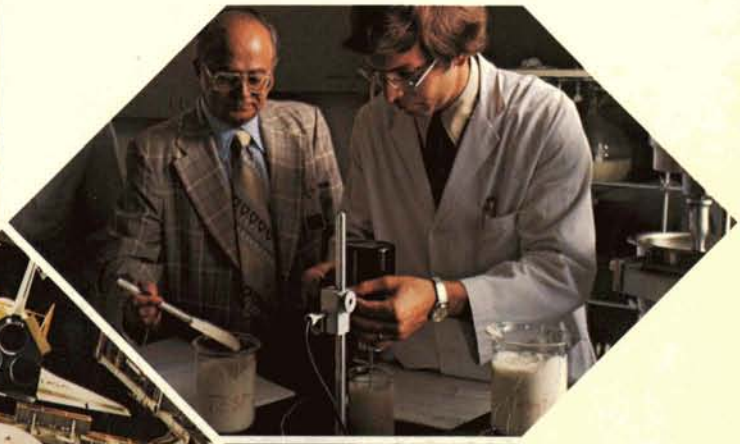
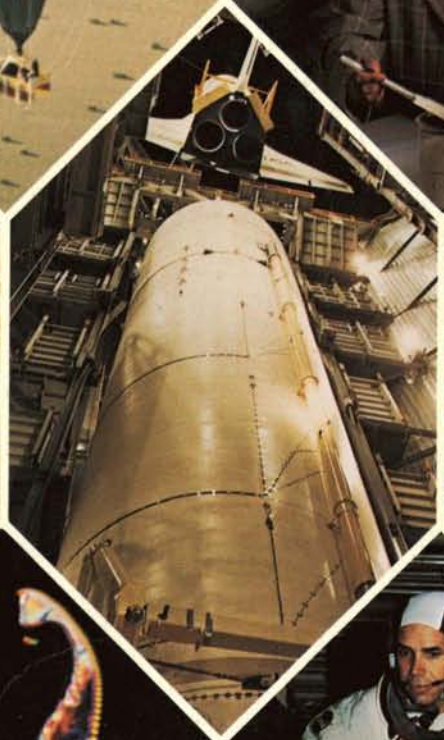
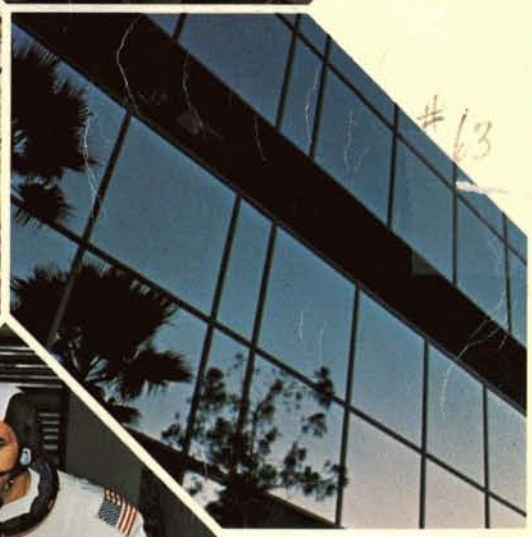
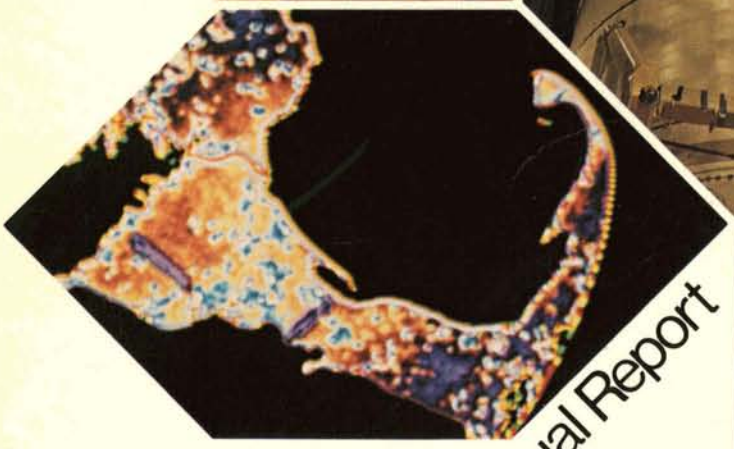
Spinoff 1979









An Annual Report

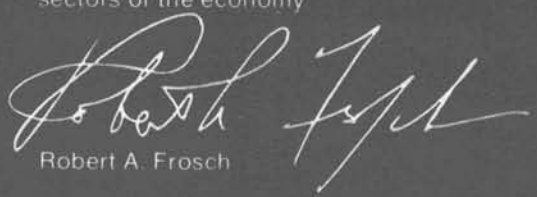
Foreword

In this 21st year of its existence, NASA is preparing to embark on a new era of space research, an era which will dawn with the first orbital flights of the Space Shuttle.

This versatile new space transportation system offers unprecedented flexibility in Earth-orbital operations. It will provide NASA the ability to do more with the funds invested in space, broaden our national capability for exploration and contribute to our continuing scientific and technological leadership. Most importantly, it will allow NASA to take even greater advantage of the opportunities for practical benefit that space affords.

Concurrently with expanded dividends from space, we can also expect increasing public benefit from NASA's program of aeronautical research, which focuses on improvements in such areas of national concern as aircraft fuel conservation, aviation safety and the environmental characteristics of the airplane.

Pursuit of the "spinoff" benefits accruing from research and development has been a NASA goal since the agency's inception. The results have been impressive. This volume describes some of the benefits which stem from NASA's space and aeronautical research, dividends accruing from both the direct application of technology and from the transfer of aerospace technology to other sectors of the economy.



Robert A. Frosch

Administrator
National Aeronautics and Space Administration

February 1979

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An Annual Report

Spinoff 1979

National Aeronautics and Space Administration

Office of Space and Terrestrial Applications

Technology Transfer Division

by James J. Haggerty

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Introduction

Technology is knowledge, the technical "know-how" employed by a society to produce things that improve the quality of human life. Like other forms of knowledge, it is transferable; once developed, technology can be applied to uses different—and often remote—from the original application.

Thus, the technology that NASA has developed in more than two decades of space and aeronautical research constitutes a valuable national resource, a bank of knowledge available for secondary utilization, or "spinoff." NASA mainline programs, by their challenging nature, are particularly demanding of technological advance; meeting their goals has forced extraordinary advancements in virtually every scientific and technological discipline. For that reason, the wealth of aerospace-generated knowledge available for transfer is exceptionally diverse, and much of it is readily applicable to secondary use over a broad spectrum of public needs and conveniences.

Through its Congressionally-mandated Technology Utilization Program, NASA seeks to promote wider use of this technological resource. The program provides a link between the technology bank and those in either the private or public sectors who might be able to re-use the technology productively. Its aim is to accelerate the transfer process, to bring to the marketplace sooner those spinoffs which might eventually occur in the normal course of events, and to gain thereby more immediate economic benefit in terms of new products and new jobs.

The program has been remarkably successful. Since its inception 17 years ago, thousands of spinoff products and processes have emerged. Some of these innovations bring only moderate increments of economic gain or lifestyle improvement, but many others amount to significant public benefits, with economic values often running to millions of dollars. Collectively, spinoffs provide a substantial bonus return on the funds invested in aerospace research.

This publication is intended to increase public awareness of the resource that is NASA's technology bank and its potential for further public benefit. It is devoted primarily to the NASA technology transfer process, but in the interests of perspective it also describes related areas of NASA endeavor.

Section 1 consists of a résumé of NASA's current mainline programs. These programs are producing *direct* public benefit through direct application of technology; at the same time, they are contributing to *indirect* benefit—spinoff—by generating new technology which may find secondary application in the future.

Section 2 is the focal point of this volume. It contains a representative sampling of spinoff products and processes employed in various avenues of everyday life, and it describes briefly the NASA technology from which these transfers derived.

Section 3 details the mechanisms of the technology transfer process, including the means by which NASA seeks to stimulate technology utilization. Also described are NASA's activities in a related area of technology transfer: provision of assistance to agencies interested in exploiting the benefit potential of satellite remote sensing technology.

Floyd I. Roberson, *Director*

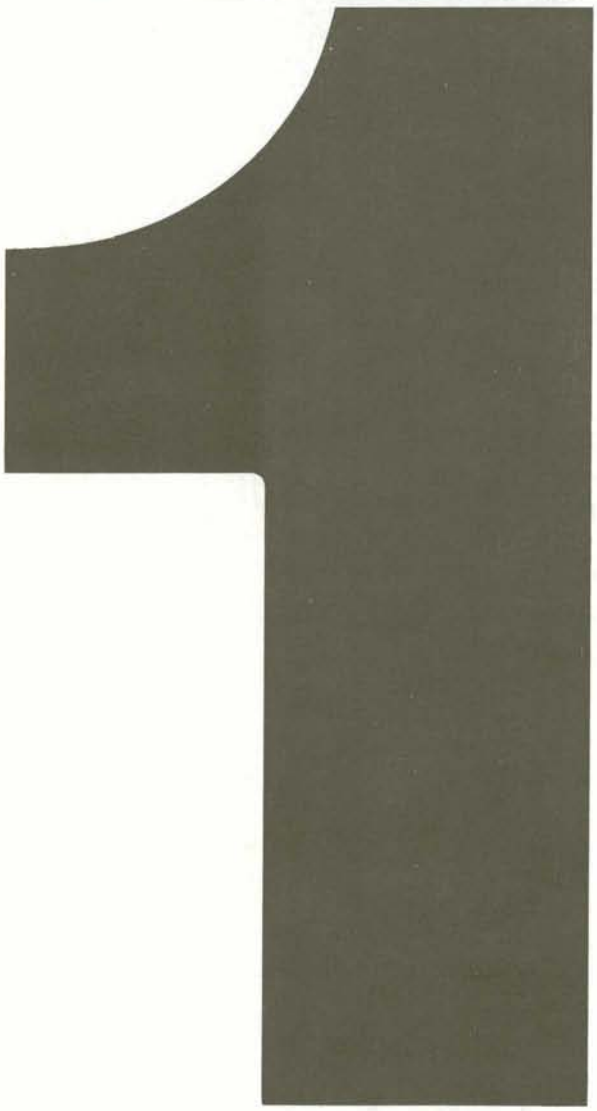
Technology Transfer Division
Office of Space and
Terrestrial Applications
National Aeronautics and
Space Administration

February 1979

Spinoff 1979 An Annual Report

Aerospace Aims

An illustrated summary of NASA's major aeronautical and space research programs, which are broadening human knowledge, expanding the American technology base, and contributing direct benefits to mankind



Soon to debut, NASA's Space Transportation System affords broader opportunity for exploiting the promise of space

Space Shuttle:

This year the U.S. space program marks its 21st anniversary, a milestone traditionally associated with the dawning of maturity. Appropriately, the American space effort is approaching an era of maturity, a time of expanding capability to do useful work in space and widen the spectrum of Earth benefits.

The key to greater usefulness in space is NASA's Space Transportation System, the principal element of which is the Space Shuttle. More than seven years in development, the Shuttle is now undergoing final ground testing preparatory to first orbital flights.

A giant step in technology advancement, the Shuttle differs from previous space vehicles in that its two principal elements—the manned Orbiter and the solid rockets which boost it—are reusable. Repetitive use of the equipment, coupled with new supporting facilities, makes access to space a matter of routine. The Orbiter can fly into space, operate as a satellite delivery vehicle or as a human-staffed laboratory, return to an Earth landing and be readied for another trip in two weeks. Such operational regularity will enable the initially-planned fleet of four Orbiters to spacelift a far greater number of payloads annually, significantly elevating NASA's capability for scientific investigation and benefit-quest.

Of equal importance is the economy afforded by the Shuttle system. Economy takes several forms. Re-use of both the Orbiter and its boosters will virtually eliminate one-shot launch vehicles. Because the Orbiter lands aircraft-fashion on a runway, the expensive sea fleets formerly employed for recovery of manned spacecraft will no longer be needed. Additionally, the Orbiter makes it possible to service satel-

Keystone of A New Era

lites in orbit or to bring them back to Earth for rework, thus extending their useful lives; that represents large-scale savings in replacement costs. These multiple cost reductions allow greater use of available funding for beneficial work in space.

Another important aspect of the Space Shuttle is its flexibility, its ability to perform many different tasks, including some never before accomplished. From bases on either coast, it can deposit satellites in any desired orbit. It can also serve as an orbital launch facility to send interplanetary spacecraft into deep space trajectories. It can make a short trip to orbit when indicated, or it can stay aloft as long as 30 days when requirements so dictate.

A particularly interesting feature of the Shuttle is its ability to serve as a space construction base. This opens up an entirely new realm of space potential: erection of large structures in orbit to serve important Earth needs. Among examples under consideration are huge antennas for far-reaching advancement of communications technology; habitable facilities for manufacture of certain items better produced in the gravity-free environment; and space-based power stations for trapping the sun's energy and converting it to Earth-use electricity.

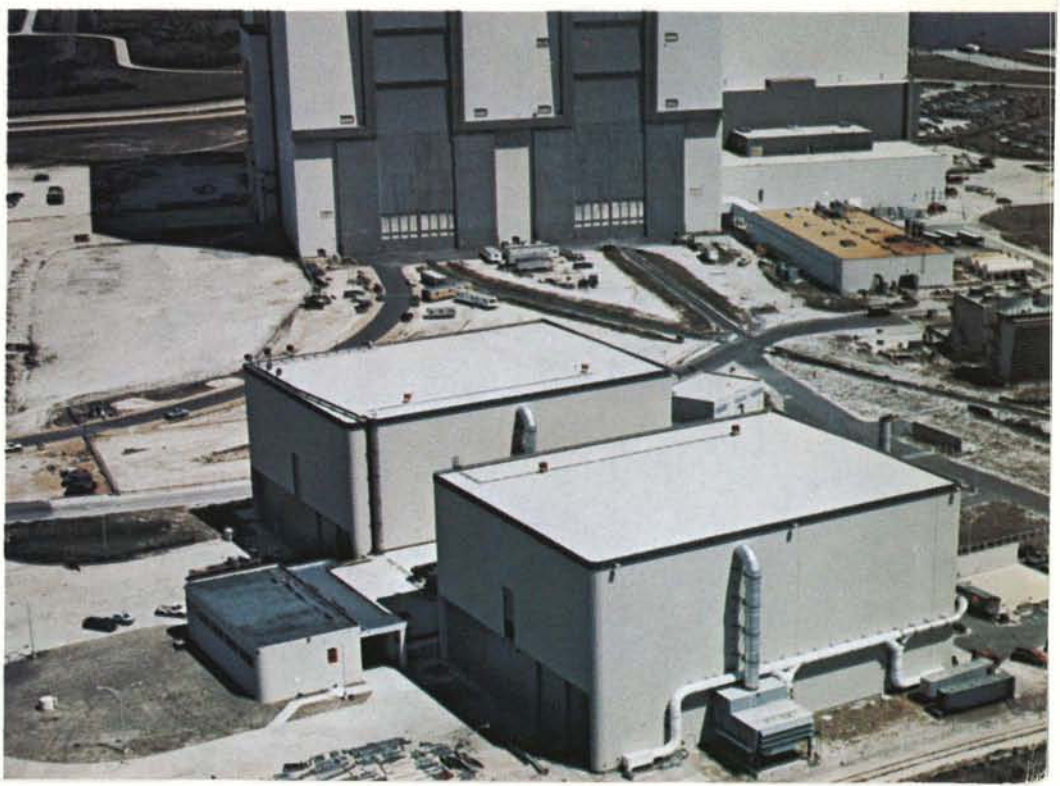
The first 21 years of American space flight were dramatically eventful and highly productive. With the Shuttle's wide range of capabilities, the remaining 21 years of this century hold even greater promise for bounty from space.

Spaceport East

Once the site of Apollo launches, Kennedy Space Center in Florida has undergone facelifting to accommodate Space Shuttle operations. In left photo, the huge central structure is the assembly building where the Shuttle Orbiter, its large external fuel tank and two solid rocket boosters are readied for flight. After these main elements are mated together atop a mobile launcher, the complete system—Shuttle and launcher—is trundled to the launch pad by a massive tracked transporter. Prelaunch checkout and blastoff is controlled by automated equipment in the launch center, situated to the right of the tall assembly building; final countdown takes only two and a half hours, compared with 28 for Apollo missions. After its trip into space, the Orbiter returns to land on the 15,000-foot runway visible at upper left. Initial Shuttle flights will operate from Kennedy Space Center; a similar West Coast spaceport is planned at Vandenberg Air Force Base, California.

Ground Turnaround

Back from a space mission, the Orbiter is towed to this Orbiter Processing Facility adjacent to the assembly building. Here, in a "clean room" environment, the spacecraft is first "safed" by removal of leftover fuel and disconnection of explosive actuating devices. Then the Orbiter's various components are inspected, serviced and refurbished. With new payloads installed, the Orbiter is towed to the assembly building to start anew the prelaunch cycle of mating, checkout and fueling. Turnaround time, from landing to relaunch, is only two weeks.



Vibration Tests

Shuttle components have been undergoing a variety of ground tests as a prelude to flight. In left photo, the Orbiter is being lowered into a 36-story vibration test facility at NASA's Marshall Space Flight Center, Huntsville, Alabama, for joining with the already-installed external fuel tank. Suspended from a large overhead truss, the mated vehicle was subjected to vibrations applied by computer-directed "exciters." Sensors recorded the characteristics of the vibrations as they passed from one area of the vehicle to another. Several months of such testing verified the Shuttle's control system design by predicting how it will react to the severe vibrations expected during launch and flight to orbit.

Orbiter Fleet

The initial fleet of Shuttle Orbiters will consist of four spacecraft, named for sea vessels of earlier days which were engaged in world exploration. First to fly in space will be the *Columbia;* subsequent Orbiters will be named *Challenger, Discovery* and *Atlantis.* The original Orbiter, the *Enterprise* shown below, is a test vehicle not equipped for orbital flight; it was used for approach and landing tests in 1977 and for vibration testing in 1978.

Booster Recovery

To confirm recoverability of the two solid rocket boosters, Marshall Space Flight Center conducted a series of tests at the National Parachute Test Range in California. Test versions of the boosters were dropped from aircraft to check the performance of the systems that will be used to return the big rockets to Earth. On a Shuttle mission, the boosters burn for about two minutes, providing more than five million pounds thrust for launch. After burnout, they are lowered to the ocean by three main parachutes. Designed to float on the surface, they are ship-recovered and towed to port for refurbishing and reuse.

Engine Tests

At NASA's National Space Technology Laboratories, Bay St. Louis, Mississippi, engineers put the Orbiter's liquid propellant main engines through several months of firing tests (photo at right). Beginning with a one-second ignition, test duration was gradually increased up to eight minutes operation at full thrust, the time the propulsion system will burn on an actual mission. The three-engine cluster produces 1.4 million pounds of thrust to supplement the boost power of the solid rockets during the ascent phase of a Shuttle flight. A separate system of smaller engines provides thrust for orbit insertion and maneuvering in space.

Manipulator Testing

Shown undergoing test in the photo below is a key component of the Shuttle Orbiter known as the Remote Manipulator System. Controlled by an operator on the Orbiter's flight deck, the 50-foot triple-jointed arm is used to extract payloads from the Orbiter's cargo bay and maneuver them in space a safe distance from the Orbiter. It is similarly employed on missions involving the servicing of orbiting satellites; the manipulator grasps the satellite and stows it in the cargo bay for on-the-spot servicing or return to Earth for refurbishment. The system is built by a Canadian industrial team under the direction of the National Research Council of Canada.

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Thermal Tiles

These photos illustrate the remarkable insulating qualities of the material which protects the Orbiter from searing re-entry heat that may reach 2,300 degrees Fahrenheit. In the left view, a technician is holding in his bare hand a "thermal tile" only seconds after its removal from the white-hot oven shown. The center of the tile still glows from the oven heat of more than 2,000 degrees, but the surface is cool to the touch. The secret is a specially-developed silica fiber insulating material in which surface heat dissipates very rapidly while heat transfer from the inside is extremely slow. The right-hand photo, taken moments later, shows how quickly heat is cast off; the tile has already lost its glow. The reusable nature of the Orbiter dictated use of this material. In earlier manned spacecraft, heat shields were made of material that literally burned away; the burning dissipated heat energy but the shield was good for only a single flight. The new material, called LI-900, can withstand repeated heating and cooling without need for replacement. LI-900 is installed on the Orbiter in individual tiles produced in thousands of shapes and sizes to fit the spacecraft's contours; it takes 34,000 of them to cover the exterior sections which must be protected—the underside and portions of the upper wings, fuselage and tail.

New Astronauts

For the faster tempo of space operations in the Shuttle era, NASA is augmenting its astronaut corps. From some 8,000 applicants, NASA selected 35 new astronaut candidates, including the first six women chosen for space training. Some of the candidates are pictured here. Below, three of the newcomers take a break from familiarization training in the Space Shuttle mockup at Johnson Space Center; below right, one of the female candidates undergoes a physical examination; below left, another of the candidates is participating in water survival training. Last July the candidates embarked upon an intensive two-year training program, at the conclusion of which they will become full-fledged astronauts. Fifteen of the group will be trained as pilot astronauts, the others as mission specialists. The latter are scientists and engineers who handle the multiple tasks associated with conducting experiments, deploying and retrieving payloads in Shuttle operations.

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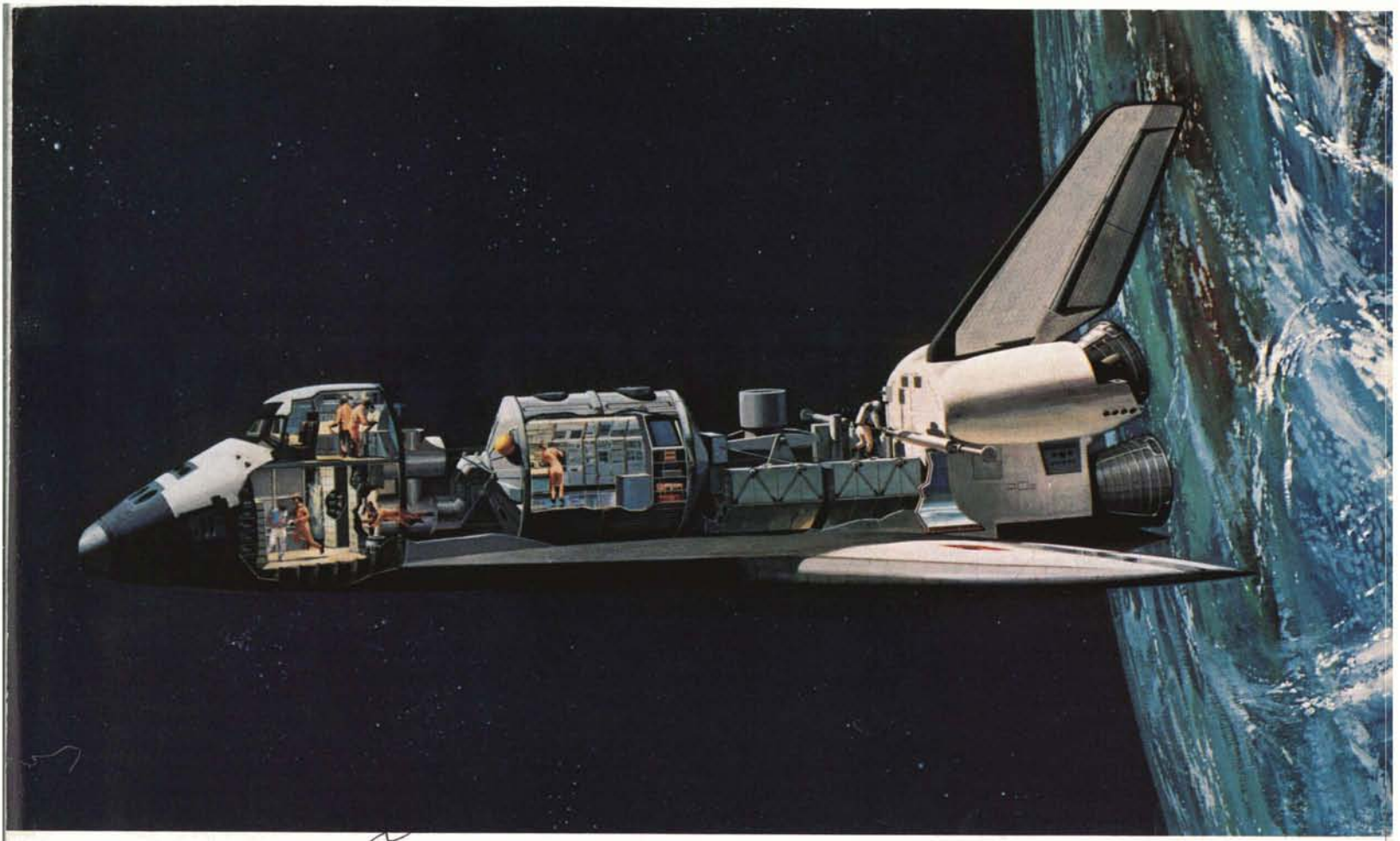


Shuttle Payloads

The Space Shuttle will accommodate a variety of payloads, among them the Spacelab pictured. Being developed by the European Space Agency, Spacelab is a pressurized laboratory module which fits into the Orbiter's cargo bay. It allows scientists to make observations and to conduct experiments in orbit, working in shirtsleeve environment for as long as 30 days. Other types of payloads include Earth-orbiting satellites, deep space probes for planetary exploration, and small experiment packages called "getaway specials," which permit schools, universities, industry and private organizations to conduct their own specialized space research at low cost. Space station segments built on Earth can be Shuttle delivered and joined in orbit to create a human-habitable facility for long-duration scientific research, Earth surveys or manufacturing in space. Long range plans contemplate erection in orbit of very large platforms, for example, a space-based solar power station capable of harnessing the sun's energy for conversion to Earth-use electricity. Such platforms could be assembled from Shuttle payloads of compactly-packaged foldable beams, unfolded in orbit and mated together to form a structure of any desired size.

