utilization network seeks to broaden and accelerate secondary application of NASA technology

Because they are challenging and technologically demanding, NASA programs generate a great wealth of advanced technology. This bank of technology is a national asset that can be reused to develop new products and processes, to the benefit of the U.S. economy in increased productivity, in new companies, new jobs and a resulting contribution to the Gross National Product.

NASA seeks to promote broader use of this technology bank through its Technology Utilization Program, which employs several types of mechanisms to stimulate the transfer of aerospace technology to other sectors of the U.S. economy. The program is managed by the Technology Utilization Division, a component of NASA's Office of Commercial Programs. Headquartered in Washington, D.C., the division coordinates the activities of technology transfer specialists throughout the United States.

An important facet of the program is the applications engineering project, in which NASA collaborates with public sector or industrial organizations to develop innovative solutions to problems through redesign or reengineering of NASA-developed technology.

One NASA instrument for this technology transfer mechanism is the Applications Team, whose job it is not only to identify NASA technologies that have potential for serving community needs, but also to assist in commercialization of a problem solution. Located at Research Triangle Institute (RTI), Research Triangle Park, North Carolina, the team has — for more than 20 years — assisted NASA field center Technology Utilization Offices in developing applications engineering projects in biomedicine, electronics, materials, robotics, rehabilitation and computer sciences.

The RTI team follows a carefully delineated process involving a five-phase plan, with go/no go decisions by all participants between each phase.

In the photo are Dr. Doris Rouse, director of the NASA Technology Application Team, team members Stephen D. Mangum (far left) and Dan Winfield (far right), and (at right center) Joe J. Mathis, Technology Utilization Officer at Langley Research Center. Mathis is holding a prototype electronics board for a Bladder Fullness Monitor, an aid to handicapped people.

Initially, the Applications Team identifies a problem through contacts with industry, professional associations, universities, advisory groups, state and federal agencies. The team prepares a problem statement, which is submitted to NASA field centers for review. NASA engineers respond with concepts for possible solutions; the team then assists NASA and the problem originator in evaluating the feasibility and commercial potential of the solution concept.

Once a decision is made to proceed, the RTI team helps NASA develop a project plan and secure the collaboration of other technical organizations and an industrial partner. The applications engineering project provides a means to perform adaptive engineering of the technology, with a final goal of commercializing the resulting product or process.

An example is the development of a Bladder Fullness Monitor, a project that originated when Dr. Doris Rouse, director of the RTI Applications Team, served on a technical advisory board of the Association for Retarded Citizens (ARC). The board recommended research into an unobtrusive, non-invasive device for measurement of bladder fullness to help the estimated five million people who experience urinary incontinence due to neurological dysfunction or learning impairment. Those who suffer from incontinence are often isolated and they require inordinate attention from their caregivers.

Research indicated that failure to learn proper toileting behavior is largely responsible for the inability to interpret properly the physiological urge to urinate. The monitor was conceived as a way to provide — to the incontinent or a caregiver — an external cue of bladder fullness.

After a technology review, the Applications Team turned to Langley Research Center for a potential solution based on ultrasound inspection of the bladder. To obtain co-funding for the project, RTI helped the ARC develop a successful grant proposal to the National Institute on Disability and Rehabilitation Research. R&D by Langley engineers and laboratory testing at the Medical College of Virginia produced a Bladder Fullness Monitor that fits into a 35 millimeter camera case, with a transducer that attaches to the wearer's abdomen. The device employs ultrasound to measure the tension on the back wall of the bladder; an increase in tension, an indicator of fullness, triggers a signal to the wearer.

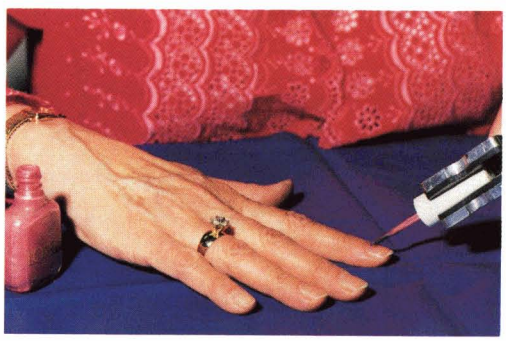
The ARC has applied for a license for medical applications of the technology and ARC/RTI are seeking a manufacturer to commercialize the device. An evaluation has shown that a next generation device can be reduced to a pocket-size, belt-mounted unit, which would facilitate broader testing in a larger population to document the benefits to toilet training. The final product offers utility as a prosthesis for people completely lacking in bladder sensation (from conditions such as cerebral palsy, spina bifida and spinal cord injury); as a training aid for developing toileting skills among the mentally retarded; and as a portable ultrasound instrument to aid in diagnosing causes of incontinence.

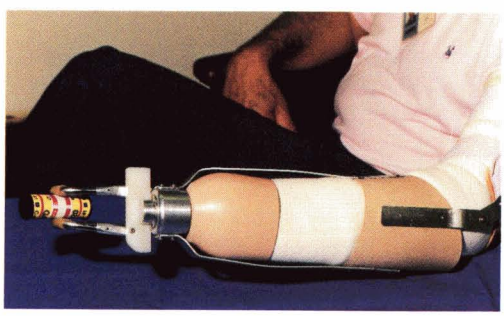
In addition to applications engineering projects, other mechanisms of the Technology Utilization Program include a network of 10 Industrial Applications Centers that offer clients access to a great national data bank; a software center that provides, to industrial and government clients, computer programs applicable to secondary use; Technology Utilization Officers, located at each of NASA's field centers, who serve as regional managers for the program; and publications that inform potential users of technology available for transfer. These mechanisms are amplified in the following pages.

Technology Applications

Providing a general purpose prosthesis to allow a wider range of activities

Applications engineering projects, in which NASA seeks to solve public sector or industrial problems through redesign or reengineering of existing aerospace technology, originate in various ways. Some stem from requests for assistance from other government agencies, others are generated by NASA technicians who perceive possible solutions to problems by adapting NASA technology to the need. NASA also employs an applications team composed of scientists and engineers representing different areas of expertise *(see previous page).*





An example of an ongoing biomedical engineering application project is an effort under way at Marshall Space Flight Center (MSFC) aimed at providing a general purpose prosthesis to allow a wider range of activities for below-the-elbow amputees. The project was initiated when an MSFC engineer lost his left hand in a home woodworking accident. On surveying the market for prosthetic devices, he found that the common "hook and harness" was the primary device available; it was expensive and it severely limited the activities in which he could participate (hunting, fishing, gardening, woodworking and many other activities were not possible).

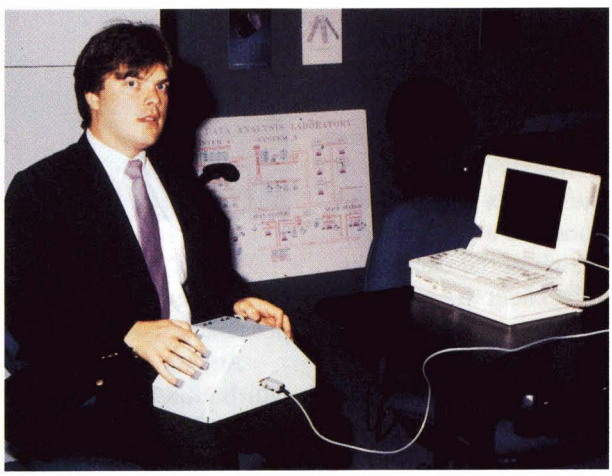
The amputee asked for help from his NASA friends and a group was formed to investigate the potential for new devices that would allow greater freedom of activity. Included in the group were the MSFC Technology Utilization Office and the Science and Engineering Directorate Graphics and Models Branch. The researchers discovered that highly sophisticated robotic devices were not the answer because of their high cost, weight and power requirements. Study emphasis focused on simple, low cost devices that could be quickly changed for different activities.

The amputee had retained the residual limb to his wrist and he could rotate his forearm. This rotational capability was utilized to design end effectors that would open and close on the rotation of the forearm and would not require cables. Light duty, quick change devices were designed to fit on the end of a short sleeve/socket molded to fit over the front end of the amputee's limb. The Marshall group built and tested a fishing reel crank; a heavy lift device for work such as lifting lumber, bricks, and rocks; a one-handed meat-cutting eating utensil; a nail holder for carpentry; a single hook end effector; and a general purpose, lightweight, rotationally actuated device without a harness. The group is continuing work to make the devices as functional and comfortable as possible.

In 1990, the group was joined by a female amputee, who is acting as a test subject for devices that will assist in such activities as holding a nail polish brush, lifting utensils and other articles useful in the home and work place. In the photo **above** are amputee test subjects Jim Carden and Amie Bradley; **at upper left,** Bradley demonstrates use of the nail polish brush and **at lower left** Carden shows how his prosthesis can manipulate an item small as a roll of film.

Another example is the Infogrip system, a cooperative development involving Stennis Space Center (SSC); Infogrip Inc., Baton Rouge, Louisiana; and the Rehabilitation Research and Training Center on Blindness and Low Vision at Mississippi State University. The project is designed to create a useful, low cost, tactile/visual training system for the handicapped (initially vision-impaired individuals) and to determine improvements in the learning process while employing the tactile feedback features of the system.

The Infogrip system is a data input system with two handgrips; each handgrip has five fingertip teaching/command keys plus two additional function keys, yielding 16,384 possible key combinations. Originally, the Infogrip was designed to teach chordic commands (combination of keys) by visual (screen display) and tactile means (the keys rise, lifting the user's fingertips); **below,** a programmer demonstrates the prototype Infogrip chordic input device. A voice synthesizer was added to enhance the utility of the system for the vision-impaired. The Infogrip system is undergoing test on two personal computers; software to allow for word processing was supplied by Infogrip Inc.