NASA aeronautical research is providing new technology for coming generations of better performing, more efficient aircraft

Flight Plan for

Air traffic is soaring. Last year U.S. airlines set an all-time record for passengers carried, but that was only an interim peak in a new upward spiral. Estimates indicate that air passenger volume will almost double over the next decade. The national air transportation system could be faced with a major problem—airport congestion.

One of several approaches to relieving that problem is diverting short-haul traffic to advanced vehicles capable of operating at separate, smaller airports. Research and technology development is under way at NASA on powered lift, short takeoff and landing (STOL) aircraft capable of operating quietly from runways measuring 1,500 to 4,000 feet, compared with the two miles or more needed by long-haul jetliners.

Undergoing flight test at NASA's Ames Research Center, the NASA Quiet Short-haul Research Aircraft (QSRA) is not a prototype airliner but an experimental craft designed to demonstrate several new NASA-developed technologies that may hasten the operational debut of the STOL passenger plane. Chief among these innovations is the use of propulsive lift, whereby the exhaust from the engines is deflected over the wing surface to increase lift, permitting the QSRA to climb and descend at steep angles, fly safely at very low speeds, and use extremely short runway lengths for takeoff and landing. Additionally, and perhaps more importantly to the general public, the QSRA employs noise reduction techniques that make it the quietest jet aircraft ever flown. Concurrently, other NASA projects are devoted to the "clean and quiet" aspects of future flight, in some cases specifically for short-haul craft and in others for all types of airplanes.

QSRA and related projects exemplify NASA's multifaceted program of aeronautical research. In these instances, NASA is simultaneously addressing two major problem areas: one seeks an answer to a predicted future difficulty—airport congestion—while the other looks for solutions to a current problem through improvement of airplanes' environmental characteristics. Generally, that sums up NASA's two main fields of aeronautical research: 1) anticipating the needs of future flight and developing applicable technology, and 2) providing new technology to resolve today's aviation problems.

A principal focus of NASA's work is on cutting aircraft fuel consumption, a matter of great importance not only to commercial operators and ticket buyers, but to the nation as a whole. Other areas of investigation include research on airfoils to improve aircraft performance, new technologies for the vast fleet of general aviation planes, and development of new types of helicopter rotor systems. Looking further into the future, NASA

Tomorrow

is exploring such potential developments as vertical takeoff and landing (VTOL) aircraft, military aircraft of extraordinary maneuverability, advanced supersonic cruise aircraft, and study concepts for the hypersonic aircraft of the next century.

Additionally, NASA is conducting a variety of investigations aimed at improving safety for all airplanes, for example, research on atmospheric phenomena as they affect flight safety, fire-resistant materials, collision avoidance, better airplane structures for improved crashworthiness, and accident reduction through an incident reporting system which helps identify hazardous conditions amenable to correction.

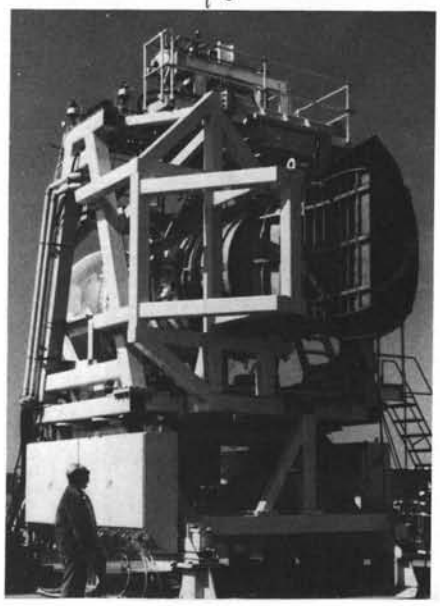
NASA's aeronautical research provides direct benefit in several forms. It helps American plane manufacturers produce better planes, vitally important today when the U.S. industry faces greater-than-ever competition from abroad; sales of U.S. aircraft, especially export sales, substantially benefit the national economy. NASA's work also helps reduce airline operating costs, to the benefit of passengers, shippers, and operators; it makes flight safer for all who fly; and it benefits everyone through its contributions to quieter flight and reduced pollution.

Quiet Jet

The experimental craft shown at left is NASA's Quiet Short-haul Research Aircraft (QSRA), which seeks answers to two major aviation problems—aircraft noise and predicted future airport congestion. The vehicle incorporates several noise reduction techniques, not only in the engines but also in aerodynamic design. QSRA employs NASA-developed propulsive-lift technology designed to enable operations from short runways to relieve airport traffic congestion.

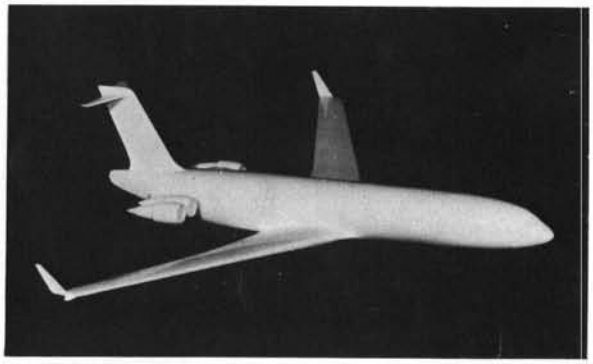
Clean, Quiet Engines

In a program known as QCSEE—for Quiet, Clean Short-haul Experimental Engine—NASA's Lewis Research Center is testing two research engines which promise major reductions in noise and air pollution. Tests in ground facilities like the one pictured below show that the 40,000-pound-thrust powerplants run eight to 12 decibels quieter than the quietest engine in civil transport service, a noise reduction of 60 to 75 percent. New technology also sharply reduces emissions of the two most troublesome air contaminants. Carbon monoxide would be reduced more than 80 percent, unburned hydrocarbons by 97-98 percent. One version of QCSEE is conventionally mounted under the airplane wing, the other, a departure from the norm, is designed for placement above the wing. In either mounting, engine exhaust is directed downward by the wing flaps to provide added aircraft lift for short runway operating capability. QCSEE technology development is directed toward short-haul aircraft (300-500 miles range), but the technology can also be applied to engines for larger commercial jetliners.



Fuel Saving Research

NASA's top priority aeronautical research program seeks sharp reductions in aircraft fuel consumption. In addition to serving the national aim of conserving energy, this program offers benefit to airplane operators in reduced operating costs, to air travelers and shippers in lower fares and cargo rates, and to the nation's foreign trade in enhanced attractiveness of American built planes in the international market. The Aircraft Energy Efficiency (ACEE) program addresses several ways of saving fuel, one of them exemplified by the model



shown, which has an advanced wing and "winglets"; these and other aerodynamic improvements reduce air resistance and cut fuel expenditure by easing the engine's workload. Lighter structures and new control systems similarly reduce fuel consumption. The engine itself, the fuel-burner, is the target of several investigations designed to promote significantly improved fuel efficiency; this research offers corollary benefit in noise reduction and cleaner engine exhausts.

17

HiMAT

This uniquely-shaped airplane offers a preview of what tomorrow's high-speed military aircraft may look like. It is one of two unmanned test vehicles to be used in the NASA/Air Force Highly Maneuverable Aircraft Technology (HiMAT) program, in which a number of advanced technologies for military planes of the 1990s are being tested. Being readied for initial flights this year, HiMAT uses both its primary wing and the small forward wing to attain exceptional maneuverability; it can make very tight turns at supersonic or near-supersonic speeds and it has twice the turning capability of the most maneuverable fighter in service today. The craft is designed in modular fashion so that wings, engine inlet and other components can be changed to investigate a variety of different configurations. In flight tests, HiMAT will be air-dropped from a B-52 carrier aircraft, then controlled by a pilot in a ground-based cockpit. This NASA-developed remotely-piloted research concept permits high-risk testing without hazard to the pilot; it also reduces the cost of the test vehicle.

Winged Helicopter

The interesting craft pictured in the lower photos is a compound helicopter, a hybrid system which combines the helicopter's vertical flight characteristics with the greater forward speed of the fixed-wing airplane. Vertical lift is provided by the five-bladed rotor, which is driven by two turbine engines; the wing adds lift for forward flight and two auxiliary turbofan engines boost forward speed. The vehicle is the Rotor Systems Research Aircraft, (RSRA) one of two in a NASA/Army research program. Heavily instrumented flying laboratories, they operate with or without wings and can accommodate a variety of different rotor systems at reduced cost. The two RSRAs are part of an expanding program in which NASA is investigating a number of promising rotorcraft concepts with future commercial or military potential.

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Convertible Flight

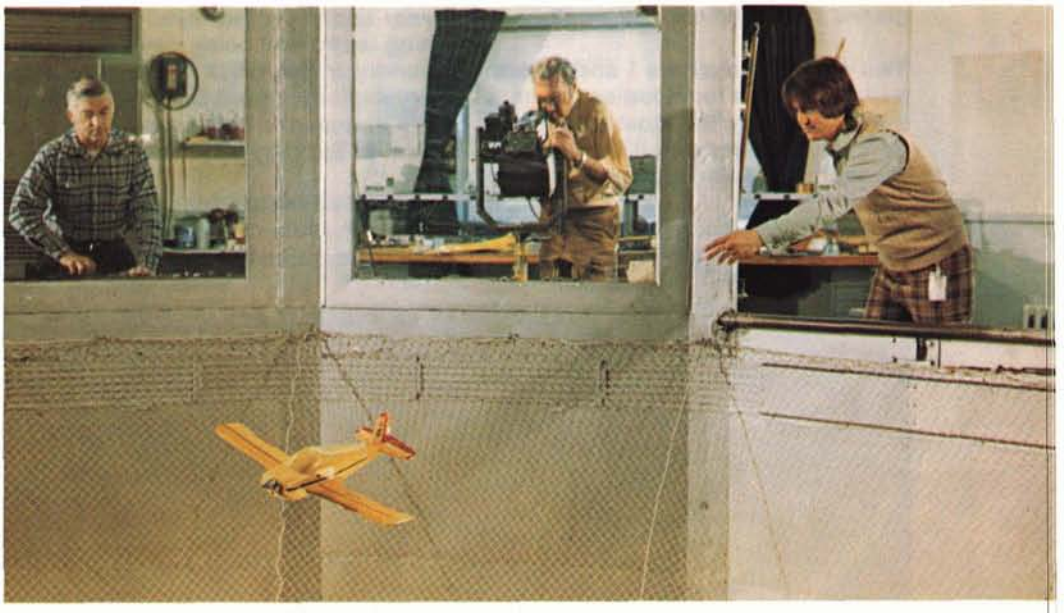
The tilting rotor concept of flight offers potential utility for future short-haul air transportation with lower aircraft noise levels and reduced congestion at civil airports. In a joint program with the U.S. Army, NASA is investigating the concept in research flights of the XV-15 Tilt Rotor Research Aircraft pictured. The craft's helicopter-like rotors permit the XV-15 to take off and land vertically. Once airborne, the rotors tilt forward for cruise flight at about 400 miles per hour.

21

#28

Lightplane Research

In the photo at right, NASA researchers are testing model airplanes in a special spin tunnel to study the characteristics of accident-causing stalls and spins, in order to develop means of preventing them; additional stall/spin data is being acquired in wind tunnels, simulators, and flight tests. This effort is one facet of a broad program devoted to new technology for general aviation, meaning all planes other than commercial airliners and military aircraft. Improved safety is a primary goal. Other work focuses on greater airplane efficiency through development of new wings and auxiliary airfoils, advanced aviation electronic equipment, small turbine engines for types of aircraft currently propeller-driven, and ways of reducing fuel burn, noise, and exhaust emissions.



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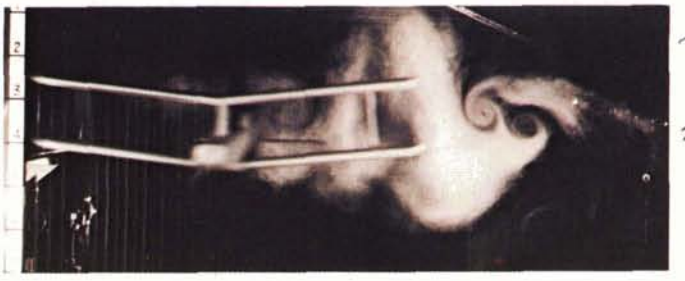
#29

Agricultural Airplane Research

These views of a model airplane flying through a gas cloud illustrate the normally invisible wake of an agricultural airplane. Photos like these help researchers determine the effect of aircraft wake on crop dusting and spraying. The tests are part of a program at NASA's Langley Research Center, Hampton, Virginia, aimed at assuring more uniform distribution of air-dispersed agricultural chemicals and preventing their wasteful drift outside of the target area. From more information on dispersal patterns and aircraft wake effect, researchers hope to develop better dispersal systems and to modify wake characteristics by means of aerodynamic changes.



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#30

NASA space scientists are learning more about Earth by exploring other parts of the universe

To the Planets

This year is a particularly active one for exploration of the planets by American spacecraft.

One, called Pioneer Venus, is orbiting Venus and conducting the first detailed survey of the neighbor planet's atmosphere and weather.

Two others—Voyagers 1 and 2—are nearing Jupiter for close encounters that will provide the most extensive data yet obtained about the largest planet in our solar system.

Pioneer 11, which departed Earth six years ago, will reach the vicinity of Saturn this September and make the first detailed reconnaissance of the ringed planet.

Meanwhile, on Earth, scientists are analyzing a wealth of data about Mars gathered over a two and a half year span by a four-spacecraft Viking team. And being developed for service in the 1980s is a new planetary explorer called Galileo, which will amplify the knowledge of Jupiter sent to Earth by Voyagers 1 and 2.

These automated spacecraft, some of which roam more than a billion miles from Earth in quest of scientific information, are monumental triumphs of man's ingenuity. Their feats of exploration are fascinating. But, the question is often asked, of what practical use are they? Why do we want to learn about Venus' atmosphere, or Jupiter's Great Red Spot, or the mysterious rings of Saturn?

The answer is that NASA is exploring the planets to learn more about Earth. "Comparative planetology," it is called; it means relating phenomena on one planet to conditions on another. Study of the planets is providing volumes of comparative data that may in time

and Beyond

enable us to understand better the complex physical processes that govern Earth—and perhaps to manage them to man's advantage. Take weather, for example. The basic causes of Earth's weather patterns are not clearly understood. Earth's atmosphere is difficult to study because of a number of complicating factors such as the mixing of ocean and continental air masses, cloud cover, the tilt to Earth's axis and our planet's rapid rotation, once every 24 hours.

But Venus is easier to study; it has a basic atmosphere, no oceans, virtually no axial tilt and it takes 243 Earth days to make a single rotation. If scientists can learn how Venus' variables affect Venus weather, they may be able to define more clearly how Earth's more complex variables impact our weather. Similarly, close-up studies of Mars' largely cloudless atmosphere, Jupiter's rapidly-spinning atmosphere, and the violently turbulent storm systems of both Jupiter and Saturn will provide further insight into Earth weather processes and perhaps hasten the day when man can "do something about the weather."

Comparative planetology is an important part of NASA's comprehensive space science program, but only a part. Our solar system, though enormous in dimension, represents only a tiny corner of the vastness we call the universe. That—the whole universe—is NASA's cosmic laboratory. In addition to planetary spacecraft, space scientists are employing a variety of other research tools—Earth satellites, space-based telescopes, instrumented sounding rockets, aircraft and balloons, ground-based optical and radio telescopes—in a sweeping study of space phenomena.

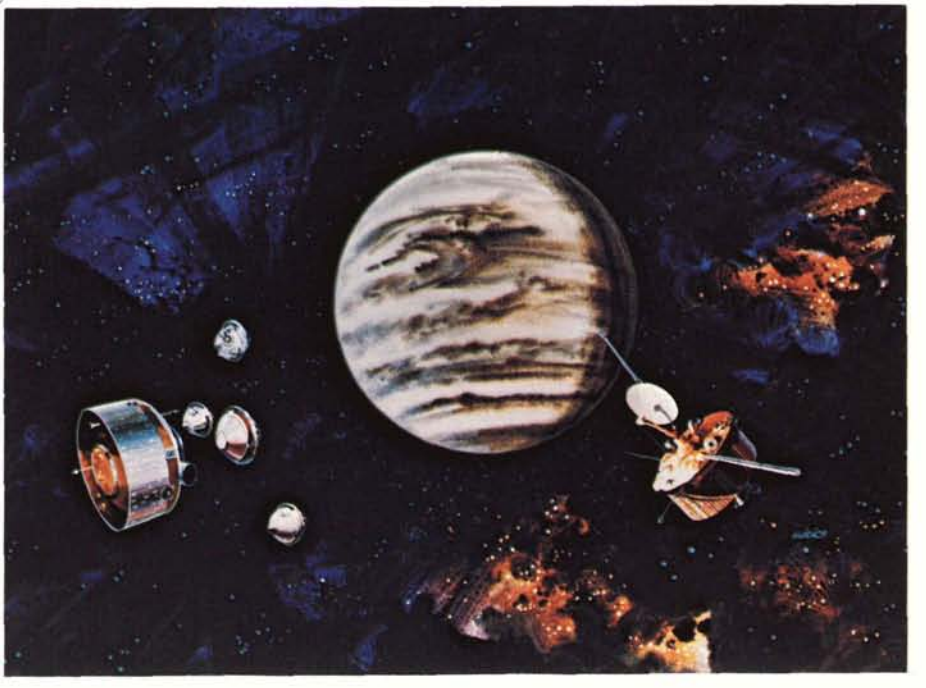
The underlying aim of all this effort is learning more about Earth by fitting our planet into the big picture that is the origin, the history and the structure of the universe. Much of the knowledge acquired will not be readily translatable into public benefit. But much of it will, for science is the foundation of advancing technology, the informational base for practical applications.

Exploring Saturn

Six years out of home port Earth, Pioneer 11 will begin the first close-up investigation of Saturn in September (photo at left). A companion spacecraft, Pioneer 10, provided information about Jupiter and is now two billion miles from Earth on an endless journey out of the solar system. From these and other planetary explorers, NASA scientists are learning more about Earth by relating Earth conditions to those of the other planets of our solar system.

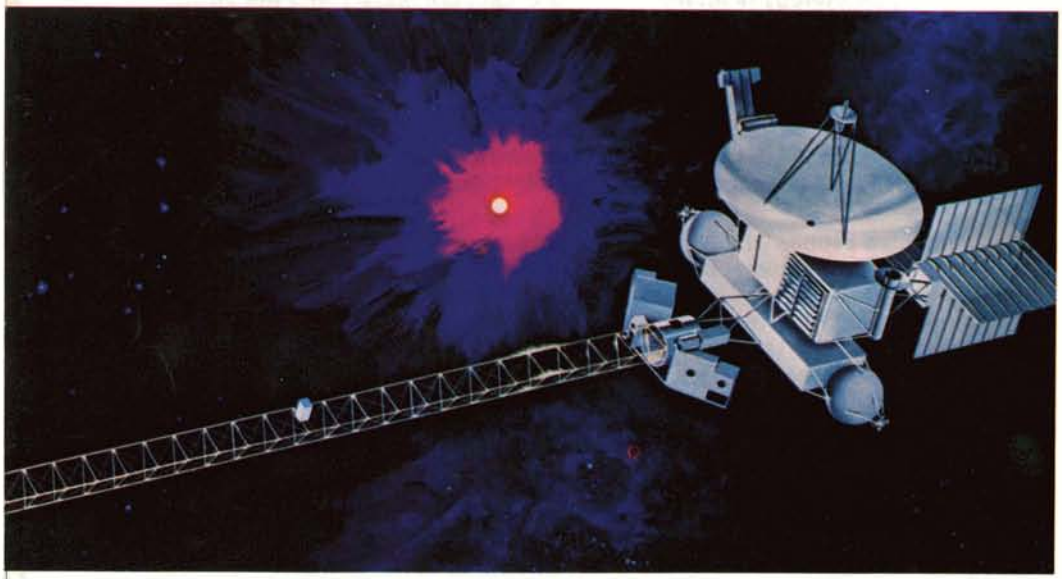
Pioneer Venus

This artist's conception shows the two members of NASA's Pioneer Venus spacecraft team. At right is Pioneer Venus 1, now orbiting around the cloudy neighbor planet and relaying data on Venus' atmosphere and weather. Its sister craft, Pioneer Venus 2, is shown as it separated into five instrumented probes which dropped to the planet's surface last December, measuring Venus' dense, searing atmosphere from top to bottom; they returned data for about an hour during the descent and were not designed to survive the landing impact. Venus rotates slowly and has no oceans. For these and other reasons, scientists feel the planet is an ideal place to investigate the mechanics of atmosphere. By studying Venus' relatively simple "weather machine," they hope to understand better the forces that influence Earth's more complex weather system.



Probing Jupiter

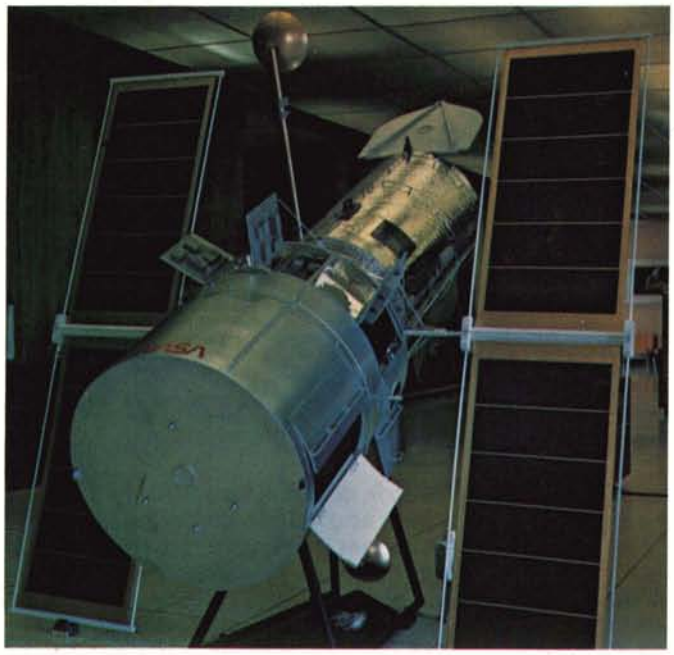
This photo of the planet Jupiter was taken from a distance of 17.5 million miles by the Voyager 1 spacecraft; it shows Jupiter's Great Red Spot and two of the planet's 13 moons, Io (right center) and Europa (far right). Hundreds of similar photos, together with a wealth of instrument-acquired scientific data, are being sent to Earth by two Voyagers engaged in an eight-month close-up study of the superplanet. The Voyagers' information is the most comprehensive yet obtained about Jupiter, but NASA plans further investigation of the largest planet in the solar system. To amplify the knowledge provided by the Voyagers, NASA is developing a new spacecraft to conduct a longer duration, more detailed examination of Jupiter; called Galileo for the father of astronomical study, it will be Shuttle-launched in 1981. Galileo consists of a main spacecraft and a separable instrumented probe. The probe will descend into the layers of gas and liquid that make up Jupiter's atmosphere and relay first-hand data on the planet's atmospheric composition and structure. The main spacecraft will swing into orbit around Jupiter and become a man-made moon. Circling repeatedly, it will study Jupiter's atmosphere, magnetic field, hurricanes and other phenomena. It will report continuously over a long period and from many different vantage points, thus vastly expanding the Voyagers' findings and filling in myriad informational gaps.



Solar Polar Mission

All the planets of the solar system revolve around the sun in the "ecliptic," an imaginary plane containing Earth's orbit about the sun and extending outward from the sun's equator. All the spacecraft ever launched have operated very close to this plane.

Consequently, there is a frontier of space still unexplored—space "out of the ecliptic," or the third dimension of space. In 1983, NASA and the European Space Agency will send a team of two spacecraft out of the ecliptic into paths that will take them over the poles of the sun rather than around its equator. The Solar Polar Mission spacecraft pictured at left will study the sun's corona, solar wind, cosmic rays and other phenomena in entirely new perspective. Their information is expected to provide better understanding of the solar forces that shape and control Earth's environment.



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Space Telescope

A program which has excited wide interest among the scientific community is NASA's Space Telescope, (right) a permanent astronomical observatory in the sky. This system will open a new door to the universe, making possible observations of celestial objects that have never been seen and permitting scientists to look back into time billions of years. With a telescope comparable to the larger Earth-based telescopes and an array of sophisticated supporting equipment, the system will view both the visible and ultraviolet light portions of the spectrum. The Space Telescope will be delivered to orbit in 1983 by the Space Shuttle and maintained thereafter by Shuttle crews, who will service it in space or bring it back to Earth for rework when necessary. The observatory's instrument bays are designed so that new and even more advanced instruments can be substituted as they are developed.

Airborne Observatory

In addition to spacecraft, NASA's space science program employs a variety of non-orbiting research vehicles such as instrumented sounding rockets, balloons and aircraft, which provide lower cost supplementary data. Shown at right is a unique observational platform which operates above 90 percent of Earth's atmosphere, a modified jet transport called the Kuiper Airborne Observatory. Equipped with a large telescope and other instrumentation, this system has produced a wealth of information, for example, the recent discovery of rings around the distant planet Uranus, which has not yet been visited by spacecraft. In photo, the large "window" atop the fuselage is a viewing port for the telescope.

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NASA's applications program promotes direct societal benefit from space and surface systems

Technology

In a growing and increasingly interdependent world, there exists a need for a global system to monitor and inventory the world's agricultural resources. In the United States, the Department of Agriculture has established a reliable and timely crop reporting system, but information about agricultural production in many of the world's important crop-growing areas is limited.

A possible answer to the global need is a system based on the emerging technology known as satellite remote sensing. Such a system could provide accurate advance information on regional, national and global crop yield and serve as an aid to planning distribution. It could advise which nations would produce surplus crops and which would experience shortfall—signposts for international agricultural trade. It could provide early warning of impending crop failure due to blight, drought or excessive rain. It could facilitate land-use planning and serve a variety of other land management needs.

A worldwide operational system is years in the future, but a large-scale, three-year experimental project completed last year demonstrated that remote sensing offers potential for better management of global food resources. Called LACIE, for Large Area Crop Inventory Experiment, the project involved use of NASA's Landsat satellites, coupled with data from other sources, to predict production of the world's most important grain crop—wheat. LACIE participants, in addition to NASA, included the Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA) and a number of university and industrial research groups.

The basis for the LACIE experiment is the fact that different types of vegetation reflect light or emit radiation in different bands of the spectrum and in different intensities. Landsat's sensitive radiation detectors can tell the difference; they supply digital data which is computer-processed to create images that show various crops in various colors, or "signatures." For LACIE, wheat was selected as the commodity for investigation because of its great importance in trade and nutrition.

NASA's Landsat satellites, constantly scanning Earth's agricultural regions, provided electronic imagery on which to base wheat predictions. Landsat data was combined with weather information from NOAA's operational satellites, with surface observations from some 8,000 worldwide weather stations, and with comparison data on weather and crop yield in previous years. Processed by ground computers, this flow of information enabled timely predictions of wheat area, yield and production, and it also provided early warning of problems influencing wheat yield. Focal point of the experiment was the Great Plains area of the United States, used to evaluate LACIE information because it represented the best source of statistical data with known reliability. The major foreign study areas were Canada and the Soviet Union; preliminary examinations were conducted for Argentina, Australia, Brazil, China and India.

When the multiple-input technique was used to monitor the 1977 Soviet wheat crop, LACIE produced an early season estimate within one percent of official Soviet figures. In the U.S. northern Great Plains and Canada, where long narrow fields are difficult to distinguish and where wheat can easily be confused with other crops, the accuracy goal of 10 percent was not achieved. Importantly, however, LACIE made a contribution by identifying what technological improvements are needed to meet the goal. Future satellites with better resolution should be able to survey smaller crop areas with accuracies similar to that achieved in surveying the Soviet Union, where fields are typically large. A LACIE evaluation group cited the need for technology improvement but concluded that "remote sensing capabilities can be combined with or substituted for conventional methods of information collection in order to improve foreign crop production estimates."

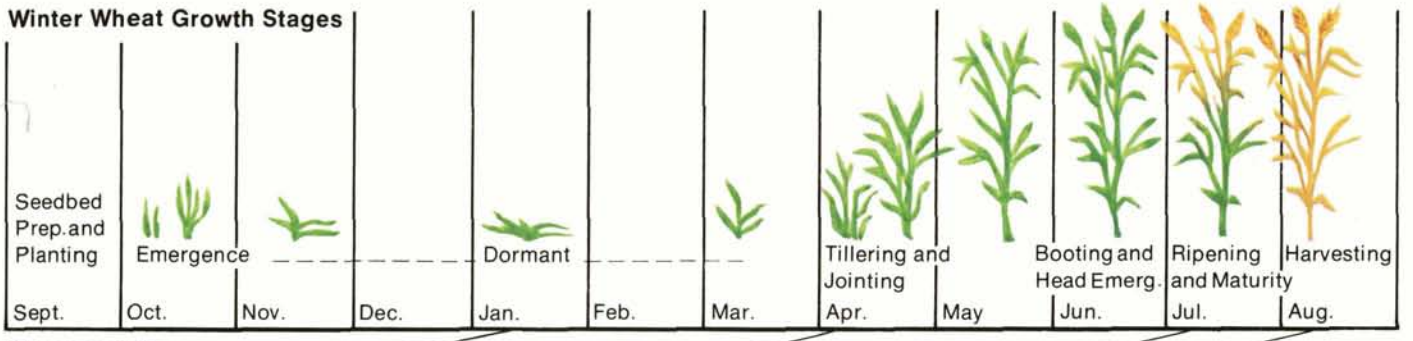
The LACIE project exemplifies NASA's broad applications program, wherein aerospace technology is being put to work to produce direct public benefit. The principal focus of the applications effort is on developing better means for managing Earth's environment and resources through satellite surveys.

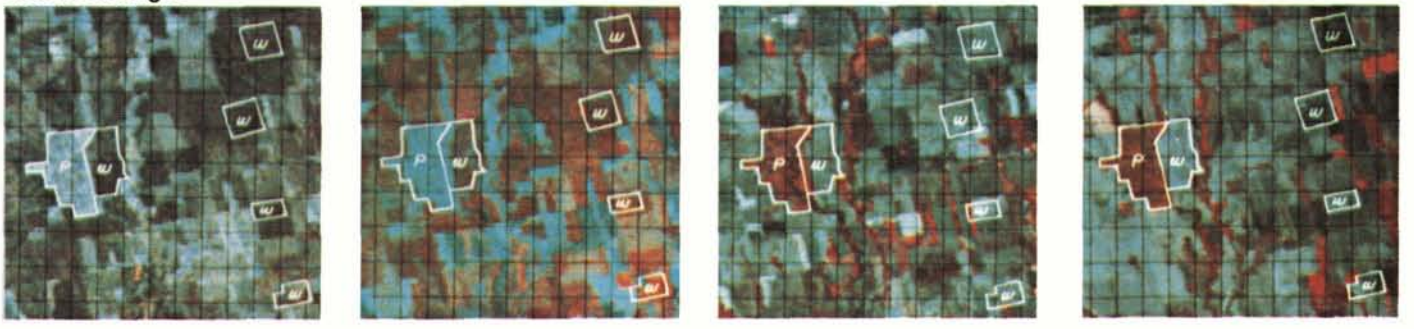
NASA's primary Earth-monitoring tool is Landsat, which has several advantages over other survey methods. Its cost per square mile is far less than that of aerial photography. A single Landsat can cover almost the entire planet every 18 days, and in a contemplated operational system multiple satellites could increase the frequency of survey. Additionally, Landsat produces information on features invisible to the human eye and features too vast to be encompassed in an aerial photo.

These capabilities offer a wide range of beneficial applications. To mention just a few examples other than agriculture where Landsat has already demonstrated its efficacy, the benefit spectrum embraces water management; geological study for earthquake prediction; flood damage assessment and prevention; land use mapping; urban planning; oil and mineral exploration; pollution monitoring; and forestry studies.

for Public Needs

NASA's applications program includes a number of other spacecraft, for example, satellites for improved public service communications, advanced weather reporting systems, environment monitors and climatic research systems. In addition, NASA is conducting a number of non-space applications projects designed to solve problems or meet specific civil needs through development of ground-based or aircraft-borne systems. NASA's applications effort has produced important dividends to the nation and it promises even greater direct benefits in the not-distant future.





Crop Inventory

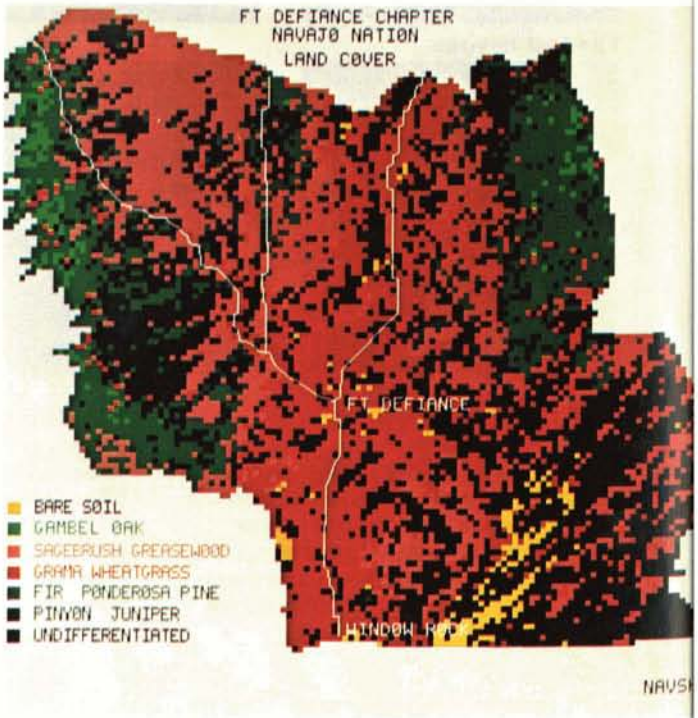
The use of satellite imagery as an aid to estimating wheat production in the world's major growing areas was investigated in a three-year project known as the Large Area Crop Inventory Experiment (LACIE). The above illustration shows how repetitive images provided by NASA's Landsat satellites traced a winter wheat crop from dormancy to harvest. In the images along the bottom row, wheat shows up in a certain color, or "signature" (areas marked W); for contrast, pasture land is indicated by P. Thousands of images like these, coupled with data from other sources, enabled analysts to predict wheat crop area, yield and production.

Landsat

One of the most important practical application systems to emerge from the space program, the Landsat Earth-survey satellite offers sweeping possibilities for direct Earth benefit. The satellite's instruments acquire Earth resources data in digital form. Computer-processed on Earth, the information is translated into images—electronic pictures—which have enormous potential for economic and social gain through better management of the planet's resources. Landsat 3 (shown) is an advanced member of the satellite family with substantially improved information-gathering capability. Launched last year, it joined Landsat 2 which has been in operational service for four years. In development and planned for service beginning in 1981 is Landsat-D, an even more advanced satellite which will significantly increase the capability of the Earth resources monitoring system. The two currently active satellites cover the entire globe every nine days, their sensors detecting changing Earth conditions and providing large-scale perspective of Earth features. The most important potential uses of Landsat data correspond to the major problems confronting Earth's peoples: energy supply, food production and control of the global environment. Some examples of Landsat utility in these and other areas are briefed in the following pages.

Navajo Nation Inventory

The illustration below is a land cover map of timber resources and other vegetation in an area of the Navajo nation around Fort Defiance and Window Rock, Arizona. Maps like this, prepared from digital data supplied by NASA's Landsat satellites, are being used to inventory the natural resources of the 16 million acre Navajo reservation in Arizona, New Mexico and Utah. NASA and the Navajo Tribal Council are working jointly on a project to establish a Landsat-based automated resource inventory system for improved use and management of Navajo land. Emphasis is being placed on high priority activities, such as range rehabilitation, timber and wildlife inventory, assessment of crop areas and prediction of harvests. In the initial phase of the project, NASA demonstrated how Landsat data can be applied to specific Navajo needs and how satellite information enables continual updating of resources changes. In the second phase, NASA is training Navajo personnel and helping to set up an operational system at Navajo Nation Headquarters, Window Rock. The Navajos will apply their experience to assist other Indian tribes in realizing Landsat benefits.



Georgia Landsat Use

The State of Georgia has established a statewide Landsat program, managed by the Georgia Department of Natural Resources and supported by a Landsat data facility at Georgia Institute of Technology. This computer-processed land cover map of the Georgia wetlands, prepared by the Earth Resources Laboratory of NASA's National Space Technology Laboratories in conjunction with Georgia authorities, shows the broad range of information available to state planners (see legend). For example, maps like this permit accurate measurement of the irregular coastline and assessment of shoreline erosion, information necessary to the allocation of funds under federal coastal zone management legislation. Landsat data allows updated delineation of coastal wetlands, which change rapidly; it helps determine the limits of tidal waters; and it provides information relative to protection of shellfish, vital to the state's economy. Georgia also uses Landsat data for determining freshwater resources, environmental planning and land use inventory.

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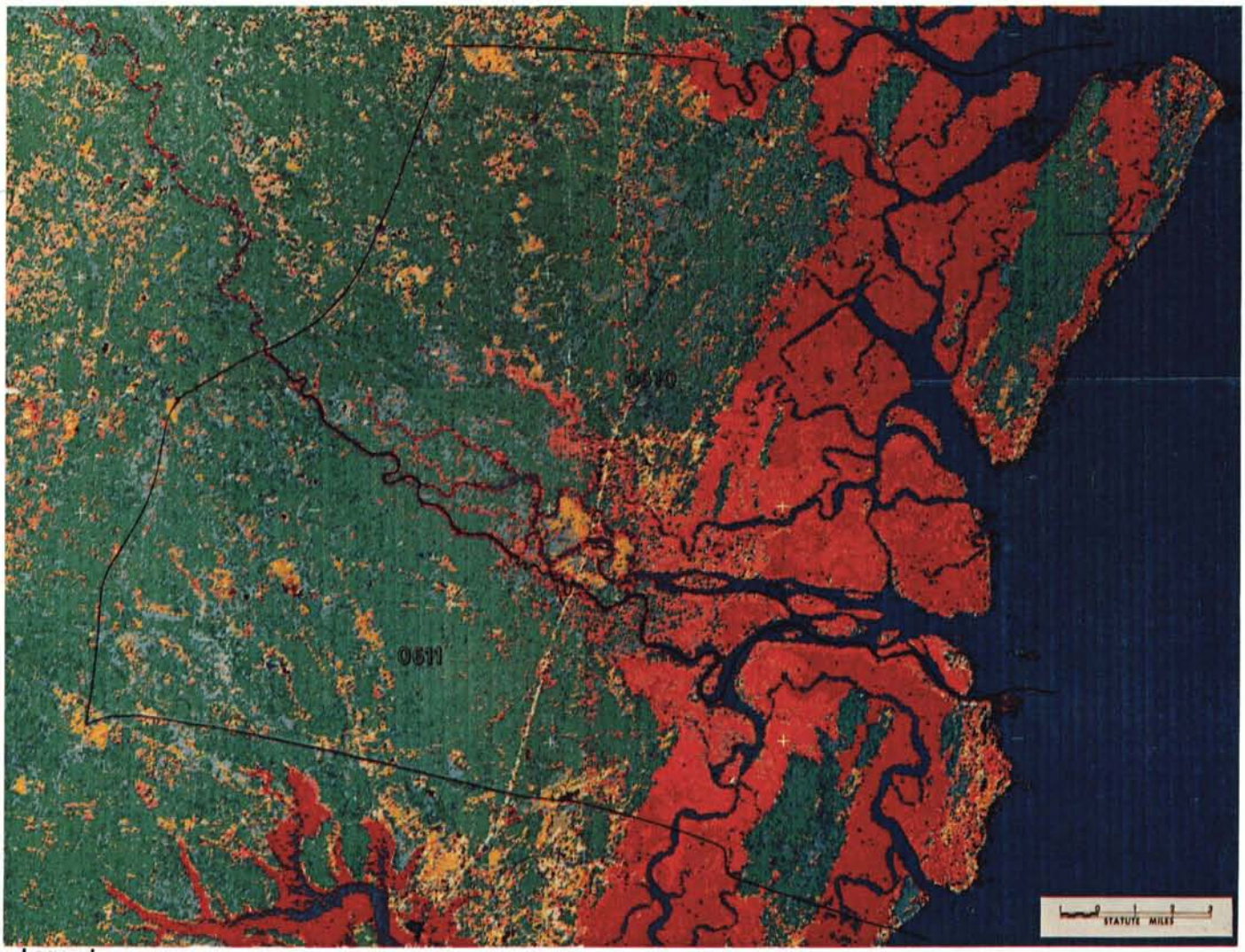
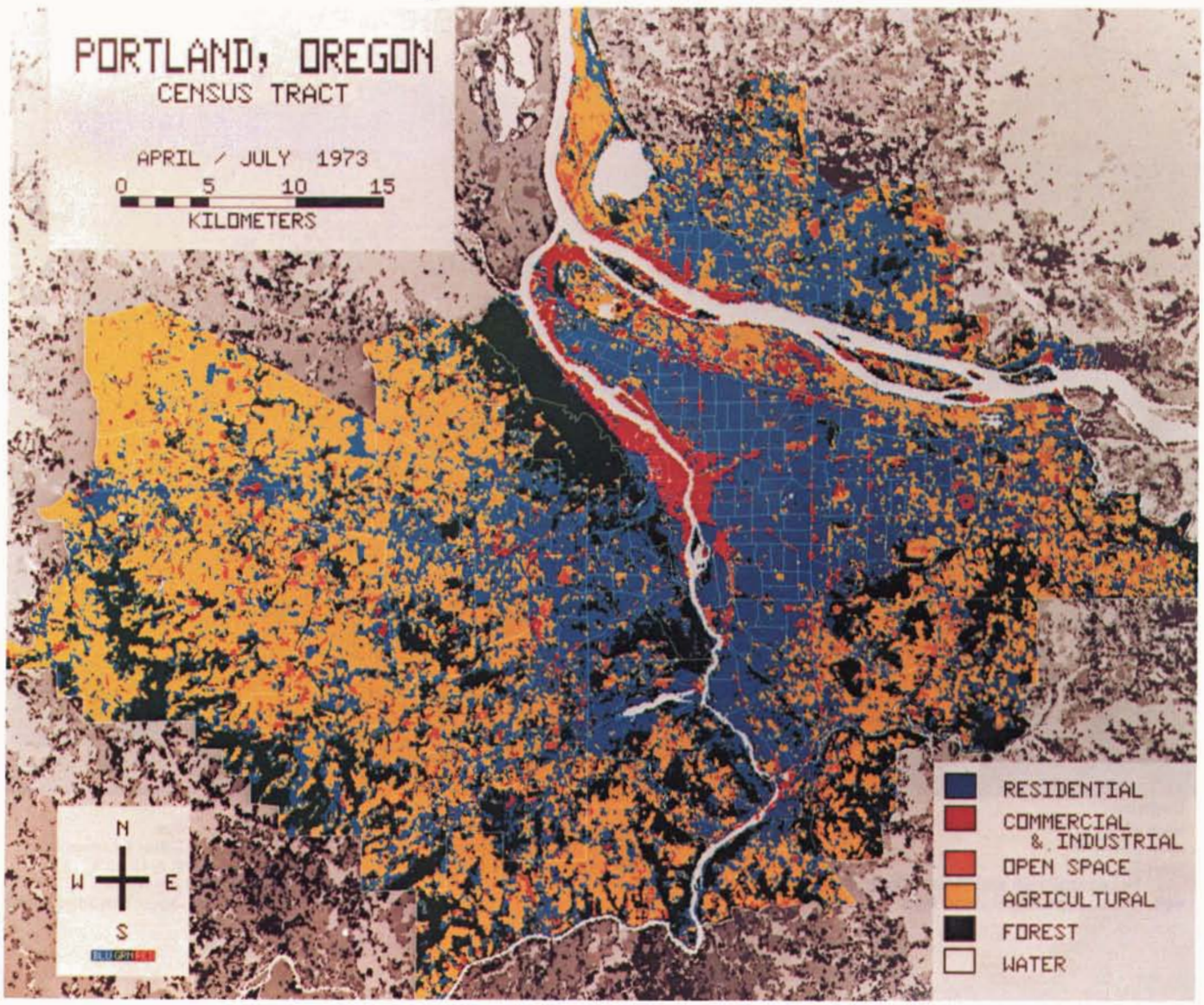


Legend

- Water
- Spartina
- Juncus
- Mixed Brackish and Fresh Marsh, Shrubs
- Beach, Spoil, and Sand Bars
- Sparsely Vegetated or Barren Land
- Bottomland Hardwood Forest
- Oak-Dominated Forest
- Pine Forest
- Corn
- Other Crops
- Pasture, Other Grasses
- High Density Urban
- Low Density Urban
- Clouds, Cloud Shadows, Uncategorized

Pacific Northwest Program

This illustration shows a computer-generated land classification map of the Portland, Oregon area, one of many maps and images developed from Landsat data for use in a large-scale natural resources management program in the Pacific Northwest. The Pacific Northwest Regional Commission, chartered to promote economic development and stability in the States of Washington, Oregon and Idaho, is conducting a three-year project in which Landsat information is being used in studies of agriculture, range lands, urban areas, forestry, water resources, noxious weed control, surface mining and coastal zone management. Other partners in the project are the U.S. Geological Survey and NASA's Ames Research Center, which provides personnel training and technical assistance. The new program, to run through 1981, is a follow-on to an earlier Pacific Northwest Landsat demonstration project; it will provide planning and resource management agencies in the three states an operational capability to extract and use data from the Landsat system. Some 45 state and local agencies acquired experience in the earlier (1975-78) project and reported valuable benefits in monetary, time and labor savings. For example, Washington's Department of Natural Resources conducted an inventory of 10 million acres of forest. The Department estimated that doing the job by standard methods would have taken two years and cost $2 million; using Landsat allowed a comparable inventory which required only half the time and one-tenth the cost.



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Texas Wildlife Study

The Landsat image shown covers a section of the Gulf Coast in the vicinity of Corpus Christi, Texas. The brown patches are urban areas, blue is water and the other colors represent various types of vegetation. This view is typical of a large number of images being used to study Texas wildlife habitat. The sprawl of urban areas, conversion of forest land to pasture, and other encroachments of civilization on natural wildlife zones require frequently updated habitat maps for wildlife management and protection. Landsat data is valuable because it identifies specific vegetation zones associated with certain animal species. Using Landsat generated vegetation maps, along with other data, wildlife biologists can determine animal population trends and assess the ability of an area to support wildlife. Wildlife habitat mapping is one of several Landsat applications in Texas. A consortium of 13 Texas resource agencies, which constitute the Texas Natural Resources Information System, is using Landsat data for coastal zone and water resources management, forestry applications and agricultural production estimates.

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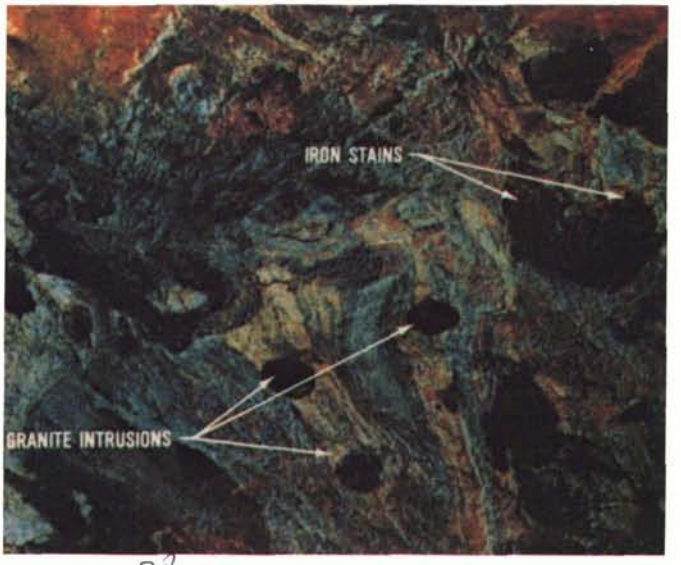

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Geological Exploration

Landsat has utility in identifying areas of the Earth which may contain mineral and petroleum deposits, because such deposits are normally associated with linear surface features such as faults and fractures. Operating at an altitude of 560 miles, Landsat provides broad views of linear features that often cannot be detected by field observation or by aerial photographs taken at lower altitudes. Landsat images are enhanced in a process called "computer stretching." The accompanying photos—at left a Landsat image of southwest Saudi Arabia and at right an enhanced version of the same image—show how stretching brings out subtle geologic differences and enables identification of candidate areas for follow-up surface exploration. Landsat data is widely used in mineral, oil and gas exploration and it is also used to identify high-yield ground water sources by mapping associated features.