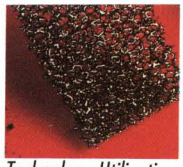
SSC developed an Infogrip Tutorial Program that utilizes the Infogrip device to teach keyboard input/output by chordic command, visual, tactile and audio means. The system employs three of the five human senses where most other teaching systems utilize sight only. The Mississippi State Low Vision Center is conducting test and evaluation of the system and center staff members have expressed enthusiasm for its utility.

Still another example is the work of Langley Research Center and the Naval Dental School in developing and testing ultrasonic techniques for quantitative dental evaluation. Existing methods for evaluating the internal quality of a tooth involve x-rays or decision-forming on the basis of various symptoms. Both methods have limitations and drawbacks. For example, x-rays used in dentistry are particularly "hard" because of tooth density; the hard ionizing radiation can cause health problems and is not recommended for frequent application. Recurrent caries can exist undetected by x-rays and some tooth problems, such as cracks, are difficult to access by radiography.

Ultrasonic imaging offers potential for enhancing the evaluation process. A cracked tooth will transmit sound in a different manner than intact enamel and dentin (the hard tissue beneath the enamel), thus can readily be identified. Carious dentin has a substantially different density than healthy dentin, thus is detectable by sonic imaging.

Langley is investigating the ultrasonic properties of tooth enamel, dentin and carious dentin, using extracted teeth provided by the Navy Dental School. Langley is also studying various methods of coupling a tooth and an ultrasonic transducer to provide for efficient transmission of ultrasonic energy. In Fiscal Year 1992, researchers will employ a prototype system to examine ultrasonically extracted teeth with known defects to see if the defects can be detected; this feasibility demonstration will include subsequent analysis by coinvestigators at the Navy Dental School. The final phase of the project will be directed toward two-dimensional imaging of a tooth's interior. This capability will enable dentists to make diagnoses in real time and develop several perspectives, allowing them to assess a problem more accurately and safely than is possible with radiographic techniques.

One project—to provide a low cost tactile/visual training system for the visually impaired

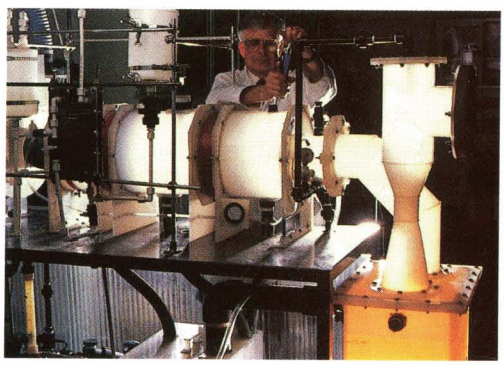


Applications Centers

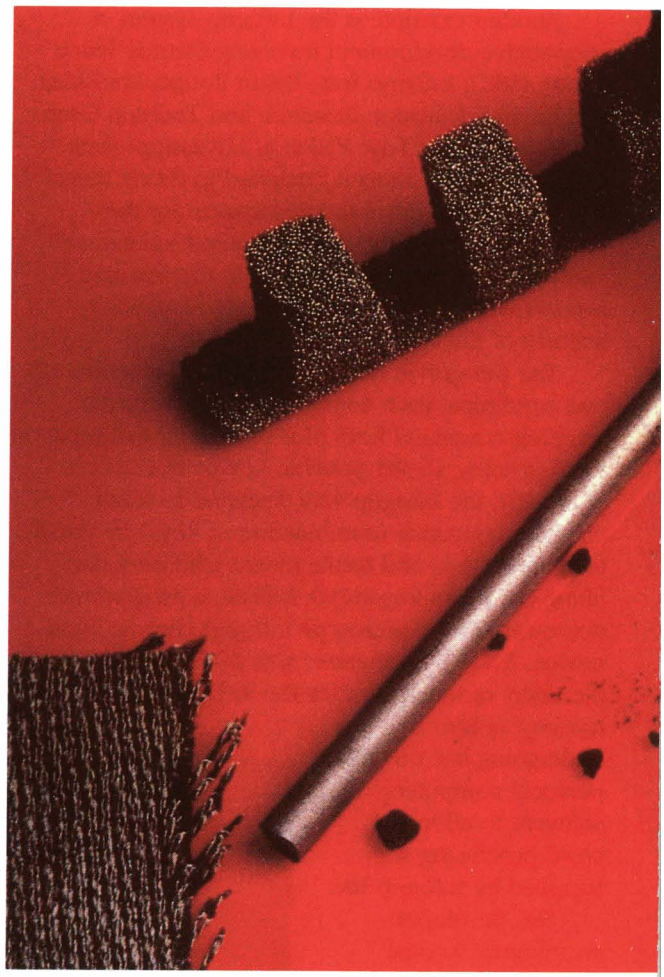
There are 10 Industrial Applications Centers across the country

To promote technology utilization, NASA operates a number of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government users. There are 10 Industrial Applications Centers (IACs) across the country. The centers are backed by off-site representatives in many major cities and by technology coordinators at NASA field centers; the latter seek to match NASA expertise and ongoing research/engineering in areas of particular interest to clients.

Through the applications centers, clients of the combined network have access to nearly 100 million documents in the NASA databank and more than 400 other computerized databases. The NASA databank includes reports covering every field of aerospace activity, plus the continually updated, selected contents of some 15,000 scientific and technical journals. Clients in many areas have access to this vast data storehouse through a Remote Interactive Search System. Clients at personal computers hundreds of miles distant can watch as an IAC representative formulates a strategy for solution of the client's problem and conducts a preliminary search of the databanks to start the process of getting the client the specific help he needs from the best source.



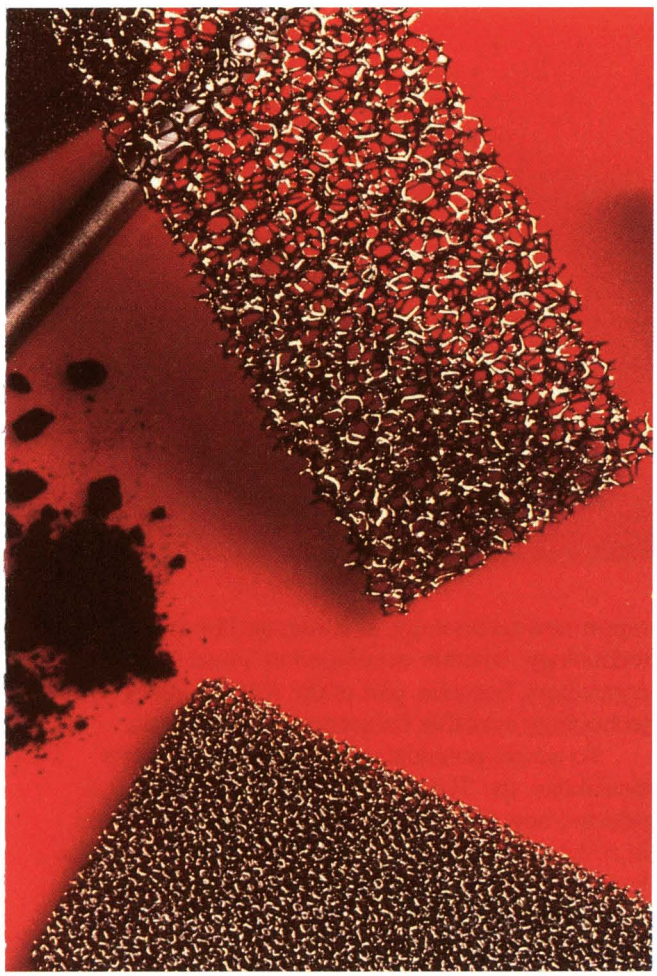
The experience of The Electrosynthesis Company, Inc., East Amherst, New York, illustrates the type of assistance provided by an IAC, in this case NERAC, Inc., Tolland, Connecticut. Electrosynthesis is a small entrepreneurial firm that seeks funding through the Small Business Innovation Research (SBIR) program **(see page 48)**. The company is a regular user of NERAC's services for help in preparing SBIR proposals, conducting customized literature searches, providing helpful technological background and current awareness information, and helping to investigate patents.



NERAC also provides information about commercial possibilities and market conditions.

Among examples of Electrosynthesis work in which NERAC assisted are several projects in R&D or production status involving a family of carbon/graphite materials known as Specifically Fluorinated Carbons, or SFC™ (**above**). SFC materials offer efficiency improvement and extended lifetimes for batteries, fuel cells and electrodes due to superior stability and electrocatalytic properties.

Another NERAC-aided company project involved development of the Electroincinerator™ System (**left**), which integrates a highly effective air scrubber with an electrochemical cell to provide an apparatus capable of destroying virtually all toxic chemicals, airborne chemicals and chemical warfare agents; among civil applications are hospital use for destruction of airborne viruses and bacteria, and industrial use for eliminating toxic solvent vapors and



Clients have access to nearly 100 million documents

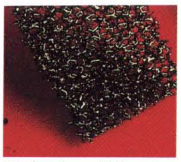
malodorous emissions.

Another example of IAC assistance is the help provided Aqua/Trends, Boca Raton, Florida. Aqua/Trends president Stuart Snyder invented a family of computer-controlled Micro-Irrigation Systems, an automated means of watering indoor plants intended to reduce maintenance costs for decor schemes that employ indoor arrangements of live plants (**top**).