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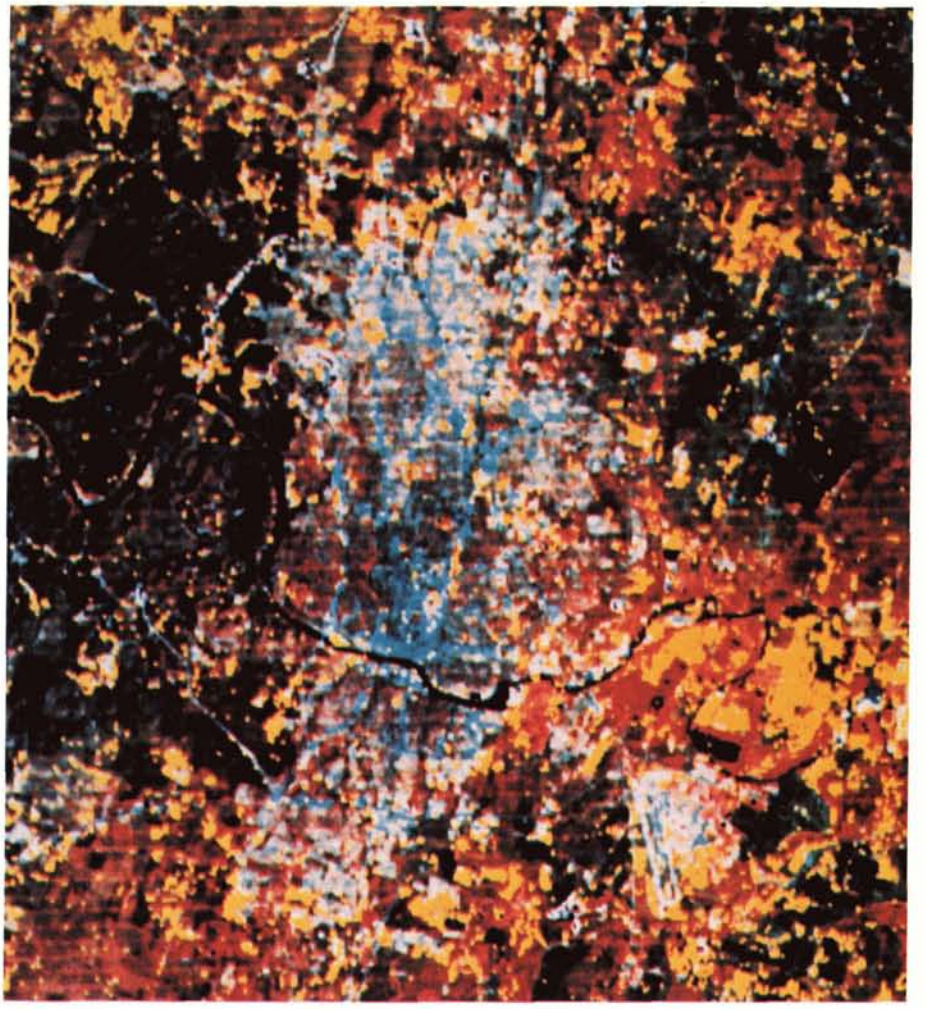
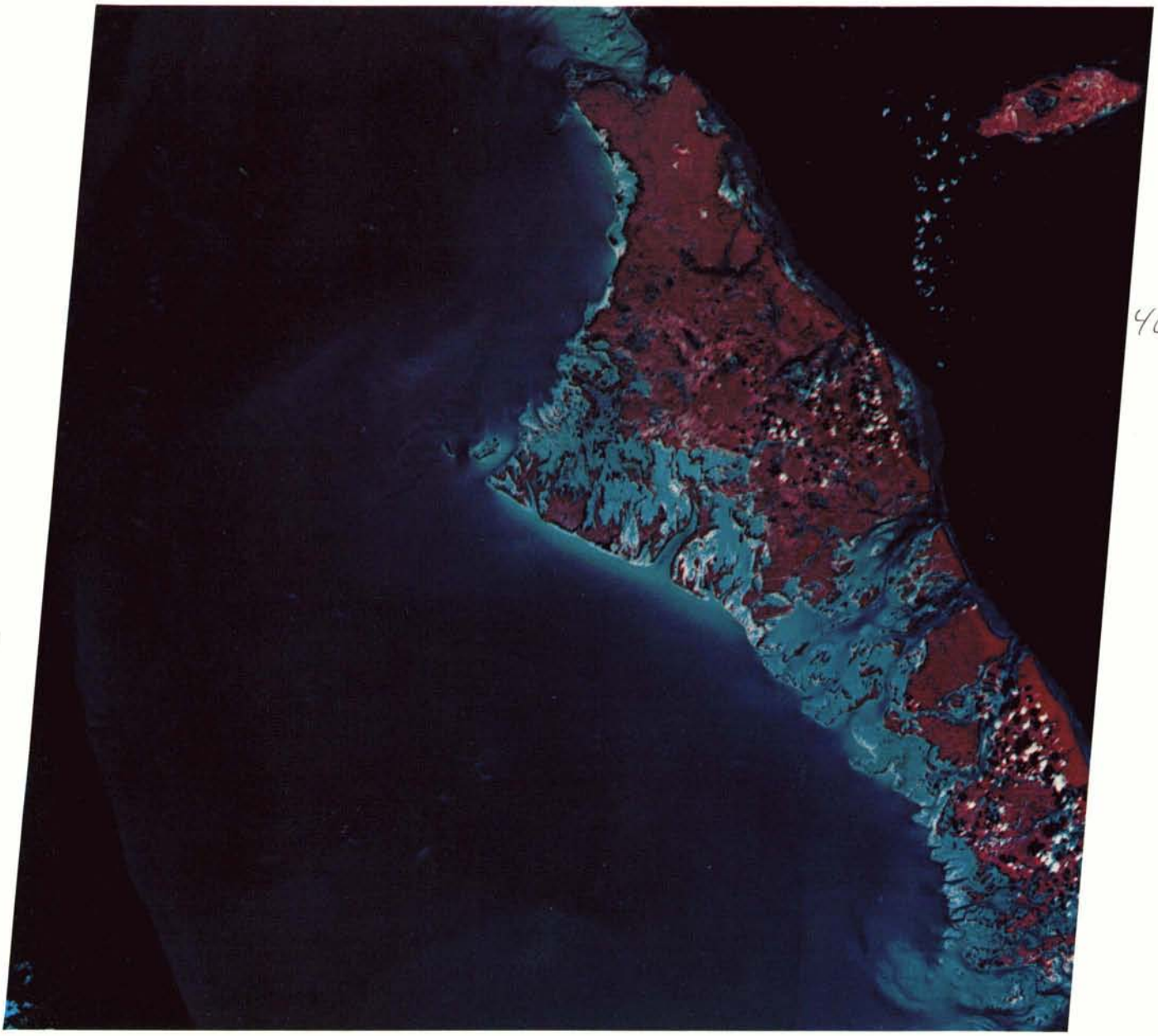
Census Aid

Landsat's repetitive coverage of Earth areas provides a capability for detecting changes over time in constantly growing urban areas. The capability is illustrated by this "image difference" picture, created by computer processing of two Landsat views of Austin, Texas, one taken in 1973 and the other in 1975. In this picture, the areas which changed appreciably over the two-year span show up in yellow. Image difference pictures are being used by the Geography Division of the Bureau of the Census in delineating boundaries of urban "fringe zones" surrounding U.S. metropolitan areas, zones which have grown to a population of more than 1,000 persons per square mile since the last census. Such information is important to planning for the next census; for example, it aids decisions as to how many field enumerators will be needed in a given metropolitan area. Fringe zone information is also important in determining what constitutes a metropolitan area from a federal loan and grant standpoint. Working toward an operational capability for using Landsat to supplement conventional census updating techniques, the Bureau of the Census is conducting tests in Orlando (Florida), Seattle (Washington), Richmond (Virginia), Boston (Massachusetts), and Detroit (Michigan), in addition to Austin.





Water Depth Measurement

This Landsat view covers an area around Andros Island in the Bahamas; the different intensities of blue or black provide indications of water depths in the vicinity. The Andros area was the subject of an experiment which tested Landsat's ability to measure depths in clear, shallow waters by combining its electronic imagery with "surface truth" information. A surface team headed by oceanographer Jacques Cousteau deposited a number of light-reflecting discs on the ocean floor at different known depths. The varying degrees of light reflectance from the discs showed up as different shades in Landsat images. By matching the known depths at disc sites with the corresponding image shadings, it was possible to produce a large-area map in which a particular shade represented a certain depth. The results of the NASA/Cousteau experiment encouraged the Defense Mapping Agency, nautical charting authority for the U.S., to undertake a global depth measurement program, which will take five years and involve some 3,000 Landsat scenes. Intent of the program is to develop updated, accurate maps of shoal areas in order to increase shipping safety and to permit more efficient ship routings with attendant fuel savings.

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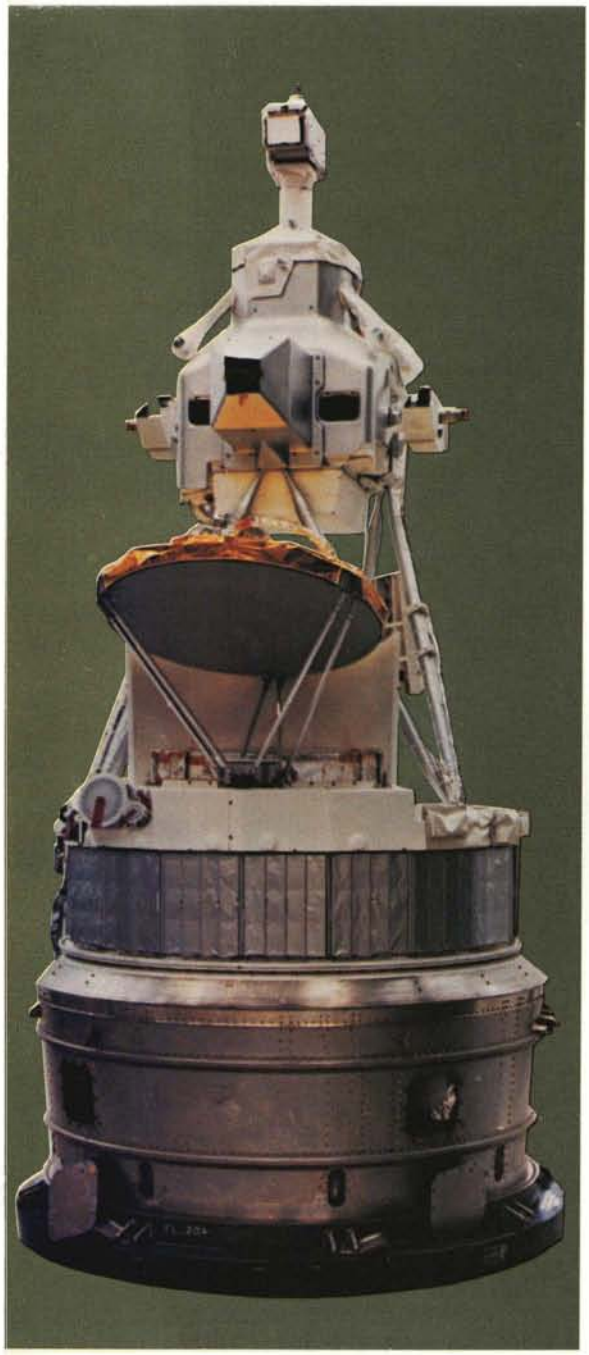

Environmental Satellite

Launched last fall, Nimbus 7 (shown) is the first satellite designed to monitor man-made and natural pollutants in Earth's atmosphere. It is also providing continuous environmental data vital to better understanding of climate, weather patterns and oceanography. From the highly sophisticated sensing equipment aboard Nimbus 7, scientists look for new insight into three matters of great importance to mankind: whether the ozone in Earth's upper atmosphere is changing; whether Earth is warming up or cooling; and the extent of pollution in the world's oceans. Nimbus 7 carries eight sensors, four of them designed to measure various atmospheric gases and pollutants, three others for improving knowledge and predictability of regional and global climate. The eighth instrument is being used to determine how water pollution—for example, oil spills, sewage, industrial waste and river sediment—can be detected and tracked. Working with NASA on the project are scientists from the U.S. National Oceanic and Atmospheric Administration, a number of American universities, and eight foreign nations.

Heat Mapping

The satellite pictured at right is equipped with heat sensors for measuring daily minimum and maximum temperatures at specific points on the Earth's surface. Called the Heat Capacity Mapping Mission (HCMM), the spacecraft provides data for preparation of color-coded temperature maps such as the one shown, which covers an area more than 400 miles wide from Cape Hatteras, North Carolina to Lake Ontario. The colors represent temperature values, with purple and blue the coldest, gray and white the hottest; the other colors indicate various intermediate temperatures. Analysis of heat maps like this provides a great deal of useful information. For example, it enables study of "heat islands," concentrations of heat rising from large metropolitan areas which appear as white patches on the map; it is known that the higher temperatures associated with heat from cities can affect local weather, but it is not known whether such temperatures cause long-lasting changes in regional climate. The HCMM also measures temperature variation among various rock formations, indications of differences in structure and composition; this permits discrimination of rock types, a possible aid to locating mineral resources. Other applications include soil moisture surveys of cultivated areas to help in predicting crop yield; observations of temperature changes in vegetated areas to find indications of plant stress; and measurement of snow field temperatures to assist scientists in calculating the time and rate of snowmelt, information valuable to areas which depend on melted snow for their water supplies. The satellite was designed and integrated by NASA's Goddard Space Flight Center, which is also responsible for data processing.

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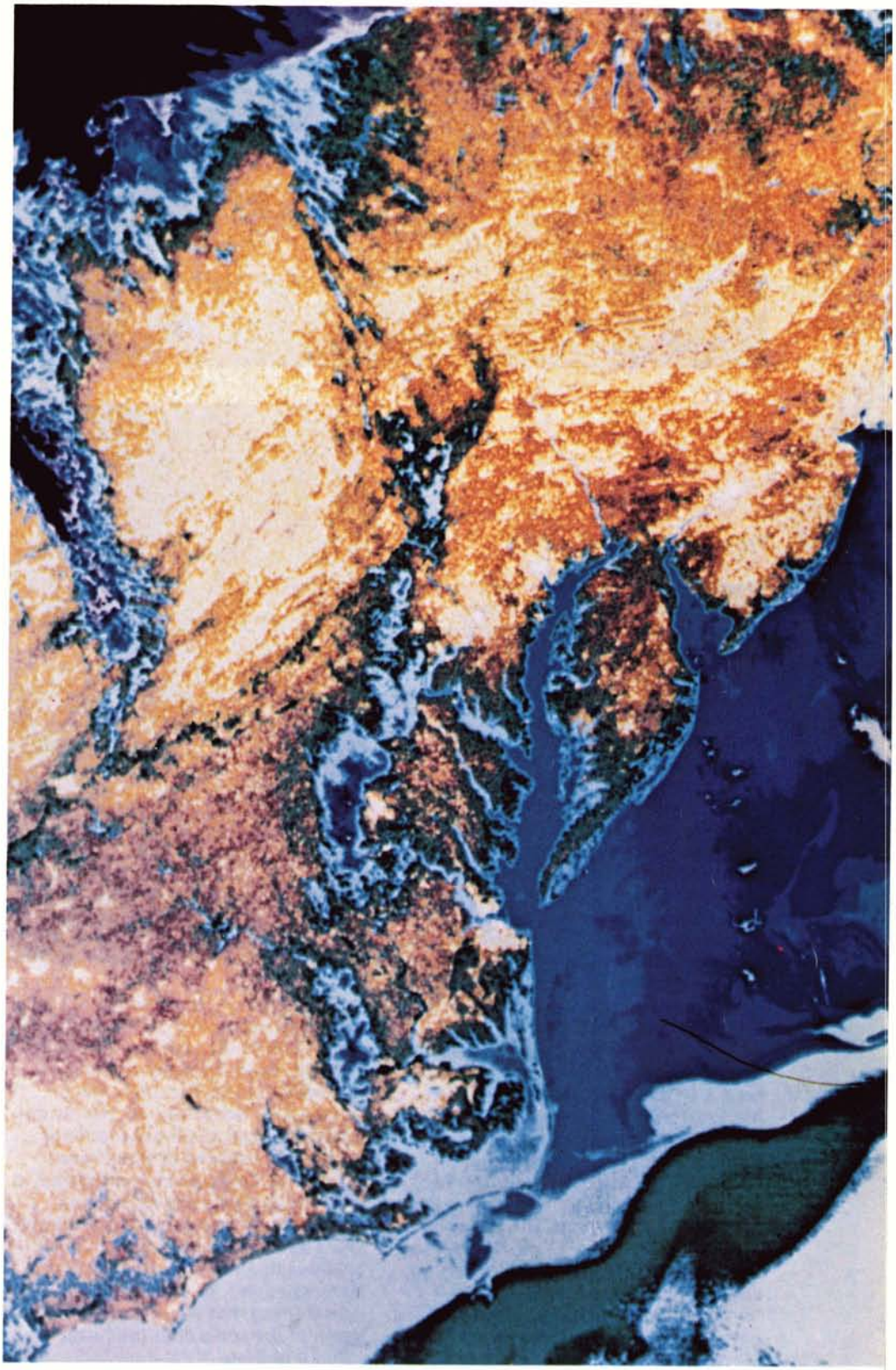

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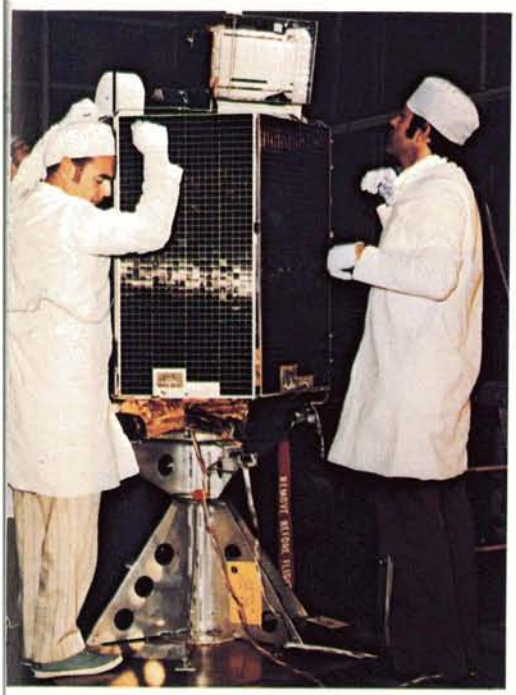

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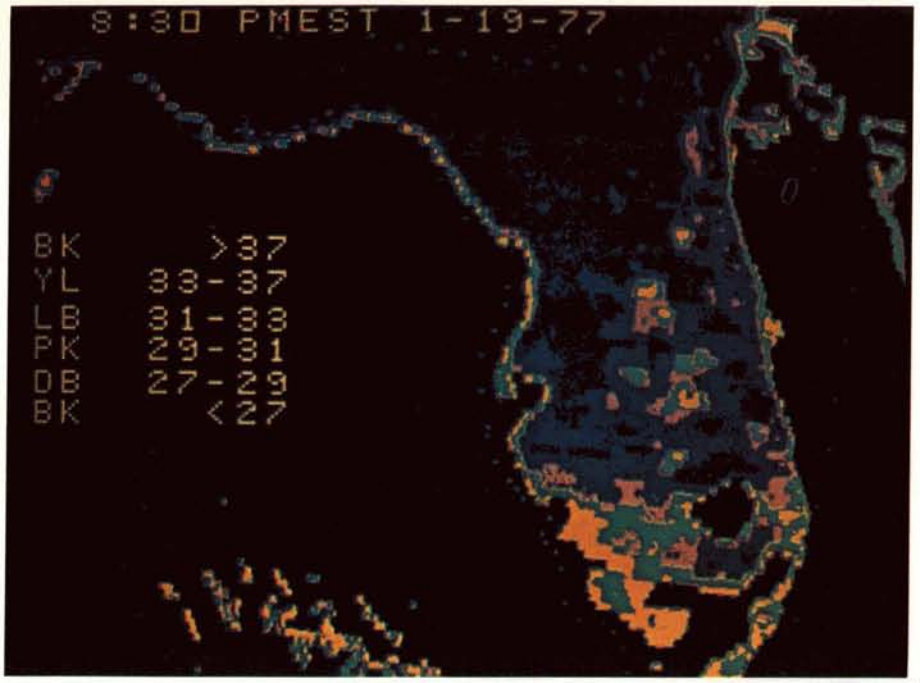

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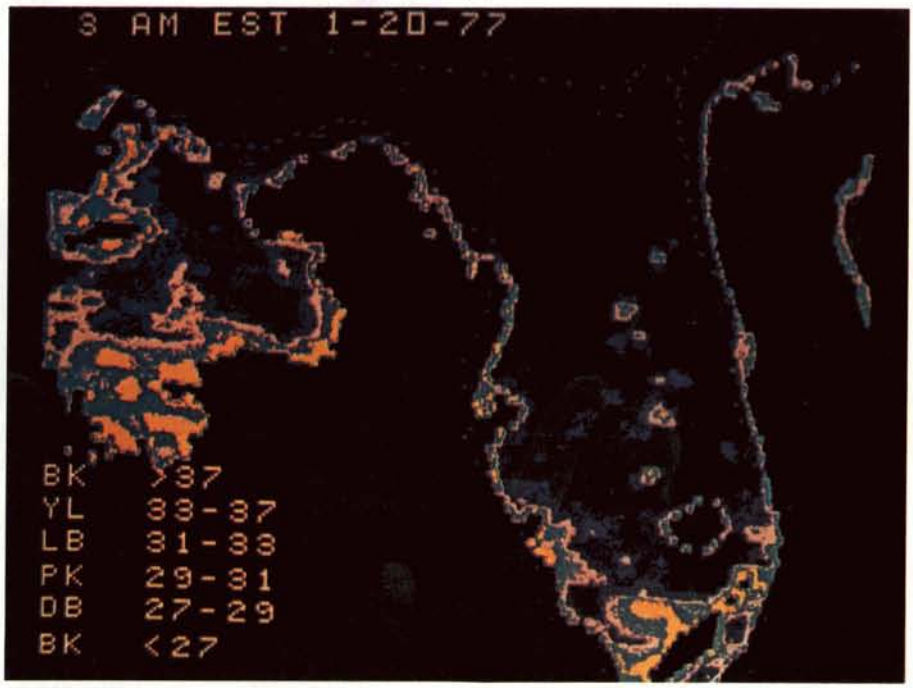


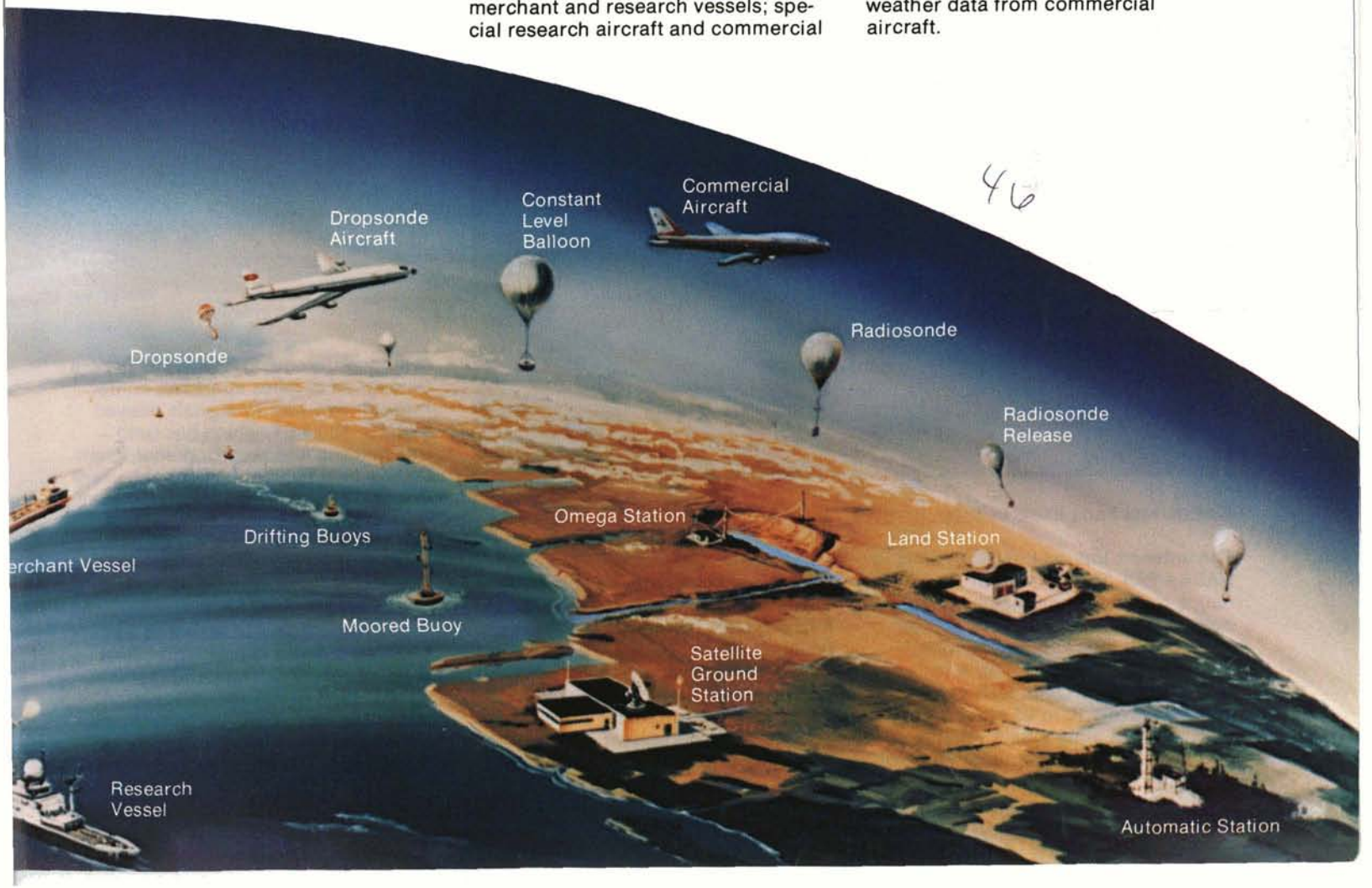
Freeze Prediction

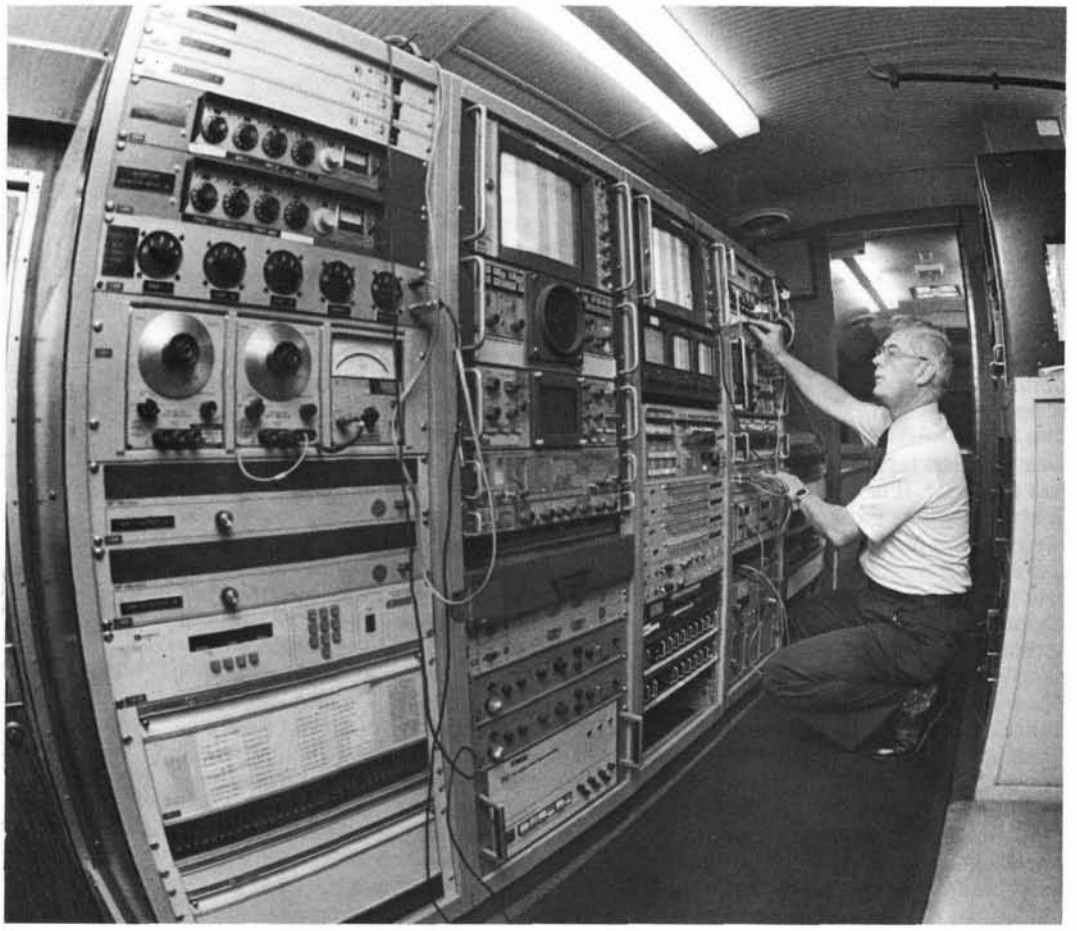
Freeze conditions pose a major problem for citrus growers. To prevent crop damage, they make extensive use of grove heaters at costs running to several million dollars daily in Florida alone. Precise freeze timing information is essential to initiate these one-shot protective measures and thus save the trees in cases of long-freeze periods. Existing forecast methods are not sufficiently accurate and they cover broad zones rather than specific growing areas. Thus, the citrus industry and other producers of cold-sensitive crops could reap tremendous benefit from a highly accurate system pinpointing exactly when and where freeze will occur. Such a system is being demonstrated in a joint program involving NASA, the National Weather Service and the University of Florida's Institute of Food and Agricultural Sciences. The system uses a GOES-1 Geostationary Orbiting Environmental Satellite to measure surface temperatures in the Florida peninsula. This information provides the basis for computer development of temperature maps such as those shown above. The upper map was made from GOES-1 observations at 8:30 p.m. on a winter evening; comparison of the colors with the temperature code at left shows temperatures generally above freezing in citrus growing areas of the peninsula.

The lower map was made at 3:00 a.m. the following morning; it shows virtually all of Florida, with the exception of small areas in the south and southwest, under the influence of subfreezing temperatures. Hourly updating of maps like these identifies trends and patterns of frost/freeze conditions. The system is expected to give growers warning of freezing temperatures that can be expected in areas as small as 25 square miles. This would allow time to initiate protective heating, or to avoid early heater firing that would result in the death of the trees after the heaters run out of fuel.

Global Weather Study

NASA is a major participant in the broadest weather-science program ever undertaken, a year-long international effort called the Global Atmospheric Research Program (GARP). The first GARP Global Experiment was initiated last December and it will last one year. It is now called the Global Weather Experiment and it will result in the most complete record of the world's weather ever assembled. The aims are to increase the global capability for extended range weather forecasting and to develop a significantly improved worldwide weather observation system. GARP is being conducted jointly by the United Nations World Meteorological Organization and the International Council of Scientific Unions; 147 nations are pooling their weather observation capabilities. Information gathering systems include satellites operated by the United States, Japan and the European Space Agency; 50 seagoing merchant and research vessels; special research aircraft and commercial airliners; hundreds of data-reporting balloons, drifting buoys and moored buoys; automatic and manned land-based weather stations; and a variety of other observational and communications systems. The great flow of information will be processed in many countries, then relayed to data centers in the U.S., the U.S.S.R. and the United Kingdom. It will be used to develop advanced mathematical models, computerized representations of the atmosphere's composition which serve as the basis for determining what the weather will be like under a given set of conditions. NASA's role involves use of its research satellites, processing of satellite and other data, and support of the National Operational Environmental Satellite System operated by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. A special NASA contribution was development of a direct aircraft-to-satellite-to-ground communications system for obtaining real-time weather data from commercial aircraft.





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Communications Experiments

The antenna-topped bus pictured is NASA's PET (Portable Earth Terminal), a mobile communications station designed by Lewis Research Center for use with the Communications Technology Satellite (CTS). A joint U.S.-Canadian project, CTS operates at power levels 10 to 20 times higher than those of other satellites. This higher broadcast power allows use of much smaller and far less expensive ground receiving equipment than is customarily required, thus enabling satellite communications in small towns or rural areas which cannot afford or justify the need for elaborate facilities. With CTS, the U.S. and Canadian governments have conducted extensive demonstrations of the potential afforded by this type of communications system. An area of particular interest is the technique of "videoconferencing," whereby people thousands of miles apart can confer through two-way TV signals relayed by CTS. The PET, which has both transmitting and receiving equipment and its own TV studio, has been used in a number of videoconference demonstrations. Last year, for example, PET and another Lewis-developed small ground station, the Transportable Earth Terminal, teamed with CTS in a three-day videoconference involving Indian officials in Montana and New Mexico and federal officials in Washington, D.C. The participants were able to exchange information and views on health, agriculture, education and other tribal concerns as though they were in the same room.

2

Technology Twice Used

Spinoff from NASA's mainline programs is providing bonus value in derivative benefits, ranging from simple devices to major problem solutions, over a wide spectrum of public needs and conveniences

A system for measuring waterflow in sewers, an aid to controlling water pollution, typifies the aerospace spinoff process

An Environmental Innovation: The Sewer Mouse

An American Digital Systems field crew prepares to install a sewer waterflow monitoring system. The system, an aerospace technology spinoff, is shown in the foreground.

In the effort to clean up America's waters, there is a little-known complicating factor: because they leak, sewer systems in many American cities are causing rather than preventing pollution of rivers and lakes. Fixing the leaks is difficult because their locations are unknown. Maintenance crews can't tear up a whole city looking for cracks in the pipes; they must first determine which areas are most likely suspects. An aerospace spinoff is providing help in that regard.

While one technician mans a safety line, another descends into a sewer to position the waterflow monitoring equipment. The system helps locate pollution-causing sewer leaks.

The problem starts with heavy rains. Rainwater naturally flows into the sewers from streets, but sewage systems are designed to accommodate it. However, they are not designed to handle the additional flow of "groundwater", rain absorbed by the earth which seeps into the sewers through leaks in pipes and sewer walls. After a storm, groundwater seepage can increase the waterflow to deluge proportions, with the result that sewage treatment plants are incapable of processing the swollen flow. When that happens the sluices must be opened, dumping raw sewage into rivers and lakes.

The Environmental Protection Agency has directed that American cities survey their sewer systems to determine the extent of their groundwater seepage problems. The basic method of doing so involves monitoring waterflow depth in the sewers under different conditions—dry, rain and after-rain—as a means of finding out when and where leakage occurs. Flow measurements can be made manually by dipsticks where there is an accessible place to make measurements. But there is another complication: the most readily accessible places, directly below manholes, are not suitable for precise measurement. Sewer design involves building small troughs in the pipes at manhole locations. These troughs help speed waterflow past manhole areas to prevent street-flooding during heavy rains, but

in so doing they create a turbulent waterflow which makes accurate depth measurements impossible. To get the requisite information, municipalities needed a system for acquiring simultaneous and continuous waterflow readings from many different points within a sewer complex.

Peter Petroff provided a solution. Petroff is a Bulgarian-born inventor with about 15 years of aerospace engineering experience; he worked for NASA as an instrumentation designer on several major space programs and served with other organizations as an electronics specialist on missile and commercial aircraft developments. Petroff designed and manufactured a sophisticated sewer flow measurement system which is contributing to more effective sewage processing.

Key to the system is a device called a "mouse," because its shape suggests that of the small rodent and it has a "tail" of long cables, which are connected to a data recorder mounted a considerable distance away under a manhole lid. The mouse, bolted to the floor of a sewer pipe and streamlined to prevent waterflow disruption which would cause inaccurate readings, houses a flow-measuring transducer. The transducer senses differences in pressure, enabling calculation of the amount of water above it. The pressure reading is translated into a water depth reading and relayed through the mousetail cables to the recorder.

Typically, 50 to 100 mouses—not mice, Petroff insists—are installed throughout a city's sewer system. Each provides a water depth reading every 15 minutes, day and night for weeks in dry and wet weather. Every few days, field crews collect the stored data from the recorders and transfer it to a central computer for processing and evaluation. The system does not pinpoint specific leaks, but it does provide clues as to suspect areas for physical investigation; such narrowing of problem zones permits substantially easier and less expensive repair of leaks.

Peter Petroff founded a company to produce the equipment and to provide sewer monitoring service. Called American Digital Systems, Inc., Huntsville, Alabama, it began as a garage industry in 1975, when 40 prototype systems were built. The company has since produced several hundred monitoring systems and its field teams have conducted sewer studies in 30 American cities.

The sewer mouse story is an excellent example of the aerospace spinoff process because it underlines several facets of technology re-use. It shows, for example, the universality of spinoff, how once-developed technology can be re-applied in virtually every avenue of everyday existence, often in ways surprisingly remote from the original application.

Inventor Peter Petroff (right) inspects a key component of the sewer monitoring system, the recorder, which collects and stores waterflow depth information from sensors within the sewer. Computer processing of waterflow data provides clues to leak locations. With Petroff is his son Ralph, marketing manager for American Digital Systems.

In this instance, Petroff applied several different aerospace technologies: aerodynamic streamlining concepts in shaping the mouse; an epoxy material for the transducer housing which stemmed from aerospace research; space-derived miniaturization technology for packaging the electronic components of the data recorder; and data acquisition technology similar to that employed by NASA satellites. In other examples of spinoff, the reverse is often the case: a single type of technology is transferred to many secondary applications, each different from the other.

Petroff's formation of American Digital Systems points up the economic potential of spinoff. As happens frequently, a technology transfer resulted in establishment of an entirely new company, with attendant benefit to the nation's Gross National Product and to job creation. Some spinoffs represent only moderate increments of economic gain, but others involve values running into millions of dollars.

In the sewer application, Petroff himself was the instrument of technology transfer. Many spinoffs are accomplished in this manner; aerospace personnel move to other industries, bringing with them skills and know-how which have non-aerospace potential. Another route by which technology transfer is effected is product diversification on the part of NASA contractors, who use their aerospace experience to develop non-aerospace applications. NASA directly promotes technology transfer in a number of ways which are detailed in Section 3 of this volume.

NASA's technology utilization program, which seeks to encourage secondary application of aerospace technology, has been going on for 17 years, during which thousands of aerospace-originated innovations have found their way into everyday use. Collectively, these spinoffs represent a substantial return on the aerospace investment in terms of economic gain, improved industrial efficiency and productivity, lifestyle innovations, and solutions to problems of public concern.

Systems which aid in underwater oil drilling highlight examples of aerospace technology applications to energy exploration, supply and conservation

Spinoff for Deepsea Drillships

In the quest for new energy supplies, oil explorers are stepping up their efforts to tap undersea sources. In doing so, they are moving more and more into deeper parts of the oceans where water depths measure thousands of feet.

As might be expected, this creates new drilling problems whose solutions demand application of new technology. Space spinoff systems are providing answers in one important area of deepwater drilling operations.

In shallow water—a few hundred feet—oil companies employ fixed-position drilling rigs anchored to the seabed by sturdy steel legs or by massive chains. But there are practical limits to the length of support legs or chains.

So for deepwater operations the self-propelled oil drillship is employed. This type of vessel resembles a cargo ship except for its large derrick, which supports the drilling equipment. Extending from the drillship to the well thousands of feet below is a "marine riser," a cylindrical steel tube usually one to two feet in diameter. The drilling equipment, or drill string, is lowered to the well through this riser. The riser is not rigid nor strictly vertical; it is described by one expert as "a very long piece of spaghetti," held in tension at the well and at the ship end by strong cables.

Obviously, the ship must remain—often for months—in a position directly over the well. If it were to drift excessively forward, aft or to either side, its movement could snap the riser and disrupt operations at a cost of millions.

That's where space technology is playing a part. The same technology employed to locate a spacecraft in orbit and maintain a precise position is applicable to drillship operation. In space, automatic navigation equipment sights on reference points—the Earth, the sun or other stars—to determine spacecraft location. If the space mission requires the spacecraft to hold a certain position, it is accomplished by the firing of computer-directed control thrusters. Two major aerospace companies—Honeywell Inc. and TRW Inc.—have applied their extensive experience in spacecraft positioning and control to the offshore drilling technique known as dynamic positioning, meaning holding the drillship in precise position over the work site.

Honeywell's Commercial Marine Operations, Seattle, Washington, developed the first computerized anchor-free mooring system for drillships and it now manufactures several dynamic positioning systems, each tailored to the needs of a specific type of vessel or to different types of offshore operations.

For a positioning reference point, the systems employ a small, battery powered beacon placed on the seabed at the drilling site. The beacon emits a sound signal which is picked up by sensitive receivers, called hydrophones, on the hull of the drillship. The signal is relayed to a shipboard computer, which studies the "phase lag" of each acoustic pulse. If, for example, the signal reaches the hydrophones simultaneously, that means the ship is exactly over the beacon. But if there is a time difference in signal reception, that indicates the ship has moved off center. The computer analyzes the signals to determine what correction is needed to nudge the ship back to proper position. Then the computer directs the ship's engines to move the vessel backward or forward, or directs lateral thrusters to move it to one side or the other, until beacon signals indicate the ship is once again properly spotted. This operation goes on continuously.

A real boon to the oil industry, this type of dynamic positioning system is now used on most drillships and it is proving effective. However, because position maintenance is vital to successful drilling, it is standard practice to employ a backup system. Sound signal systems are occasionally subject to what is called "acoustic drop-

Deepsea drillships such as Discoverer Seven Seas *drill for oil and gas through thousands of feet of water. Unanchored, they need a method of holding position directly over the drill site, often for months. Spinoff systems which trace their origins to NASA's Apollo program are providing answers.*

out," the deepsea equivalent of radio static. Other noise in the vicinity—for example, the ship's engines and thrusters, the clanging of the riser or the movement of marine life—may cause temporary interference with hydrophone signal reception and inadequate input to the computer.

Applying its experience in spacecraft control, TRW Subsea, a unit of TRW's Defense and Space Systems Group, has developed a backup system which does not rely on sound signals. Called the Riser Positioning System, it measures the angles of the riser at its top (ship) and bottom (seabed) connections. Small pendulum-like devices at either end maintain a continually vertical attitude; the angle between riser and pendulum is measured and transmitted electrically through a cable to the computer. The computer compares the angles with other stored information—water depth, tension of the riser connections, riser buoyancy, and a number of other characteristics of the riser and the drill string within it. Computer analysis then determines the ship's position and, as in the primary system, the computer sends adjusting instructions to the ship's engines or thrusters. The backup system gathers information continuously and is always ready for immediate service, but it goes into action only when the primary system experiences dropout.

The Honeywell Automatic Station Keeping System, which is based on spacecraft positioning technology, is an anchor-free mooring system for drillships. Using a beacon on the sea-bed as a reference point, the system computes the ship's location relative to the well and automatically directs fore-and-aft and side-to-side movement to keep the ship properly positioned.

Drillship positioning is vital to successful drilling, so it is standard practice to use a backup ship positioning system in case undersea sounds interfere with a primary acoustic system like Honeywell's. A non-acoustic backup instantly available if the primary system encounters interference is TRW Subsea's Riser Positioning System, whose development was based on the company's experience in spacecraft control. The system measures angles between ship and well as reference points for determining proper ship location, then automatically corrects ship's position.

Alaska Pipeline Insulation

Crude oil moving through the 800-mile Trans-Alaska Pipeline must be kept at a relatively high temperature—about 180 degrees Fahrenheit—to maintain the fluidity of the oil. In Arctic weather, that demands highly effective insulation. General Electric Co.'s Space Division, Valley Forge, Pennsylvania, provided it with a spinoff product called Therm-O-Trol. Shown being installed on the pipeline, Therm-O-Trol is a metal-bonded polyurethane foam especially formulated for Arctic insulation.

A second GE spinoff product, Therm-O-Case, solved a related problem involved in bringing hot crude oil from 2,000-foot-deep wells to the surface without transferring oil heat to the surrounding permafrost soil; heat transfer could melt the frozen terrain and cause dislocations that might destroy expensive well casings. Therm-O-Case is a double-walled oil well casing with multi-layered insulation which provides an effective barrier to heat transfer. Therm-O-Trol and Therm-O-Case are members of a family of insulating products which stemmed from technology developed by GE Space Division in heat transfer/thermal control work on Gemini, Apollo and other NASA programs.

Aid to Solar Collector Development

Below, an engineer is testing a sample coating to determine its "emissivity," meaning the degree to which it emits radiant energy. The instrument he is using, called the McDonald Emissometer, is useful to companies engaged in development of solar energy collectors. Originally developed by NASA, the system is manufactured for the commercial market by International Technology Corporation, Satellite Beach, Florida.

Solar heating and cooling systems employ coatings to increase efficiency. Designers want a coating which absorbs solar heat to the maximum extent possible with minimal emittance of infrared radiation, which occurs when the collector plate gets hot. The coating is important because too much coating causes energy loss by emittance, too little reduces the collector's ability to absorb heat.

NASA's Lewis Research Center, which conducts solar energy research, saw a need for a simple means of testing coating samples for emittance. Such equipment is available to research laboratories, but it is complex and expensive. To provide an equally accurate but relatively low-cost system for wide use by manufacturers of solar equipment, Lewis undertook development of the emittance measuring device in conjunction with Willey Corporation, Melbourne, Florida and the Institute of Optics, University of Rochester, New York.

In use, the emissometer is placed above a heated sample and the radiation from the sample is focused on a detector within the instrument. Rising temperature, determined by heat sensing equipment, indicates the degree of emittance, which is measured and displayed on a meter. The emissometer permits easy testing of various experimental coatings and also helps determine how the coatings will react to increases in temperature or time in use, information important to development of efficient solar collectors.

Window Insulation

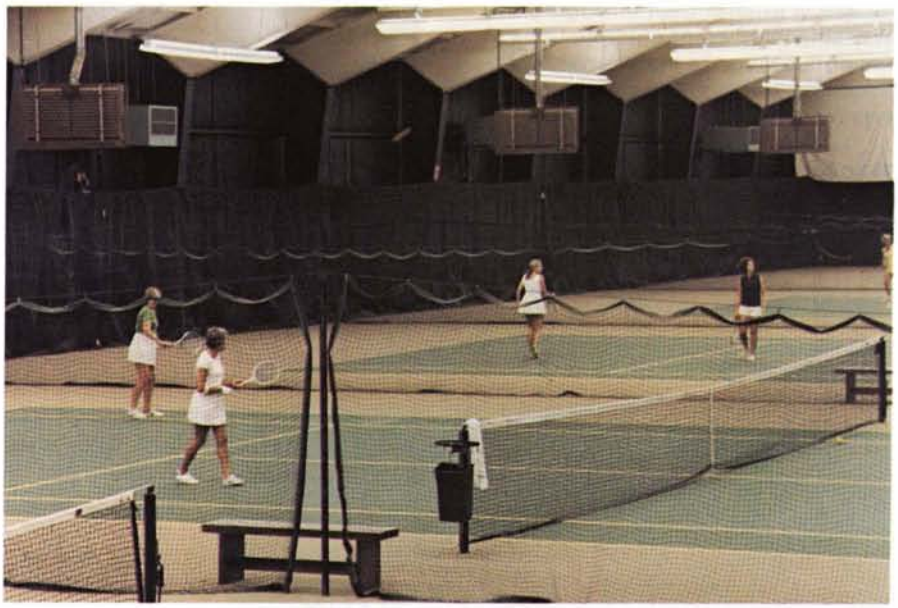
A highly reflective insulating material developed to protect NASA spacecraft from intense solar radiation is now being used in a commercially-available window-insulating product which offers significant energy savings. Called Nunsun, it is a thin metallized film adhesively bonded to windows of homes, office buildings, schools, industrial plants and other facilities; the film reflects the sun's heat and glare outward, thereby cutting down on energy costs for cooling. Trained dealer personnel can affix the film to windows of any size in minutes (right), converting ordinary glass to heat-reflective mirror glass at a fraction of the cost. Manufactured by National Metallizing, a division of Standard Packaging Corporation, Cranbury, New Jersey, Nunsun is also available in windowshade form.

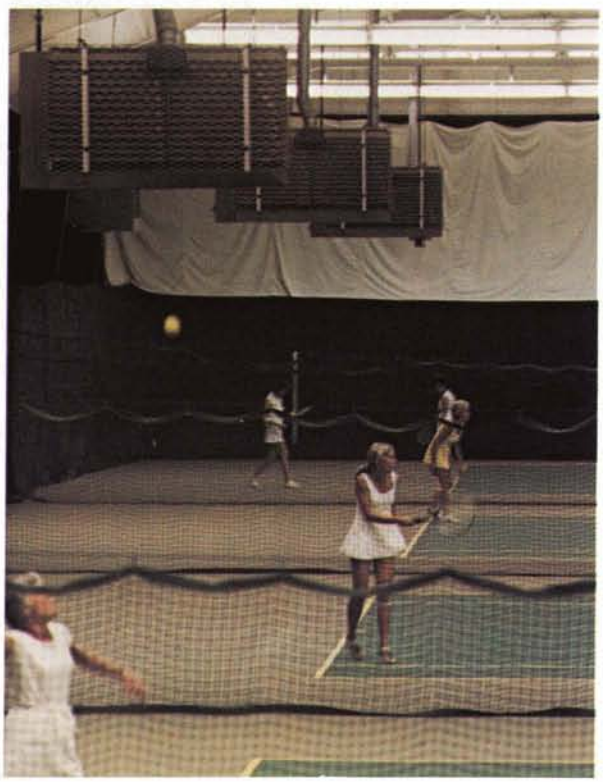
Fully transparent and easily cleaned, Nunsun filters out 75 percent of the sun's infrared heat rays which would otherwise penetrate the glass and heat interior space, the company says. In summer, the film substantially reduces air conditioning requirements. It affords additional energy savings in winter by blocking the escape of interior heat through glass. Available in 12 color combinations, it has bonus value in that it protects draperies, carpets and other furnishings from sun-fading.

National Metallizing participated in development of the original reflective insulating film, used on the Echo communications satellite 20 years ago. From the know-how thus acquired, the company developed a variety of advanced reflective films used on a number of unmanned satellites and on such manned spacecraft as Apollo, Skylab and the Space Shuttle.

Infrared Heaters

The heating units shown in the accompanying photos are Panelbloc infrared heaters, energy savers which burn little fuel in relation to their effective heat output. Produced by Bettcher Manufacturing Corporation, Cleveland, Ohio, Panelblocs are applicable to industrial or other facilities which have ceilings more than 12 feet high, such as those pictured: at left the Bare Hills Tennis Club, Baltimore, Maryland and at right, CVA Lincoln-Mercury, Gaithersburg, Maryland. The heaters are mounted high above the floor and they radiate infrared energy downward.





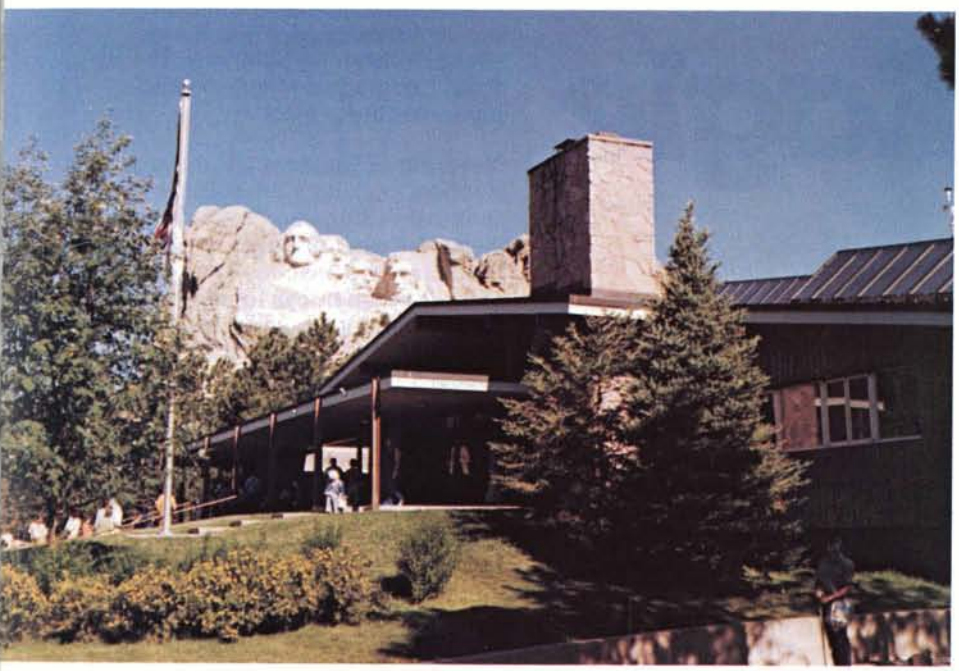
Panelblocs do not waste energy by warming the surrounding air. Instead, they beam invisible heat rays directly to objects which absorb the radiation—people, floors, machinery and other plant equipment. All these objects in turn re-radiate the energy to the air.

A key element in the Panelbloc design is a coating applied to the aluminized steel outer surface of the heater. This coating must be corrosion resistant at high temperatures and it must have high "emissivity"—the ability of a surface to emit radiant energy. The Bettcher company formerly used a porcelain coating, but it caused a production problem. Bettcher did not have the capability to apply the material in its own plant, so the heaters had to be shipped out of state for porcelainizing, which entailed extra cost. Bettcher sought a coating which could meet the specifications yet be applied in its own facilities. The company asked The Knowledge Availability Systems Center, Pittsburgh, Pennsylvania, a NASA Industrial Applications Center (IAC), for a search of NASA's files.

The NASA center located several pertinent reports on radiator coatings used on spacecraft. One in particular described the coating known as Pyromark, produced by the Tempil Division of Big Three Industries, Inc., South Plainfield, New Jersey. Pyromark, a spray-on paint with exceptionally high emissivity, had been employed as a protective coating for the Apollo Lunar Module and it is now being used on the Space Shuttle. It is also used in many industrial applications and in consumer products. Through contact with the Tempil Divison, Bettcher was able to set up its own coating facility. Thus, the NASA IAC contributed not only to Bettcher's realization of substantial savings but also to an increase in the radiant efficiency of the company's infrared heaters.