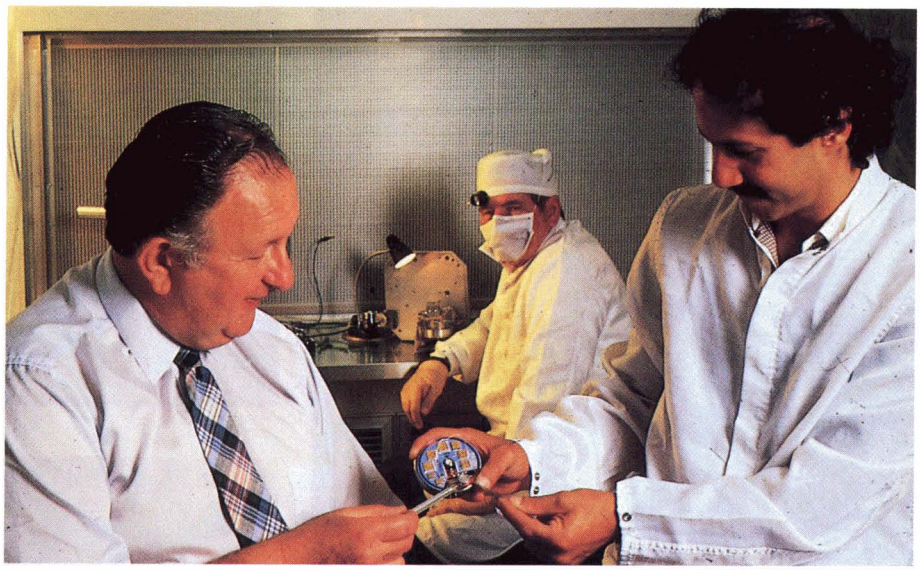
Aqua/Trends systems come in various sizes, from a simple residential system that takes care of 10-12 houseplants to a system that waters all the greenery in a large office or apartment building. A key element of the system is an electronic controller programmed to dispense water according to the differing needs of the various plants in the installation. **At right**, Snyder is pictured with some of the elements of his system in a home installation.

NASA provided Snyder assistance during development of the Aqua/Trends line through the Southeast Area Office of the Southern Technology Applications Center (STAC), located at Florida Atlantic University, Fort Lauderdale. STAC furnished pertinent NASA technical reports, advised Snyder of seminars useful in product development, and put him in contact with NASA's John C. Glennis Space Center (JCGSC). JCGSC conducts an ongoing research effort in plant use for water/air purification and pollution control and The Center made available to Snyder reports of this work.

™SFC and Electroincinerator are trademarks of The Electrosynthesis Company, Inc.



Technology Utilization Officers



An important element among the NASA mechanisms for accelerating and broadening aerospace technology transfer is the Technology Utilization Officer or TUO. TUOs are technology transfer experts at each of NASA's nine field centers and one specialized facility who serve as regional managers for the Technology Utilization Program.

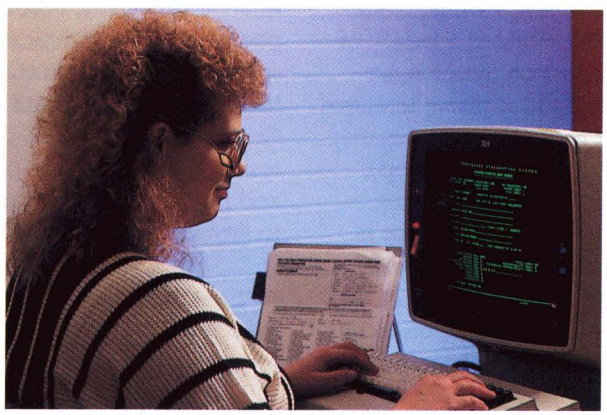
TUOs are technology transfer experts at each of NASA's nine field centers

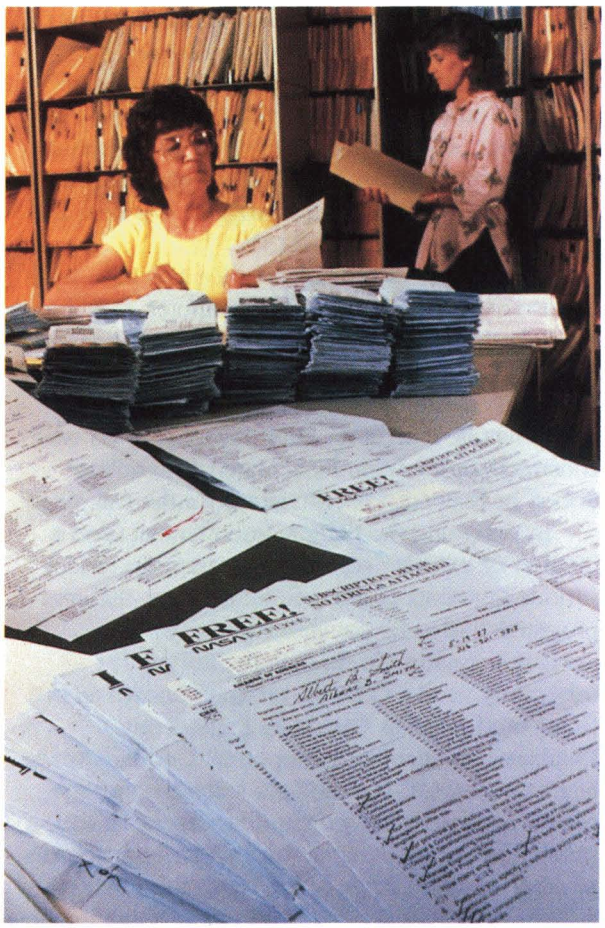
Representative of the group is Donald S. Friedman, TUO at Goddard Space Flight Center, shown in **above** (white shirt, necktie) conferring with Goddard Technologists about an implantable medication dispenser developed at Goddard under an applications engineering project.