Solar Energy Demonstrations

The building at upper left houses the offices of the Reedy Creek Utilities Company, a Walt Disney Productions subsidiary which provides utility services for the 27,000-acre Walt Disney World resort complex at Orlando, Florida. The photos below show the Visitors Center at Mount Rushmore, South Dakota. These are two of more than 100 solar-powered facilities managed by NASA's Marshall Space Flight Center for the Department of Energy's National Solar Heating and Cooling Demonstration Project. Aim of the program is to promote national energy conservation by stimulating interest in solar energy as an alternative to fossil fuels.



Solar energy furnishes all of the heating and hot water needs, plus 80 percent of the air conditioning, for the two-story Reedy Creek building. A unique feature of this installation is that the 16 semi-cylindrical solar collectors (center photo on opposite page with closeup of a single collector below it) are not mounted atop the roof as is customary, they actually *are* the roof. This arrangement eliminates the usual trusses, corrugated decking and insulating concrete in roof construction; that, in turn, reduces overall building costs and makes the solar installation more attractive economically. The Reedy Creek collectors were designed and manufactured by AAI Corporation of Baltimore, Maryland.

The Mount Rushmore installation is somewhat different. It employs 112 individual collectors which are smaller than Reedy Creek's and are flat plates rather than concave. They supply more than half the building's heating/hot water needs and about 40 percent of the cooling requirement. Lennox Industries, Marshalltown, Iowa produced the Mount Rushmore collectors.

Marshall Space Flight Center's role in the National Solar Heating and Cooling Demonstration Project is that of supervisor and technical advisor for a variety of demonstrations in such facilities as industrial plants, office buildings, schools, museums, libraries and private homes. The Center lends its broad solar energy expertise in handling contract negotiations, reviewing designs and overseeing construction. A major Marshall responsibility is monitoring solar equipment performance. Sensors installed by the Center's engineers take frequent data samplings at each site. The information is stored on tape and relayed once a day to a central processing facility at Marshall's Huntsville, Alabama headquarters. There it is analyzed and evaluated to determine the effectiveness of the various types of equipment being used in different parts of the country, providing information that can be applied to development of advanced solar energy systems for the future.

A life-saving satellite beacon heads a list of technology transfers for improving safety and the environment

Tracking the Double Eagle

Last summer a trio of aeronauts made aviation history. Ben Abruzzo, Maxie Anderson and Larry Newman, all of Albuquerque, New Mexico, piloted their balloon *Double Eagle II* from Presque Isle, Maine to Miserey, France, some 50 miles from Paris. They were the first to negotiate a successful Atlantic crossing in a freeflying balloon after a score of attempts over a span of more than a century.

A year earlier, Abruzzo and Anderson had made an unsuccessful try in their predecessor balloon *Double Eagle*. On that occasion, a NASA-developed satellite beacon helped save their lives.

Carried aboard the balloon, the simple, seven-pound beacon continuously transmitted signals to NASA's Nimbus-6 satellite. Nimbus relayed the signals to monitors at Goddard Space Flight Center, enabling Goddard to compute the balloon's position. Position reports were then telephoned regularly to *Double Eagle's* control center at Bedford, Massachusetts. This monitoring system proved invaluable when the balloon encountered trouble several days after liftoff.

Caught in a massive, swirling storm, *Double Eagle* was forced down off Iceland. Heavy rain made voice communication impossible. But thanks to the beacon, Nimbus-6 and Goddard's tracking, the downed balloon's position was known. A Navy rescue plane promptly arrived on the scene.

Needless to say, the beacons—two of them this time—were aboard *Double Eagle II* on last year's successful crossing. Afterward, Abruzzo and Anderson visited Goddard Space Flight Center to express their thanks for NASA's tracking assistance on both flights and for saving their lives on the first attempt. The beacons, said Abruzzo, were "the most important pieces of equipment aboard."

The beacon figured in other headline-making events last year; it was carried by Japanese explorer Naomi Uemura on two Arctic expeditions. The first was a 54-day solo dog-sled trek from Ellesmere Island in Canada's Northwest Territories across 600 miles of Arctic wasteland to the North Pole. Later, Uemura dog-sledded the length of Greenland, some 2,170 miles.

On both trips, Goddard tracked Uemura's progress by means of Nimbus-relayed signals. Both journeys were successful and no rescue was needed, but Uemura's beacon had a special switch to indicate emergency as a backup to his voice communications. The beacon served another purpose: the Smithsonian Institution, which requested NASA participation, wanted an accurate record of Uemura's daily positions for correlation with snow, ice and air samples he was taking. Beacon cost was defrayed by Uemura's Japanese sponsors, Mainichi Newspapers and Bungei Shunju Publishing Company. The National Geographic Magazine also supported the project.

Still another Goddard effort last year involved tracking a Smithsonian scientific expedition across the desolate Western Desert of Egypt. In other applications, the beacons are extensively used on buoys to track currents for oceanographic and environmental studies. The U.S. Coast Guard puts beacons on icebergs, to help predict their drift routes in the waters off Greenland and Labrador as an aid to the International Ice Patrol. And in ecology studies conducted by the Department of the Interior, a mini-version of the beacon has been used to track polar bears in their Arctic wanderings.

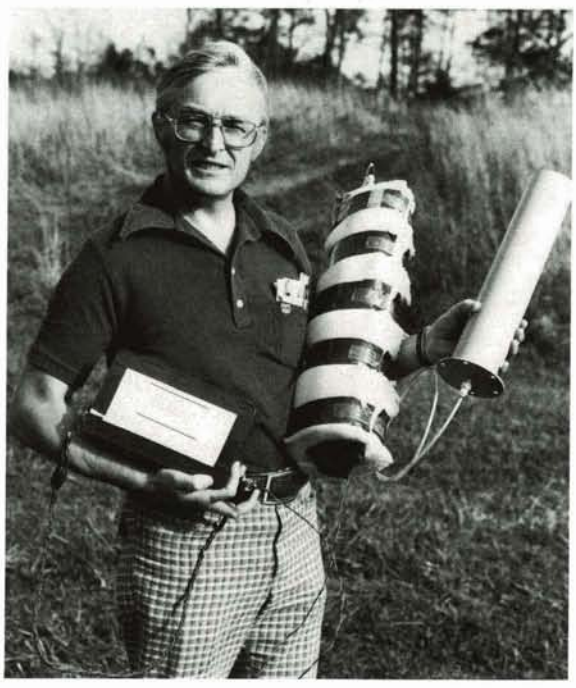
The relatively low-cost beacon—officially the Random Access Measurement System (RAMS)—was originally developed by Goddard for a major meteorological experiment in which Nimbus-6 gathered data from some 450 balloons free-floating in tropical areas. Such location and interrogation of weather platforms was not new, but beacons used in earlier work were expensive and they also used large amounts of transmitting power. Innovations in Nimbus-6 permitted development of the simple, economical, low-power RAMS.

The beacons are manufactured by Handar, Inc., Santa Clara, California. In a new development, Handar has repackaged the satellite beacon technology in a hand-held, battery-powered Emergency Location Transmitter which allows the receiving satellite to pinpoint the source of the signals. The principal application is for rescue utility aboard private aircraft flying over sparsely-populated areas.

Double Eagle II *is shown over Brittany, France as it neared the end of a momentous journey last year, the first successful transatlantic balloon flight. The balloon carried a NASA satellite beacon which had helped save the lives of two crewmen on an earlier attempt to cross the Atlantic.*

Arctic explorer Naomi Uemura is pictured at the North Pole after a 600-mile dog sled trek from northwestern Canada. The equipment on his sled included the NASA beacon, whose satellite-related signals enabled Goddard Space Flight Center to track Uemura's progress.

Bungei Shunju
Magazine, Tokyo



A NASA engineer displays the three components of Goddard Space Flight Center's satellite beacon: at right, the antenna; in the center, the signal transmitter; and at left the battery pack.

Naomi Uemura pauses to consult his map during a second 1978 Arctic exploration on which he dog-sledded the length of Greenland. The hooded instrument at Uemura's right is the NASA beacon which provided a record of his daily positions. The information was used to determine locations of snow, ice and air samples he collected.

Bungei Shunju Magazine, Tokyo

Water Quality Monitor

In the photo above, the cylindrical container being lowered into the water is a water quality probe developed by NASA's Langley Research Center for the Environmental Protection Agency (EPA) in an applications engineering project. It is part of a system—which also includes recording equipment in the helicopter—for on-the-spot analysis of water samples. It gives EPA immediate and more accurate information than the earlier method, in which samples are transported to a laboratory for analysis. Designed primarily for rapid assessment of hazardous spills in coastal and inland waters, the system provides a wide range of biological and chemical information relative to water pollution.

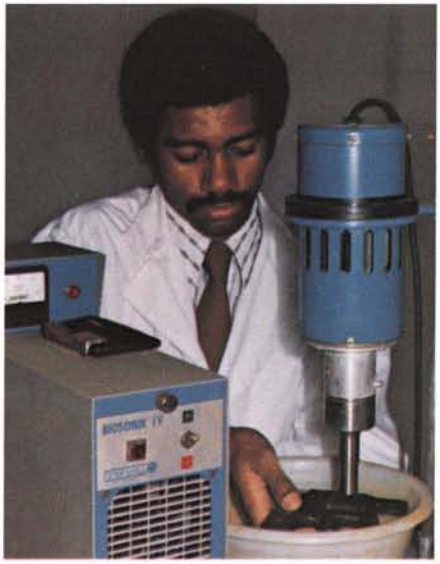
Lowered into the water at a selected site, the system's sensors acquire data—for example, the presence of harmful microorganisms—and automatically transmit the information to the helicopter cockpit, where it is recorded. The helicopter then flies to the next site, covering as many as 28 closely-located data stations in one hour. The system greatly increases the number of samples EPA can take in a given time, and the resulting information is more accurate because analysis is immediate. Where tests indicate that more detailed analysis is required, the helicopter-borne probe can obtain a water sample for laboratory use. In developing the system, Langley Research Center adapted several aerospace technologies, particularly microelectronics.

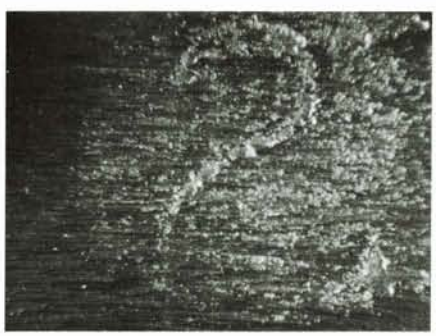
Weather Forecasting Aid

Weather forecasters are usually very precise in reporting such conditions as temperature, wind velocity and humidity. They also provide exact information on barometric pressure at a given moment, and whether the barometer is "rising" or "falling"—but not how rapidly or how slowly it is rising or falling. Until now, there has not been available an instrument which measures precisely the current rate of change of barometric pressure. A meteorological instrument called a barograph traces the historical ups and downs of barometric pressure and plots a rising or falling curve, but, updated every three hours, it is only momentarily accurate at each updating.

The instrument pictured below, a spinoff from environmental control technology developed for NASA's Space Shuttle, goes a step further. Called a Barorator and developed by Carleton Controls Corporation, East Aurora, New York, it provides a reading of the barometric rate of change in millibars per hour. The information is provided to the meteorologist every 15 minutes on an automatic printout. Tied in with other weather data, pressure rate of change information adds a useful dimension for predicting exactly when a high or low pressure weather system will reach a particular locale. It is also useful in tracking high altitude air movements such as jetstreams and it has special potential for predicting the onset of severe storms or tornadoes, which are accompanied by sharp drops in barometric pressure. In tests, the Barorator has given two to three hour warnings of severe storms. The instrument is in use at the University of Mexico's Storm Studies Center.

Heart of the Barorator is a vibrating wire pressure transducer which senses and measures pressure changes. In the Space Shuttle, the transducer, together with associated electronic microprocessors, alerts the crew to any measurable increase or decrease in cabin pressure.





Restoration Process

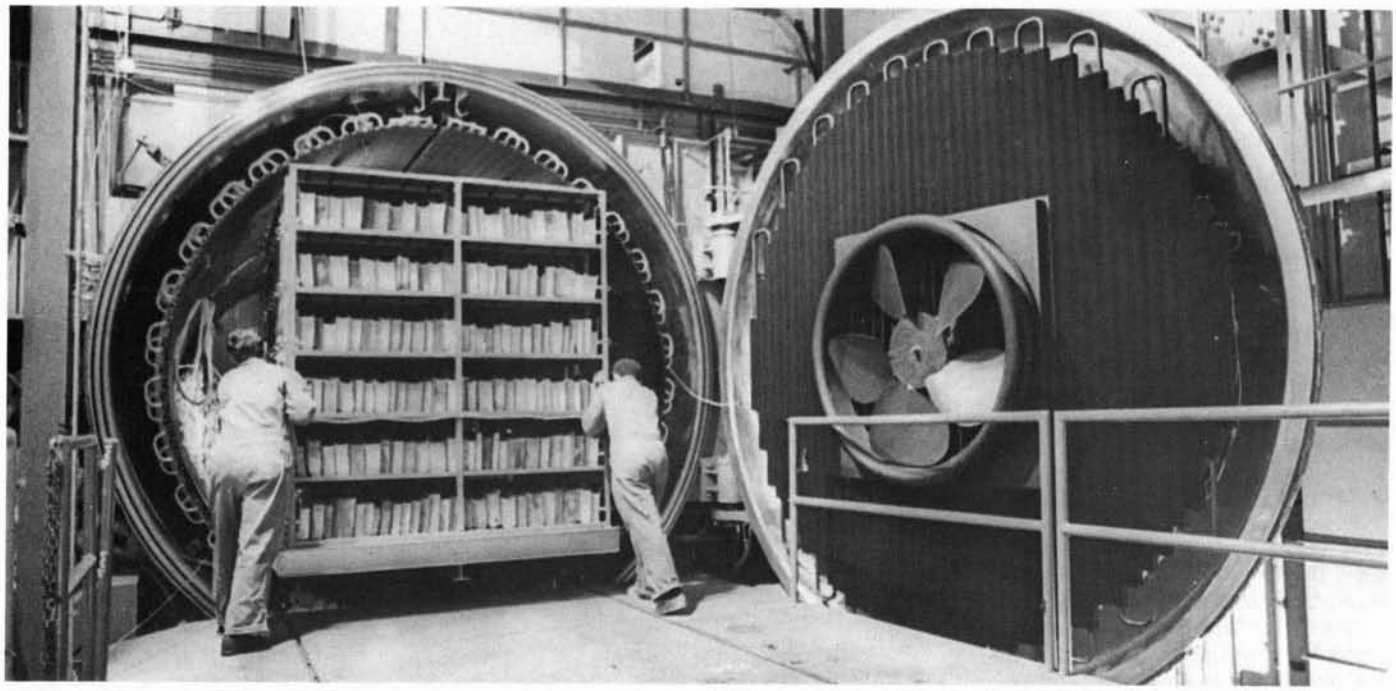
In the accompanying photos, a laboratory technician is restoring the once-obliterated serial number of a revolver. The four-photo sequence shows the gradual progression from total invisibility to clear readability. The technician is using a new process developed in an applications engineering project conducted by NASA's Lewis Research Center in conjunction with Chicago State University.

Serial numbers and other markings are frequently eliminated from metal objects to prevent tracing ownership of guns, motor vehicles, bicycles, cameras, appliances and jewelry. To restore obliterated numbers, crime laboratory investigators most often employ a chemical etching technique. It is effective, but it may cause metal corrosion and it requires extensive preparatory grinding and polishing. The NASA-Chicago State process is advantageous because it can be applied without variation to any kind of metal, it needs no preparatory work and number recovery can be accomplished without corrosive chemicals; the liquid used is water.

The basis of the new process is a phenomenon called "cavitation," which occurs when a liquid is subjected to rapid vibration. Cavitation is the formation of tiny vapor bubbles in the liquid—something like boiling effect, except that vibration rather than heat causes the bubbling. Because the vapor bubbles contain high energy, they etch, or pit, the surface of the metal they strike. In vibrating flight vehicles, cavitation is a major headache—it leads to deterioration of tubes and tanks carrying liquids. But long experience in dealing with the problem enabled NASA-Lewis researchers to effect a turnaround whereby the troublesome phenomenon could be applied beneficially.

In the NASA-Chicago State process, the metal object is immersed in water and a probe is positioned immediately above it. Ultrasonic energy is applied, causing the probe to vibrate rapidly and induce cavitation. The resulting vapor bubbles impact the metal surface and pit it. Pitting around the area where the serial number was stamped gradually restores the number.

With support from the Cleveland (Ohio) Police Department and the National Auto Theft Bureau, Lewis Research Center conducted successful feasibility demonstrations. NASA then enlisted Chicago State University for the task of improving the technique. Last year NASA and Chicago State produced a handbook detailing the new technique and comparing it with other restoration methods. The handbook generated wide favorable response and won the endorsement of a number of civil and military law enforcement agencies.



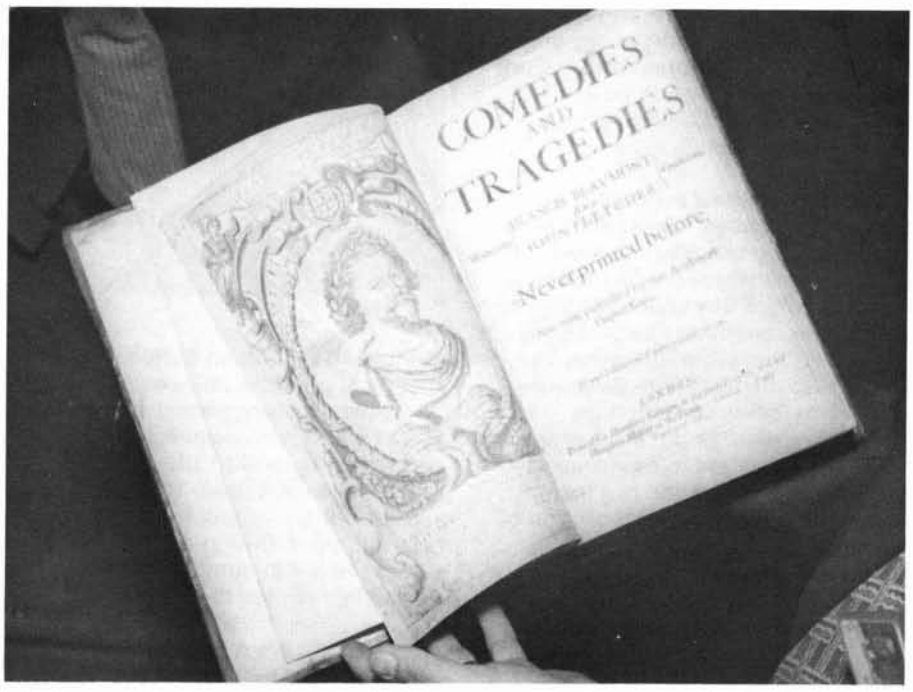
Vacuum Drying Technique

At Valley Forge, Pennsylvania, General Electric Company's Space Division has a large environmental chamber for simulating the conditions under which an orbiting spacecraft operates. Normally it is used to test company-built space systems, such as NASA's Landsat and Nimbus satellites. It is also being used in a novel spinoff application—restoring water-damaged books and other paper products and textiles.

This unique technology transfer began in 1972 when Temple University's Klein Law Library caught fire. In the course of extinguishing the fire, almost 60,000 books, some irreplaceable, were completely soaked by tons of water from high-pressure fire hoses. Looking for a means of salvage, Temple's insurance company contacted GE's Space Division, whose officials felt that the space vacuum chamber could be effectively employed as a dryout tank. Temple's books were loaded onto wheeled racks and placed in the chamber 4,000 at a time; the upper photo shows one rack of 750 Temple volumes being wheeled into the 3,000-cubic-foot chamber. The technique worked and Klein Law Library's books are back on their shelves. GE is now providing the service regularly, treating items damaged by storms, floods, fire-fighting activities, waterline ruptures or other environmental conditions. An example of a badly water logged book restored to excellent condition is the rare 17th century volume shown in the photo at right.

When the books are in place and the vault-like door secured, chamber pressure is reduced to spacelike conditions of 1/100th of an atmosphere, promoting evaporation of water. As the water evaporates, it freezes in the near-vacuum. After 24 hours, pressure is increased to break the vacuum. Then hot freon gas is introduced to the chamber, causing the ice to melt; the water is drained off through an opening in the chamber. This process is repeated until the damaged materials are thoroughly dry.

The process represents a major improvement over an existing method, which involves blotting individual pages by hand and air-drying them slowly at a cost of about $100 a volume. The space simulator process costs only $2 per book. GE has used it to dry many loads of books, blueprints, important government records, historical documents, a stamp collection and several thousand pairs of shoes. Among the numerous customers who have benefited from the technique are the University of Pittsburgh, Otis Elevator, Corning Glass, the Paul Mellon estate, Hillside Jewish Memorial Hospital and a number of state, city and county governments.



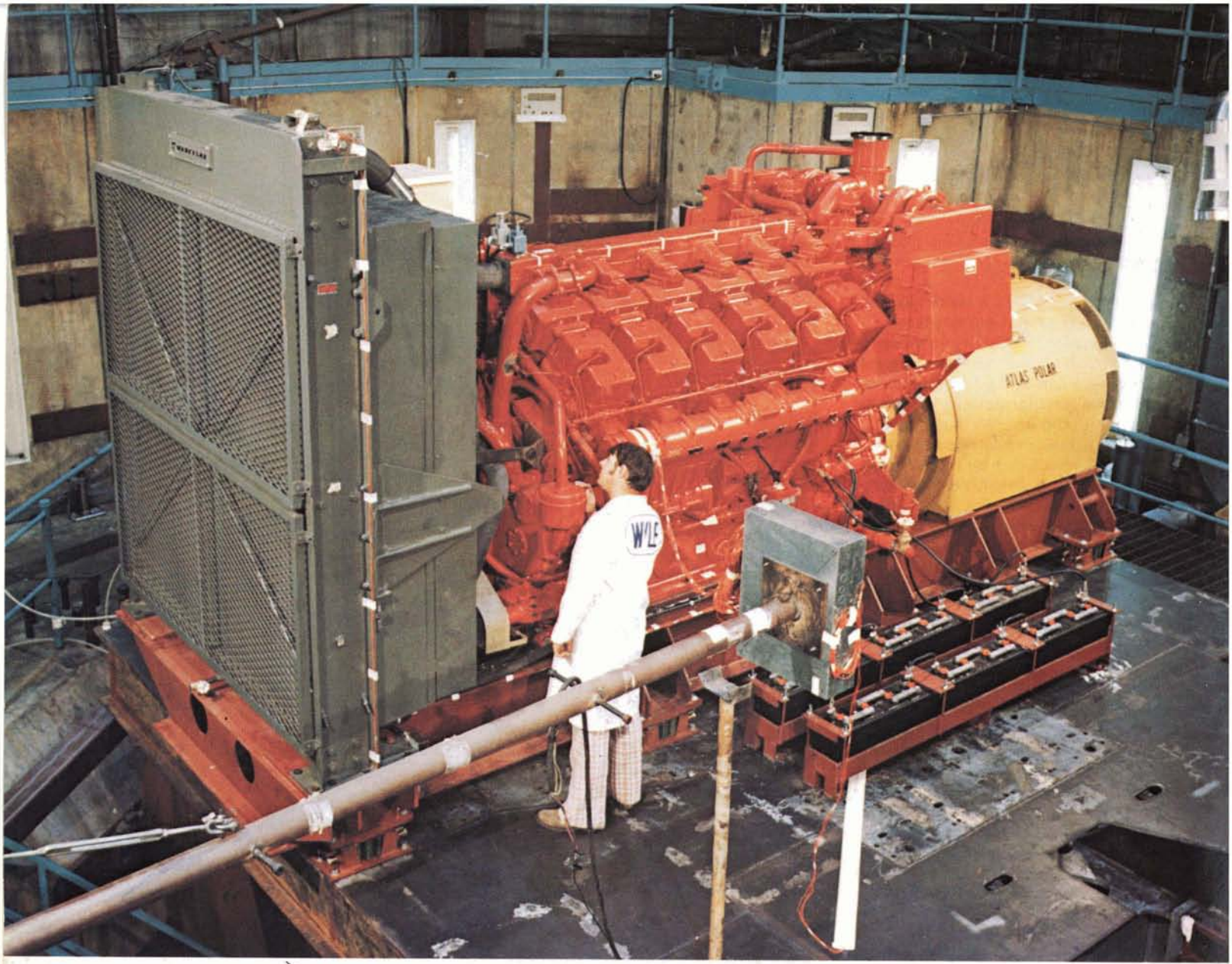
Airport Safety Aid

An airplane generates a wake like that of a ship, except that the airplane's wake is invisible. The plane's movement through the air creates—at each wing tip—a "vortex," a turbulent wind moving in a circular pattern like an air whirlpool. Large aircraft, such as commercial jetliners, produce powerful vortices which can be hazardous to small planes following closely behind. For that reason, the Federal Aviation Administration requires a five-mile spacing between large and small aircraft approaching a runway, to allow time for the vortices to dissipate. At busy terminals, this spacing requirement restricts landing operations and contributes to airport congestion.

With an eye toward reducing the spacing requirement while assuring lightplane safety, the Department of Transportation is conducting research on the characteristics of aircraft wake. The spinoff system pictured—atop the checkerboard van in the lower photo and in close-up at upper right—is producing valuable information which will enable airport controllers to determine when it is safe for a lightplane to land. Developed by Lockheed Missiles and Space Company, Sunnyvale, California, it is called a Laser Doppler Velocimeter, or LDV.

The LDV was originally developed by NASA's Marshall Space Flight Center for use in measuring airflow disturbances in wind tunnels and in flight. Lockheed was one of the contractors working with Marshall on the LDV project, and the company has applied that experience to development of the new remote wind sensing system.

Lockheed's LDV takes advantage of aerosols normally present in the atmosphere—dust particles, for example—to reflect infrared light beamed out by a laser. The reflected radiation is picked up by the LDV, and since the aerosols move with the wind, it is possible to measure wind velocities, including aircraft wake winds and turbulence. The LDV's computer translates radiation reflected by the aerosols into graphic displays which make it possible to measure the severity of vortices generated by large aircraft and how long it takes them to dissipate. Last year the LDV was used to monitor more than 2,500 jetliner landings at Chicago's O'Hare International Airport. The LDV has applicability beyond wake turbulence research. It can be used as a meteorological tool to measure winds aloft with greater accuracy than weather balloons, or as a means of measuring smokestack pollution dispersion patterns.



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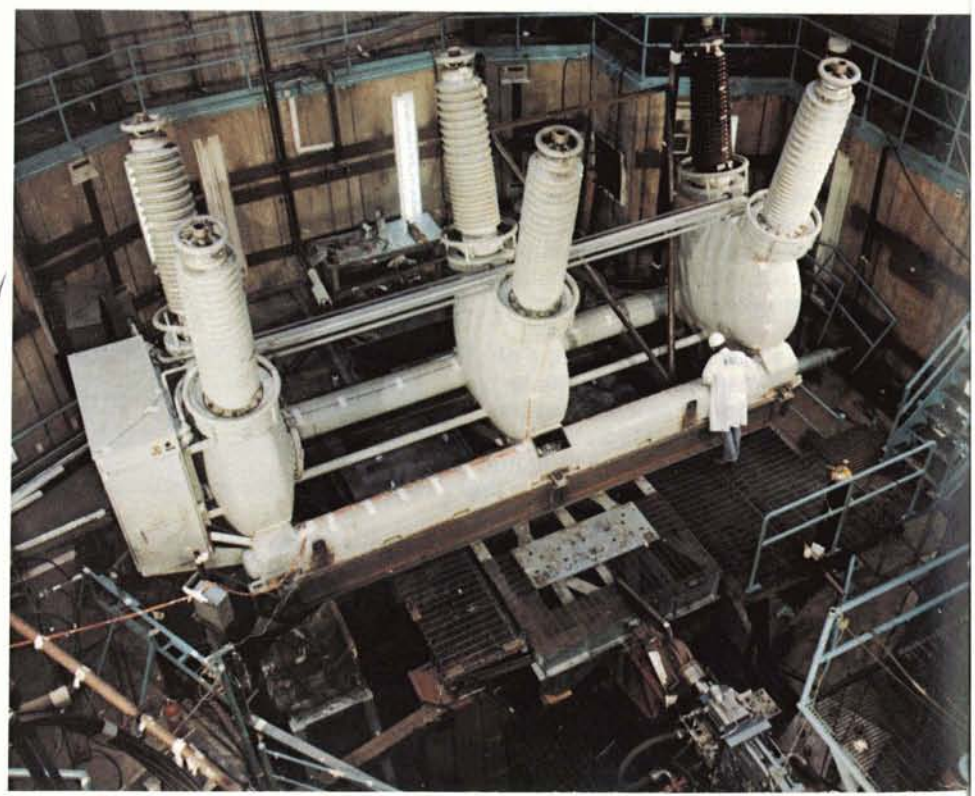

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Earthquake Testing

During NASA's Apollo program, it was necessary to subject the mammoth Saturn V launch vehicle to extremely forceful vibrations to assure the moonbooster's structural integrity in flight. Marshall Space Flight Center assigned vibration testing to a contractor, the Scientific Services and Systems Group of Wyle Laboratories, Norco, California. Wyle-3S, as the group is known, built a large facility at Huntsville, Alabama, and equipped it with an enormously forceful shock and vibration system to simulate the liftoff stresses the Saturn V would encounter.

Saturn V is no longer in service, but Wyle-3S has found spinoff utility for its vibration facility. It is now being used to simulate earthquake effects on various kinds of equipment, principally equipment intended for use in nuclear power generation. Government regulations require that such equipment demonstrate its ability to survive earthquake conditions. In upper left photo, Wyle-3S is preparing to conduct an earthquake test on a 25-ton diesel generator built by Atlas Polar Company, Ltd., Toronto, Canada, for emergency use in a Canadian nuclear power plant. Being readied for test in the lower left photo is a large circuit breaker to be used by Duke Power Company, Charlotte, North Carolina. Electro-hydraulic and electro-dynamic shakers in and around the pit simulate earthquake forces.

Wyle-3S has had extensive aerospace research experience and has been particularly successful in developing spinoff applications. In addition to earthquake testing, the company has adapted its shaking technology to simulation of dynamic transportation environments, in order to evaluate effects on such equipment as railway cars, rail or road-transported cargo, and truck refrigeration units. A variation of this technology provides a non-destructive method of testing highway pavements.

In its work for NASA, Wyle-3S also developed technology for data acquisition and processing systems. A number of spinoff applications have evolved from this experience. Examples include systems for processing data to evaluate solar heating and cooling equipment and microprocessors for recording data on aircraft, auto and truck noise. Another example of how this technology is being applied is illustrated in the photo below. The boat pictured is equipped with a portable microprocessor system which records data on the performance of pleasure boat operators and how they are affected by noise, fatigue and other environmental and psychological factors. The tests are being conducted by Wyle-3S for the U.S. Coast Guard as part of a program designed to improve boating safety.

A propulsion system for boats and small ships leads a sampling of spinoffs in the field of transportation

Space-Derived Waterjets

The American Enterprise, *a high speed crewboat and supply vessel for the offshore oil industry, is propelled by three Rocketdyne waterjets. The propulsion units are direct spinoffs from the company's line of turbopumps, which feed propellants to rocket engines on space launch vehicles.*

On Apollo lunar missions, the five mighty engines of the Saturn V moonbooster delivered an aggregate launch thrust of more than seven and a half million pounds. In producing thrust of such enormous order, the engines gulped liquid propellants at the incredible rate of 200,000 gallons per minute. The important job of feeding propellants to the engines under high pressure was handled by systems called turbopumps.

The turbopumps in Saturn V were the most powerful ever employed in space launches, but pumping systems of lesser capacity are used in most liquid rocket launch vehicles. The principal manufacturer of high-performance space-use turbopumps is Rocketdyne Division of Rockwell International, Canoga Park, California, which has built more than 7,000 of them. Now Rocketdyne is producing direct derivatives of its space-developed turbopumps for nonspace applications. Called Powerjets, they are propulsion systems for high speed boats and small ships.

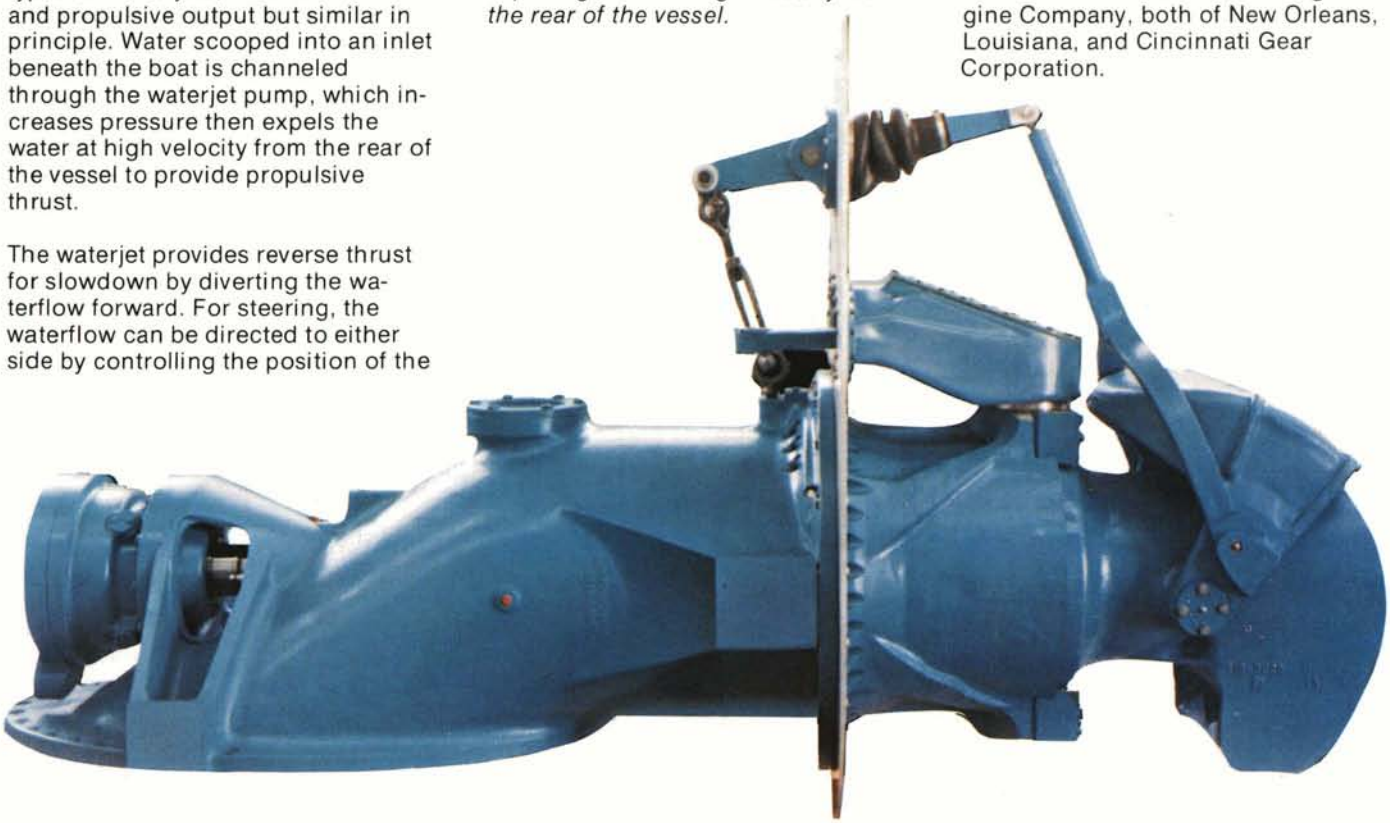
The company manufactures three types of Powerjets, different in size and propulsive output but similar in principle. Water scooped into an inlet beneath the boat is channeled through the waterjet pump, which increases pressure then expels the water at high velocity from the rear of the vessel to provide propulsive thrust.

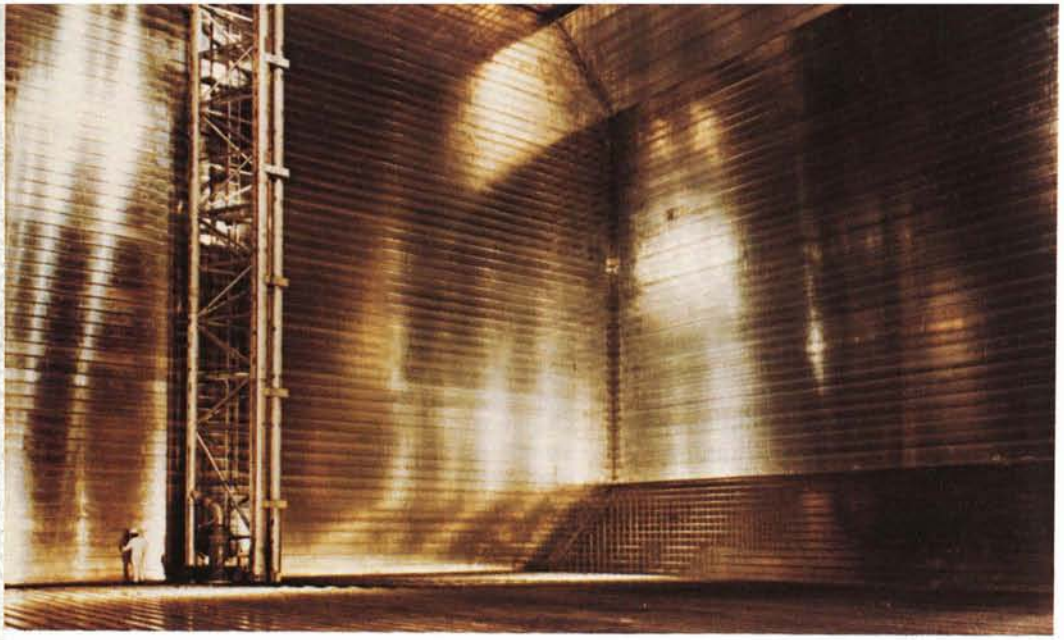
The waterjet provides reverse thrust for slowdown by diverting the waterflow forward. For steering, the waterflow can be directed to either side by controlling the position of the waterjet's outlet nozzle; this allows elimination of the rudder, which in turn permits boat operation in very shallow water. The simplified design of the waterjet pumps also contributes to ease of maintenance.

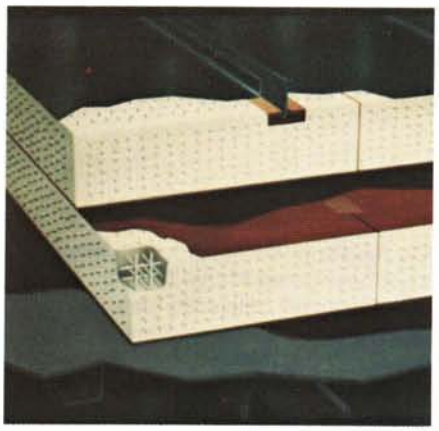
Rocketdyne's mid-size pump, Powerjet 20, has demonstrated reliability in more than 26,000 hours of operation aboard The Boeing Company's Jetfoil passenger boats, whose design also incorporates other aerospace technology. Two Powerjets, driven by Detroit Diesel Allison gas turbine engines, propel the Jetfoil at 45 knots. Capable of carrying up to 300 passengers, Jetfoils are operating across the South China Sea between Hong Kong and Macao, on inter-island service in the Sea of Japan, and on island-to-mainland service in Venezuela. Two new services across the English Channel will start this year, one from London to Ostend (Belgium), another from Brighton (England) to Dieppe (France). Next spring Jetfoil service connecting Dublin (Ireland) and Liverpool (England) will be inaugurated.

The latest application of the Powerjet line is to the *American Enterprise,* a high-speed (35-38 knots) crewboat designed primarily to serve the offshore petroleum industry; it offers considerably faster surface transfer of crews and supplies to offshore oil rigs than is available with current vessels. The 105-foot, 90-passenger crewboat is driven by three pumps, a centerline Powerjet 24, largest of Rocketdyne's pumps, and two smaller Powerjet 16s. The *American Enterprise* was developed by a five-company team, including Rocketdyne and Detroit Diesel Allison division of General Motors, whose engines power the pumps; other developers include Halter Marine Services, Inc. and George Engine Company, both of New Orleans, Louisiana, and Cincinnati Gear Corporation.

The Powerjet 24 shown is the primary propulsion pump for the American Enterprise, *which also has two smaller pumps. These spinoff waterjets provide propulsive thrust by expelling water at high velocity from the rear of the vessel.*







layers of a new type of 3D designed specifically for the special needs of LNG containment. Above is a cutaway of the combined Invar-3D system. The top layer of Invar is the primary barrier, in physical contact with the LNG. The secondary barrier, shown in white, consists of two four-inch layers of 3D separated by a fiberglass liner. The Gaz-Transport/McDonnell Douglas system offers reduced boiloff, high strength, low cost and long durability.

First use of Invar-3D will be aboard two LNG ships now under construction; the cutaway view in the bottom photo shows one of the insulated tanks at midship. These ships are being built by the Sun Shipbuilding and Dry Dock Company, Chester, Pennsylvania, for Western LNG Terminal Associates, a subsidiary of Pacific Lighting Corporation, Los Angeles, California. Beginning in 1982, they will carry LNG from Alaska to California, where the fuel will be converted to gaseous state for distribution to consumers by Southern California Gas Company, Pacific Lighting's utility subsidiary, and by Pacific Gas and Electric Company, San Francisco, California.

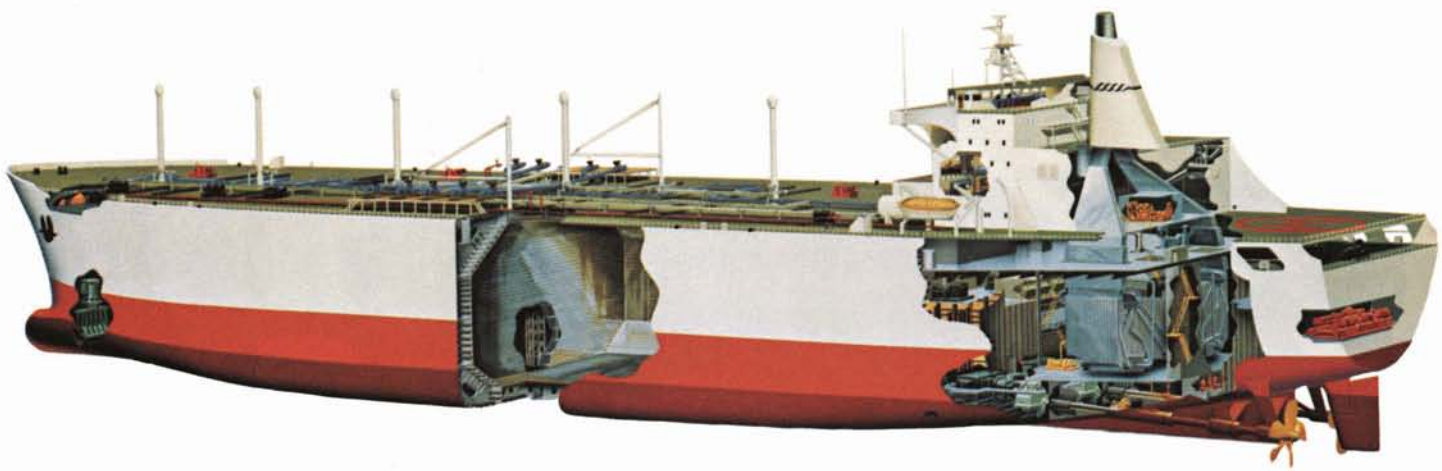
Tank Insulation

For NASA's Apollo program, McDonnell Douglas Astronautics Company, Huntington Beach, California, developed and built the S-IVB, uppermost stage of the three-stage Saturn V moonbooster. An important part of the development task was fabrication of a tank to contain liquid hydrogen fuel for the stage's rocket engine. The liquid hydrogen had to be contained at the supercold temperature of 423 degrees below zero Fahrenheit. The tank had to be perfectly insulated to keep engine or solar heat from reaching the fuel; if the hydrogen were permitted to warm up, it would have boiled off, or converted to gaseous form, reducing the amount of fuel available to the engine.

McDonnell Douglas' answer was a supereffective insulation called 3D, which consisted of a one-inch thickness of polyurethane foam reinforced in three dimensions with fiberglass threads. Over a 13-year development and construction period, the company built 30 tanks and never experienced a failure. Now, after years of additional development, an advanced version of 3D is finding application as part of a containment system for transporting Liquefied Natural Gas (LNG) by ship.

For ship movement, converting gas to liquid form reduces its volume by more than 600 times, making it an easily manageable and economically attractive cargo. LNG is reconverted to gaseous state after it reaches destination. Like space-used liquid hydrogen, LNG must be contained at very low temperatures—about 260 degrees below zero Fahrenheit—to prevent loss by boiloff.

McDonnell Douglas Astronautics has teamed with a French firm—Gaz-Transport S.A.R.L. of Paris—in development of an advanced technology liquefied gas containment system for LNG carrier ships. Gaz-Transport had earlier developed a metal insulating membrane called Invar, which has already logged several million safe sea miles aboard LNG ships; the upper left photo shows the interior of an Invar-insulated shipboard tank. The new jointly developed system couples an outer layer of Invar with inner



Weight-Saving Technology

The helicopter pictured is the twin-turbine S-76, produced by Sikorsky Aircraft division of United Technologies, Stratford, Connecticut. It is the first transport helicopter ever designed purely as a commercial vehicle rather than an adaptation of a military design. Being built in large numbers for customers in 16 countries, the S-76 is intended for offshore oil rig support, executive transportation and general utility service. The craft carries 12 passengers plus a crew of two and has a range of more than 450 miles—yet it weighs less than 10,000 pounds. Significant weight reduction was achieved by use of composite materials, which are generally lighter but stronger than conventional aircraft materials.

NASA composite technology played a part in development of the S-76. Under contract with NASA's Langley Research Center, Sikorsky Aircraft designed and flight-tested a helicopter airframe of advanced composite materials. The materials and the experience gained in the NASA project were subsequently incorporated in the design of the S-76. By using composites instead of traditional materials in such components as the horizontal stabilizer, tail rotor, doors, pylons, fairings, cockpit canopy and floors, Sikorsky was able to save about 30 percent in the weight of these components. The weight-saving contributed to a substantial increase in the helicopter's performance. Sikorsky's NASA work also led to use of composites in the company's Army Black Hawk combat support helicopter and the Navy/Marine Corps CH-53 transport helicopter, both being produced in quantity.

Aircraft Design Analysis

The airplane shown below is the Beech Super King Air, an executive transport built by Beech Aircraft Corporation, Wichita, Kansas. Its development was aided by the NASA computer program known as NASTRAN® (NASA Structural Analysis), which electronically analyzes a computerized design and predicts how it will react to many different conditions of stress and strain. In this instance the program was employed in analysis of the airplane's structure and engine mounts.

NASTRAN was similarly used in development of other Beech planes, such as the T-34C military trainer and the new single-engine Skipper lightplane, which is making its debut this year. At its Boulder, Colorado facility, Beech has used NASTRAN in analysis of fuel tanks for space vehicles. The company reports it has achieved cost savings and improved its design/analysis capabilities through use of the NASA program. NASTRAN and other government-generated computer programs are made available to industry through NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia.

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Preserving Perishables

A new commercial product that can preserve perishable commodities for weeks without freezing, so that they can be shipped fresh without the cost of air freight, has been developed by Grumman Corporation, Bethpage, Long Island, New York. The development benefited from the company's experience in developing the environmental control system for the Lunar Module, which delivered Apollo astronauts to the surface of the moon.

Called Dormavac, the system provides a commodity-preserving environment within an aluminum container (shown above and at left) that can be transported by truck, rail or ship. Dormavac creates a cold—but above freezing—environment with high relative humidity and very low air pressure. The saturated air minimizes commodity weight loss and the air is automatically changed several times

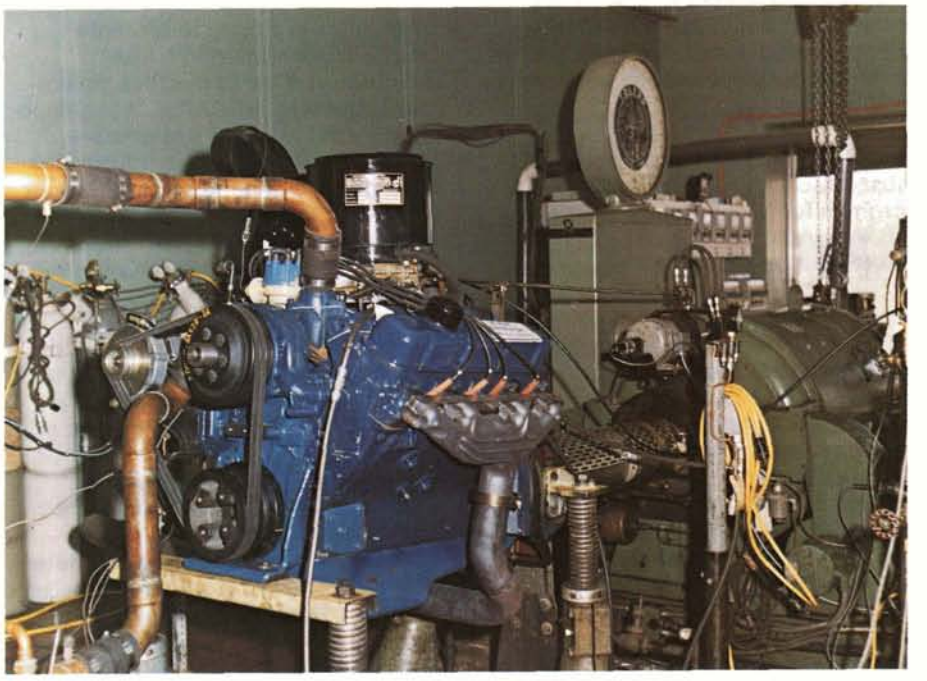
an hour to flush away odors and harmful gases released by the commodities. According to company literature, Dormavac significantly extends the transportation life of perishables. For example, pork has a normal cold storage life of about seven days, beef two weeks and tomatoes three weeks; with Dormavac, pork remains fresh for three weeks, beef more than six weeks and tomatoes seven weeks or more.

Dormavac is manufactured and marketed by Grumman Allied Industries, Woodbury, New York. In developing the system, Grumman Allied drew upon the technological resources of another company subsidiary, Grumman Aerospace. Engineers who had earlier worked on Lunar Module environmental control brought their know-how and experience to the Dormavac development.

Auto Emissions Testing

The photos at right show automobile engines being tested for nitrous oxide emissions, as required by the Environmental Protection Agency (EPA), at the Research and Engineering Division of Ford Motor Company, Dearborn, Michigan. NASA technical information helped the company develop a means of calculating emissions test results.

Nitrous oxide emission readings vary with relative humidity in the test facility. EPA uses a standard humidity measurement, but the agency allows manufacturers to test under different humidity conditions, then apply a correction factor to adjust the results to the EPA standard. NASA's Dryden Flight Research Center developed analytic equations which provide a simple, computer-programmable method of correcting for humidity variations. A Ford engineer read a NASA Tech Brief describing the Dryden development and requested more detailed information in the form of a technical support package, which NASA routinely supplies to industry on request. Ford's Emissions Test Laboratory now uses the Dryden equations for humidity-adjusted emissions data reported to EPA.