The TUO's basic responsibility is to stay abreast of research and development activities at his center that have significant potential for generating transferrable technology. He assures that the center's professional people identify, document and report new technology developed in the center's laboratories and, together with other center personnel, he monitors the center's R&D contracts to see that NASA contractors similarly document and report new technology, as is required by law. This technology, whether developed in-house or by contractors, becomes part of the NASA bank of technology available for secondary application.

To advise potential users of the technology's availability, the TUO evaluates and processes selected new technology reports for announcement in NASA publications and other dissemination media. Prospective users are informed that more detailed information is available in the form of a Technical Support Package (TSP).

The TUO also serves as a point of liaison among industry representatives and personnel at his center, and between center personnel and others involved in applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology. On such projects, the TUO prepares and coordinates applications engineering proposals for joint funding and participation by federal



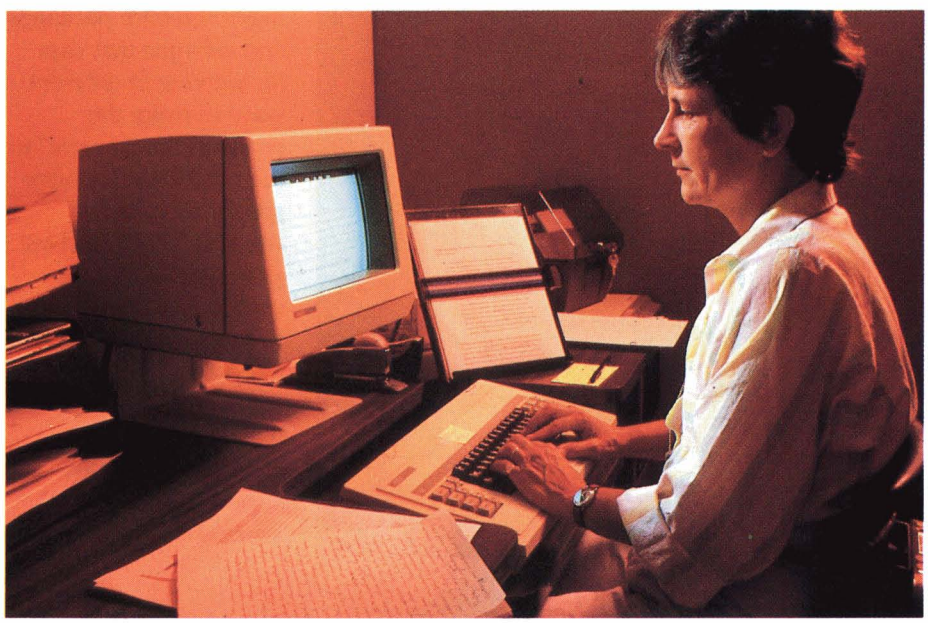


agencies and industrial firms.

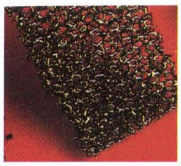
NASA conducts, independently or in cooperation with other organizations, a series of conferences, seminars and workshops designed to encourage broader private sector participation in the technology transfer process and to make private companies aware of the NASA technologies that hold promise for commercialization. The TUO plays a prominent part in this aspect of the program. He arranges and coordinates his center's activities relative to the meetings and when — as frequently happens — industry participants seek to follow up with visits to the center, he serves as the contact point.

Support for the TUOs — and for all other elements of the NASA technology utilization network — is provided by the Technology Utilization Office at the Center for AeroSpace Information (CASI). This office executes a wide variety of tasks, among them maintenance of the subscription list for *NASA Tech Briefs* (**lower left**), the principal tool for advising potential users of technologies available for transfer; maintenance and mailout of TSPs (**left**) which requires a reproduction effort of more than 1.5 million pages annually; and responding to requests for information (**below**), an activity that entails processing of some 120,000 letters and other inquiries and mailout of more than 200,000 documents a year.

The TUO/CASI is also responsible for research, analysis and other work associated with this annual *Spinoff* volume; for distribution of technology utilization publications; for retrieval of technical information and referral of highly technical requests to appropriate offices; for developing reference and bibliographic data; and for public relations activities connected with media, industry and trade show interest in technology utilization matters.



New technology, whether developed in-house or by contractors, becomes part of the NASA bank of technology available for secondary application



Software Center

COSMIC gets a continual flow of government developed software and identifies those programs that can be adapted to secondary usage

In the course of its varied activities, NASA makes extensive use of computer programs in such operations as launch control, analyzing data from spacecraft, conducting aeronautical design analyses, operating numerically controlled machinery and performing routine business or project management functions.

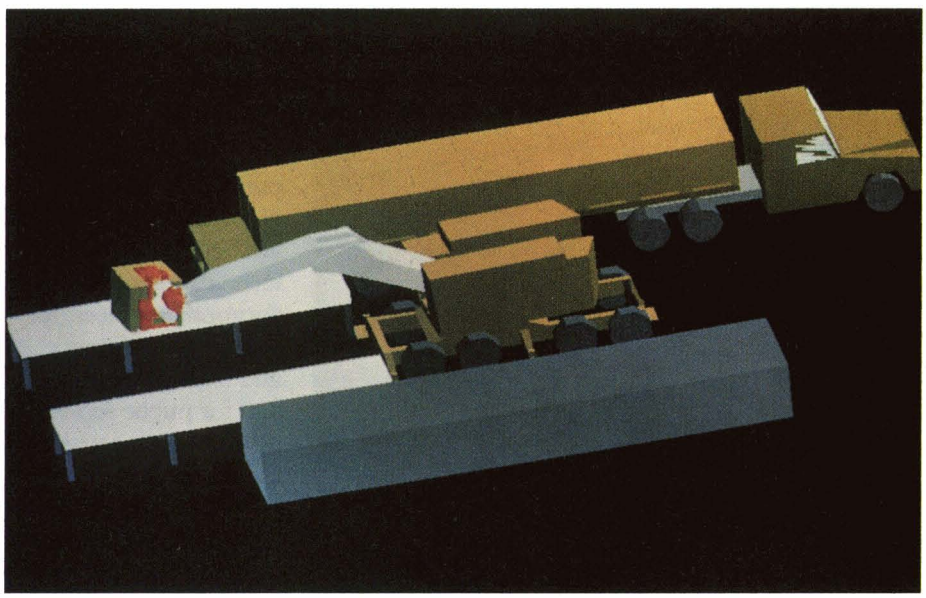
To meet such software requirements, NASA and other technology generating agencies of the government have of necessity developed many types of computer programs. They constitute a valuable resource available for reuse. Much of this software is directly applicable to secondary applications with little or no modification; most of it can be adapted to special purposes at far less than the cost of developing a new program.

Therefore, American businesses can save time and money by taking advantage of a special NASA technology utilization service that offers software capable of being adapted to new uses. NASA's mechanism for making such programs available to the private sector is the Computer Software Management and Information Center (COSMIC)®.

Located at the University of Georgia, COSMIC gets a continual flow of government developed software and identifies those programs that can be adapted to secondary usage. The center's library contains more than 1,200 programs for such purposes as structural analysis, artificial intelligence, computational fluid dynamics, thermal analysis, image processing, project management and a great variety of other functions. COSMIC customers can purchase a program for a fraction of its original cost and get a return many times the investment, even when the cost of adapting a program to a new use is included **(see pages 110–113)**.

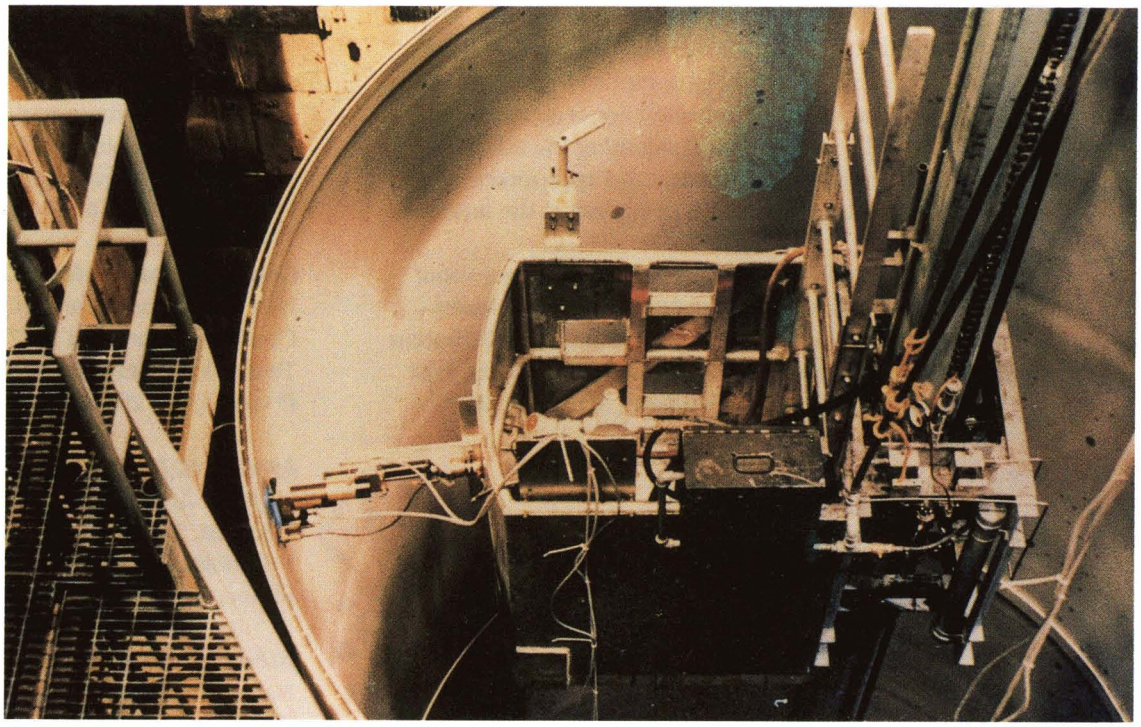
An example of how this service aids industry is the use of a COSMIC-supplied computer program by the Robotics Laboratory of Martin Marietta Aero and Naval Systems, Baltimore, Maryland. The Robotics Laboratory designs, analyzes and simulates robot manipulators. One of its major recent projects was construction of a huge Field Materials-handling Robot, or FMR (**model pictured**) for the U.S. Army.

In designing the FMR, Martin Marietta used a number of separate computer programs to model various segments of the system. All these different programs had to be patched together in one integrated system. To do that, the Robotics Laboratory used a COSMIC program known as IAC (Integrated Analysis Capability Engineering Database). Originally developed by Goddard Space Flight Center, IAC is a modular software package containing a series of technical modules that can stand alone or be integrated with data from sensors or other software tools. In the case of the FMR, the Robotics Laboratory was able to take data from 15 major software packages and reformat that data for viewing in different ways to make the program "transparent" to the user. This flexibility greatly facilitated construction of the FMR prototype and contributed substantially to reducing the cost of the project.



®COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Publications



An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed technology is available for transfer. This is accomplished primarily through the publication *NASA Tech Briefs*.

The National Aeronautics and Space Act requires that NASA contractors furnish written reports containing technical information about inventions, improvements and innovations developed in the course of work for NASA. Those reports provide the input for *Tech Briefs*. Issued monthly, the publication is a current awareness medium and problem solving tool for more than 150,000 government and industry readers. It is a joint publishing venture of NASA and Associated Business Publications of New York City.

Each issue contains information on newly developed products and processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs, and other innovations originating at NASA field centers or at the facilities of NASA contractors. Firms interested in a particular innovation may get more detailed information by requesting a Technical Support Package; more than 120,000 such requests are generated annually.

An example of how *Tech Briefs* spreads the word and inspires secondary applications of NASA technology is illustrated in the photo, which shows a segment of a Space Shuttle solid rocket motor being scanned by a motorized contamination sensing device that assures surface cleanliness prior to bonding of a rubber liner.

The sensor and scanning system are part of a family of OP1000 Surface Quality Monitors developed by Photo Acoustic Technology, Inc. (PAT), Westlake Village, California. The monitors are based on an inspection tool and technique known as Optically Stimulated Electron Emission (OSEE), invented in the early 1980s by Dr. Tennyson Smith of Rockwell International under contract to Marshall Space Flight Center.

PAT, which produces the sensors and scanning systems but not the associated robots, was founded on OSEE technology, which is described as a significant advance in measuring thin layer contamination on the surface of the material. Mantosh Chawla, president, chief executive and one of PAT's founders, learned of the technology through a *Tech Briefs* article. That beginning led to development by PAT of the OP1000 line, a series of non-destructive, non-contact surface contamination detection systems with wide industrial applicability.

Available to scientists, engineers, business executives and other qualified technology transfer agents in industry or government, *Tech Briefs* is the principal publication of the Technology Utilization Program. Among others are this annual *Spinoff* volume and the *NASA Patent Abstracts Bibliography*, a semiannually updated compendium of NASA patented inventions available for licensing, which number almost 4,000 (the latter publication can be obtained from the National Technical Information Service, Springfield, Virginia 22101).

Tech Briefs is a current awareness medium and problem solving tool for more than 150,000 government and industry readers

NASA's Technology Transfer System

The NASA system of technology transfer personnel and facilities extends from coast to coast and provides geographical coverage of the nation's primary industrial concentrations. For specific information concerning the activities described below, contact the appropriate technology utilization personnel at the addresses listed.

For information of a general nature about the Technology Utilization program, address inquiries to the Manager, Technology Utilization Office, Center for AeroSpace Information, Post Office Box 8757, Baltimore, Maryland 21240.

△ ***Field Center Technology Utilization Officers:*** manage center participation in regional technology utilization activities.

● ***Industrial Applications Centers:*** information retrieval services and assistance in applying technical information relevant to user needs.

■ ***The Computer Software Management and Information Center (COSMIC):*** offers government-developed computer programs adaptable to secondary use.

▲ ***Application Teams:*** assist agencies and private institutions in applying aerospace technology to solution of public problems.

△ Field Centers

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, California 94035
Technology Utilization Officer: *Geoffrey S. Lee*
Phone: (415) 604-4044

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771
Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 286-6242

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas 77058
Technology Utilization Officer: *Dean C. Glenn*
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899
Technology Utilization Officer:
Thomas M. Hammond
Phone: (407) 867-3017

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia 23665
Technology Utilization Officer: *Joseph J. Mathis, Jr.*
Phone: (804) 864-2484

Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135
Technology Utilization Officer: *Anthony F. Ratajczak*
Phone: (216) 433-2225

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812
Director, Technology Utilization Office: *Ismail Akbay*
Phone: (205) 544-2223

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Manager: *Norman L. Chalfin*
Phone: (818) 354-2240

NASA Resident Office—JPL
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Officer: *Arif Husain*
Phone: (818) 354-4862

John C. Stennis Space Center
Mississippi 39529
Technology Utilization Officer: *Robert Barlow*
Phone: (601) 688-2042

● Industrial Applications Centers*

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