Highlighting spinoffs in the field of construction is a NASA-developed computer program for analyzing energy considerations in building design

An Energy Saver Called NECAP

Energy requirement has long been a matter of significance in building design, but in recent years planning for utmost energy efficiency has become a matter of paramount importance. Energy prices have risen sharply and the expectation is that they will continue to climb. Thus, architects and engineers must explore every avenue of design innovation to offset soaring fuel costs by reducing energy usage. In so doing, they are getting valuable assistance from a relatively new design tool: the energy analysis computer program, which considers the many factors related to energy consumption of buildings and identifies energy-saving design features for new buildings or modifications to existing facilities.

One of the most comprehensive and most effective programs is NECAP, an acronym for NASA Energy Cost Analysis Program. Developed by Langley Research Center, NECAP operates according to heating/cooling calculation procedures formulated by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). The program enables examination of a multitude of influences on heat flow into and out of buildings. For example, NECAP considers traditional weather patterns for a given locale and predicts the effects on a particular building design of sun, rain, wind, even shadows from other buildings. It takes into account the mass of structural materials, insulating values, the type of equipment the building will house, equipment operating schedules, heat thrown off by people and machinery, heat loss or gain through windows and other openings and a variety of additional details. NECAP ascertains how much energy the building should require ideally, aids selection of the most economical and most efficient energy systems and suggests design and operational measures for reducing the building's energy needs. Most importantly, NECAP determines cost effectiveness—whether an energy-saving measure will pay back its installation cost through monetary savings in energy bills.

Originally developed to promote energy conservation in NASA buildings and those of other government agencies, NECAP is available to commercial building designers—through NASA's Computer Software Management and Information Center (COSMIC) ® at the University of Georgia—and the program has found wide acceptance in the construction industry.

A major NECAP user is McGaughy, Marshall & McMillan of Norfolk, Virginia, one of the world's leading architectural engineering firms and a pioneer in computer-aided construction planning. Five years ago, McGaughy, Marshall & McMillan started development of an energy conservation/management computer program. The firm compared a number of commercially available programs and ultimately selected NECAP as the one which considered more variables than the others investigated. McGaughy, Marshall & McMillan purchased NECAP from COSMIC, adapted it to the firm's own computer, refined it and, beginning in 1977, put it into service. In that year, NECAP demonstrated its effectiveness on three major company projects, including the design of two new buildings for the U.S. Navy and modification of an older government building in Washington, D.C.

Since then, McGaughy, Marshall & McMillan has continued to make extensive use of NECAP as a primary planning and evaluation tool in the firm's widespread operations, which include design and supervision of construction projects costing more than $100 million annually. A current example involves development and construction of the Georgia Public Safety Training Center. The Center, a project of the Georgia State Office of Planning and Budget, is intended to serve as a large "university" which will provide academic and operational training for state and local peace officers, firefighters, correction officials and other state safety personnel. This project represents a special challenge with regard to designing for energy efficiency because of the many different building environments—academic, training, administrative, dormitory, medical, security and food service facilities, together with a number of special laboratories. To prevent potentially enormous energy losses resulting from the extremely diverse nature of the Center's activities, McGaughy, Marshall & McMillan is using NECAP to incorporate maximum energy efficiency into the

plans. NECAP's contribution to anticipated energy cost savings has not yet been computed, but the Norfolk firm expects it to be "impressive."

In another Georgia project, Georgia Institute of Technology is using NECAP for a comprehensive analysis of the factors involved in controlling the environments of campus buildings. The university is developing a computer-directed system for monitoring and controlling energy expenditure in 85 campus buildings, 14 of which are already being monitored. The goal is to reduce energy consumption by 20 percent and the potential savings run to millions of dollars.

In addition to McGaughy, Marshall & McMillan, a number of other large architectural-engineering firms are using in-house versions of NECAP, among them Stearns-Roger Incorporated of Denver, Colorado; Smith, Henchman and Grylls, Detroit, Michigan; and TEC Incorporated, Kansas City, Missouri. NECAP has also served as the basis for a number of other widely used programs developed by such organizations as the Corps of Engineers, the State of California working jointly with the Department of Energy, and GARD, Incorporated, a Chicago-based architectural and engineering firm.

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This drawing shows the layout of the planned Georgia Public Safety Training Center, a multi-building complex for training state and local police, fire fighters and other safety personnel. The Center is being designed with careful attention to energy conservation, but it poses a challenge because of the many different building environments. For example, the academic building (Number 5 above), administration building (6), dormitory (10), weapons training center (11), vehicle maintenance building (13), sewage plant (21) and fire research laboratory (24) have substantially different energy requirements and involve different energy-saving design measures. The designers—McGaughy, Marshall & McMillan of Norfolk, Virginia—expect to achieve large scale energy cost savings through use of the NASA Energy Cost Analysis Program (NECAP), a comprehensive computer program which is helping architects and engineers design for maximum energy efficiency.

The firm of McGaughy, Marshall & McMillan used NECAP in planning construction of this striking structure, a club for enlisted personnel at the U.S. Naval Academy, Annapolis, Maryland. NECAP is an energy analysis computer program which considers the many factors related to building energy consumption and identifies energy-saving design features.

The building shown is one of 85 facilities on the campus of Georgia Institute of Technology involved in a major energy conservation program. The university is installing a central computer-directed system for monitoring and controlling energy expenditure in the buildings, aiming to reduce energy consumption by 20 percent. NECAP is being used to analyze the many influences which must be taken into consideration in controlling building environments.

Oil Industry Aids

The accompanying photos show two types of offshore oil platforms used by Exxon Corporation. In the upper photo is a leg-supported gravity platform; the other structure is a "jacket-type" platform, built in sections, towed to sea and assembled on-site. In construction of platforms like these, Exxon Production Research Company, Houston, Texas, conducts extensive structural investigations of decks, supporting members and other platform components, making use of the NASTRAN ® (NASA Structural Analysis) computer program. NASTRAN is a predictive tool which analyzes a computerized design and reports how the structure will react to a great many conditions it will encounter in its operational environment; in this case, NASTRAN studies the effects of waves, winds, ocean storms and other stress-inducing factors. NASTRAN allows Exxon Production Research to perform more complex and more detailed analysis than was possible with previous programs. The same program has also been used by Exxon Research and Engineering Company, Florham Park, New Jersey, in analysis of pressure vessels, turbine components and composite building boards.

NASTRAN is made available to the Exxon companies through NASA's Computer Software Management and Information Center (COSMIC), which routinely supplies computer programs developed by NASA and other government agencies to interested industrial firms. In addition to NASTRAN, several other COSMIC programs have found use among Exxon subsidiaries and affiliates. For example, Exxon Production Research has used the Ship Hull Characteristics Program (SHCP) to evaluate the stability and strength of drillships and barges, aiding company selection of vessels to be leased. The same company has also used a program called SMIPS (Small Interactive Image Processing System) to study the potential of satellite imagery in exploring for mineral and hydrocarbon deposits. Exxon Research and Engineering Company has incorporated a COSMIC subroutine into its Steam Network Program, employed in analyzing energy requirements for production of petrochemicals. Exxon Company, U.S.A., Houston, Texas, has used COSMIC's SUPERMON to monitor and help improve the performance of the company's computing systems. Collectively, use of COSMIC programs has resulted in savings to the Exxon group running into millions of dollars.

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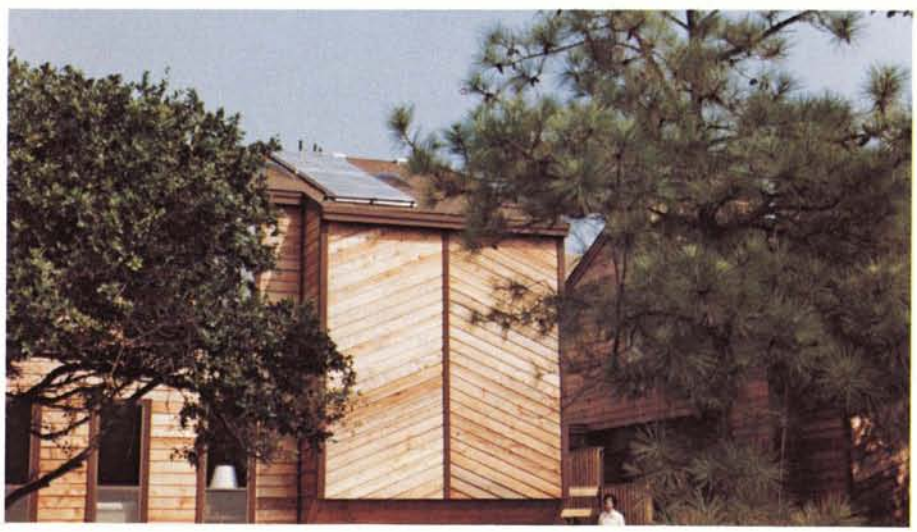
Pipelaying Barges

The vessel pictured is the *Hugh Gordon*, a pipelaying barge designed and built by Brown & Root, Inc., Houston, Texas. The largest engineering and construction firm in the United States, Brown & Root is engaged in such activities as construction of chemical and petroleum plants, pulp and paper plants, highways and bridges, and offshore petroleum facilities. The computer program SHCP (Ship Hull Characteristics Program) is used by Brown & Root engineers as a tool in designing barges, such as the one shown, for offshore pipelaying projects. Made available to industry by NASA's Computer Software Management and Information Center (COSMIC), SHCP is a composite program designed to solve basic naval architecture problems and to assess the structural integrity and stability of a vessel design; it is used extensively by marine industry designers.

Solar Systems

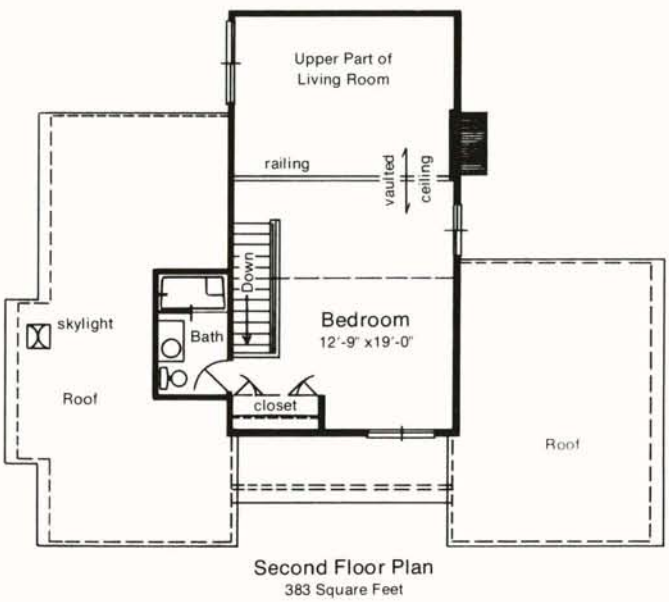
The solar collectors shown are elements of domestic solar hot water systems produced by Solar One Ltd., Virginia Beach, Virginia. Design of these systems benefited from technical expertise provided Solar One by NASA's Langley Research Center. The company obtained a NASA technical support package describing the design and operation of solar heating equipment in NASA's Tech House, a demonstration project in which aerospace and commercial building technology are combined in an energy-efficient home. Solar One received further assistance through personal contact with Langley solar experts. The company reports that the technical information provided by NASA influenced Solar One's panel design, its selection of a long-life panel coating which increases solar collection efficiency, and the method adopted for protecting solar collectors from freezing conditions.



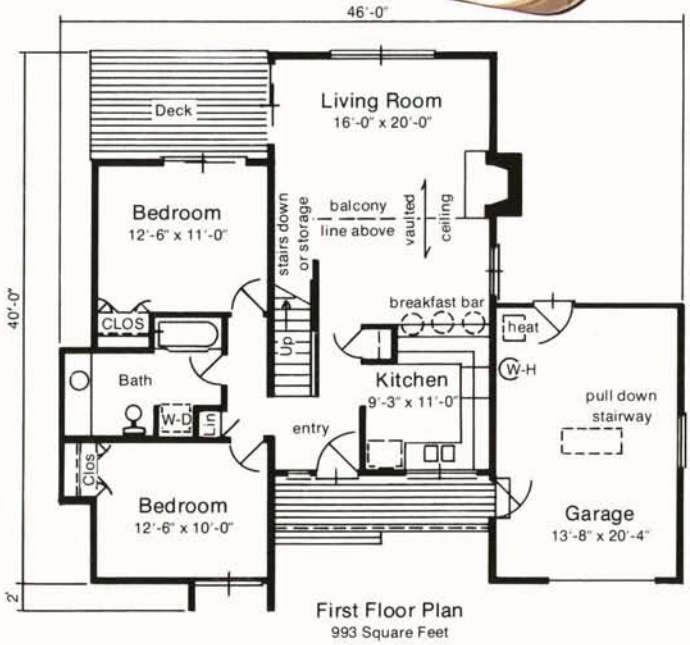
Solar Schematic

The home shown at right is specially designed to accommodate solar heating units; it has roof planes in four directions, allowing placement of solar collectors for best exposure to the sun. Plans (bottom) and complete working blueprints for the solar-heated house are being marketed by Home Building Plan Service, Portland, Oregon.

The company also offers an inexpensive schematic (center) showing how a homeowner only moderately skilled in the use of tools can build his own solar energy system, applicable to new or existing structures. The schematic is based upon the design of a low-cost solar home heating system built and tested by NASA's Langley Research Center; used to supplement a warm-air heating system, it can save the homeowner about 40 percent of his annual heating bill for a modest investment in materials and components. Home Building Plan Service saved considerable research time by obtaining a NASA technical report which details the Langley work. The resulting schematic includes construction plans and simplified explanations of solar heat collection, collectors and other components, passive heat factors, domestic hot water supply and how to work with local heating engineers.



Second Floor Plan
383 Square Feet



First Floor Plan
993 Square Feet

An automated system for analyzing microorganisms in the human body heads an array of spinoff developments in the field of health and medicine

A New Tool for the Hospital Lab

Hospital costs being what they are these days, any innovation that offers reduced hospital stay-time is a very welcome advance in health care service. One such innovation, a space spinoff, is a time-saving system for analyzing a patient's body fluid sample; it automatically detects harmful microorganisms, identifies the type of microbe that is causing the infection, and in some cases suggests the most effective treatment.

Called the AutoMicrobic System (AMS), it is the product of years of research and development by McDonnell Douglas Corporation. The project originated in a NASA-sponsored study aimed at development of a fully-automated microbial detection and identification system for the space program. AMS is now commercially available through Vitek Systems, Inc., Hazelwood, Missouri, a McDonnell Douglas subsidiary.

The multi-module AutoMicrobic System (AMS), whose development stemmed from space-biomedical research, is an automatic, time-saving system for detecting and identifying disease-producing microorganisms in the human body.

The traditional manual method of testing for harmful microorganisms, or pathogens, requires these steps: First, specimens of body fluid—urine, for example—are prepared in cultures. These cultures are, in effect, "food" for specific types of microbes. The cultures are incubated for two to three days and studied for cell growth; from such study microbiologists can determine the presence of disease-producing organisms and identify the pathogens.

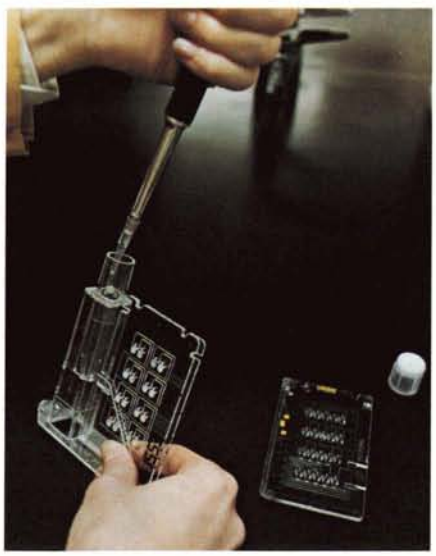
AMS does the same job quicker. Specimens are exposed to microbe nutrients for the nine most common pathogens. During a 4 to 13 hour incubating cycle, an electro-optical scanner studies each specimen once an hour. Changes in cell growth on each culture are monitored by computer. When growth reaches a predetermined level, it indicates the presence of pathogens. The system automatically enumerates the pathogens and specifies the type. On push-button command, the information is displayed in video or reported on a printout.

AMS enables the microbiology laboratory to furnish guidelines for antimicrobial therapy the day after specimen collection; this amounts to a time saving of 50-80 percent over standard laboratory methods. The system also minimizes human error, reduces technician time and increases laboratory output, for AMS can handle up to 240 specimens at one time. Of greatest importance to the patient is shorter time in the hospital due to faster analysis of the infection and earlier treatment.

The basic AMS has recently been improved by development of an additional capability called "susceptibility testing." When the system's count of an identified pathogen shows a level potentially harmful to the patient, a growth sample is subjected to several different microbe-killing agents, such as penicillin or other antibiotics. AMS watches the reactions to determine which drug would be most effective in eliminating the pathogens. The Food and Drug Administration has approved susceptibility testing for one type of bacteria—a common form known as *E. coli*—and expansion of this capability to other types is planned.

About a dozen of the Vitek systems are now in use at Veterans Administration and university hospitals and a number of additional installations are expected this year. Development work aimed at advancing the overall analysis capability of the system is continuing.

A tray containing the body fluid specimens of several patients, each with its own plastic identification card, is inserted into the AutoMicrobic System. The system automatically prepares cultures, incubates them, analyzes them and reports the presence and identity of pathogens, or harmful microorganisms.



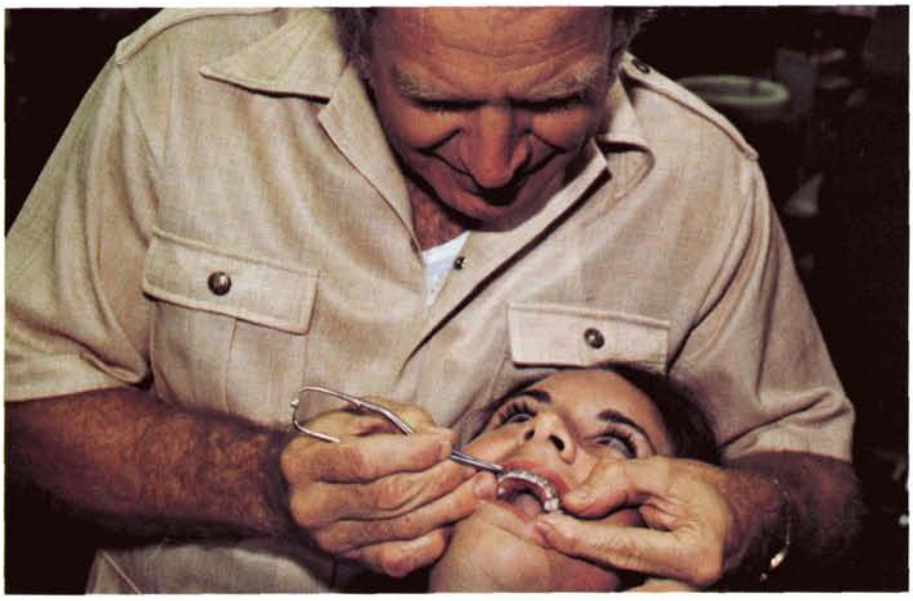
In the photo at left, a laboratory technician is transferring a "positive" growth sample–one known to contain pathogens–from the patient's identity card at right to an injector tube for a further processing step. The AutoMicrobic System will subject the sample to several types of antibiotics and report which drug will most effectively eliminate the infection-causing microbes.

Dental Arch Wire

Straightening teeth is an arduous process requiring months, often years, of applying corrective pressure by means of arch wires—better known as braces—which may have to be changed several times in the course of treatment. A new method has been developed by Dr. George Andreasen, orthodontist and dental scientist at the University of Iowa. The key is a new type of arch wire material, called Nitinol, with exceptional elasticity which helps reduce the required number of brace changes.

An alloy of nickel and titanium, Nitinol was originally developed for aerospace applications by the Naval Ordnance Laboratory, now the Naval Surface Weapons Laboratory, White Oaks, Maryland. NASA subsequently conducted additional research on the properties of Nitinol and on procedures for processing the metal.

In installing the brace, the orthodontist must bend the wire to attach it to out-of-line teeth. When bent, the customarily-used stainless steel wire tends to kink and lose its ability to exert pressure, necessitating frequent adjustment and sometimes a complete brace change. Nitinol has the ability to return to its original shape after bending; it does not kink but continues to pull on the teeth. The comparison photos at the bottom of the page illustrate the alloy's advantage over stainless steel. The arch wire in the left photo is stainless steel, bent once and released; the arch line is irregular. In the right photo is a Nitinol arch wire bent and released 100 times; it still maintains its original shape.



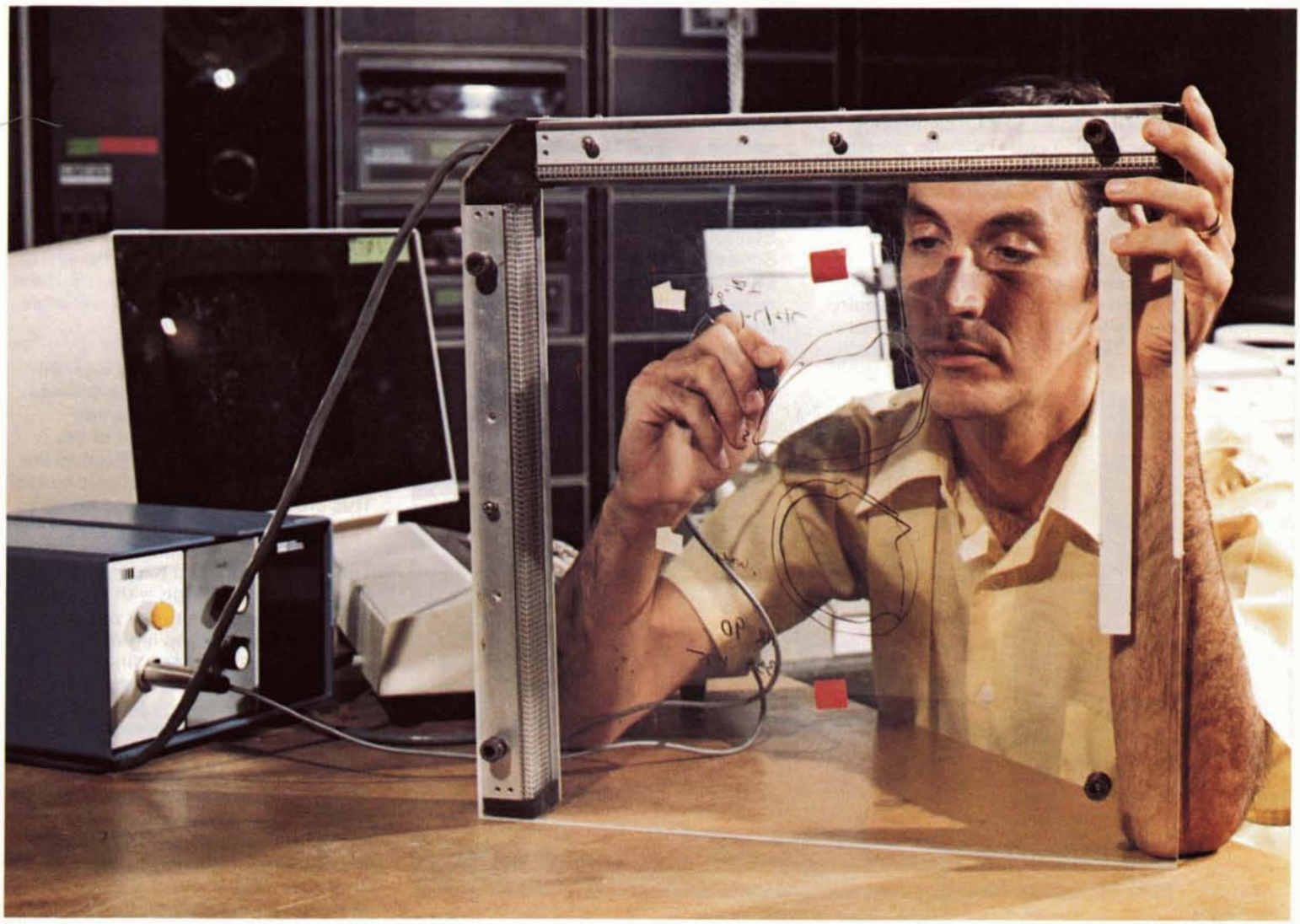
Dr. Andreasen has used Nitinol wire in treatment of many patients and he has found that in some instances the same wire arch can be used for the entire treatment. Patients report less discomfort and in certain cases the continuous pulling effect afforded by Nitinol's elasticity has reduced the frequency of office visits and trimmed overall treatment time. The orthodontic application of Nitinol represents a decade of development by Dr. Andreasen, who was provided assistance by the Naval Ordnance Laboratory and by Unitek Corporation, Monrovia, California. Unitek is now producing several types of Nitinol wire for orthodontic use under the trade name Activ-arch.

Duke Data Bank

NASA computerized image processing techniques are an integral part of a cardiovascular data bank at Duke University Medical Center. Developed by Dr. C. F. Starmer and colleagues at Duke, the data bank documents the Center's clinical experience with more than 4,000 heart patients as an aid to diagnosis and treatment of heart disease. Data is stored in a computerized system that allows a physician to summon detailed records of former patients whose medical profiles are similar to those of a new patient. A video display (photo) and printed report shows prognostic information for the new patient based on similar past experience.

In developing the data bank, the Duke team encountered some difficult problems with respect to need for an input mechanism for graphic data, and for a data storage system capable of using the accumulated information to develop prognoses. NASA's Biomedical Applications Team at Research Triangle Institute, North Carolina, suggested that image processing techniques developed by NASA's Jet Propulsion Laboratory (JPL) might solve these problems. Dr. Starmer took several months of training in image processing at JPL and incorporated the NASA techniques in the data bank.

The system, proving effective at Duke, has also been installed at the Harvard School of Public Health.

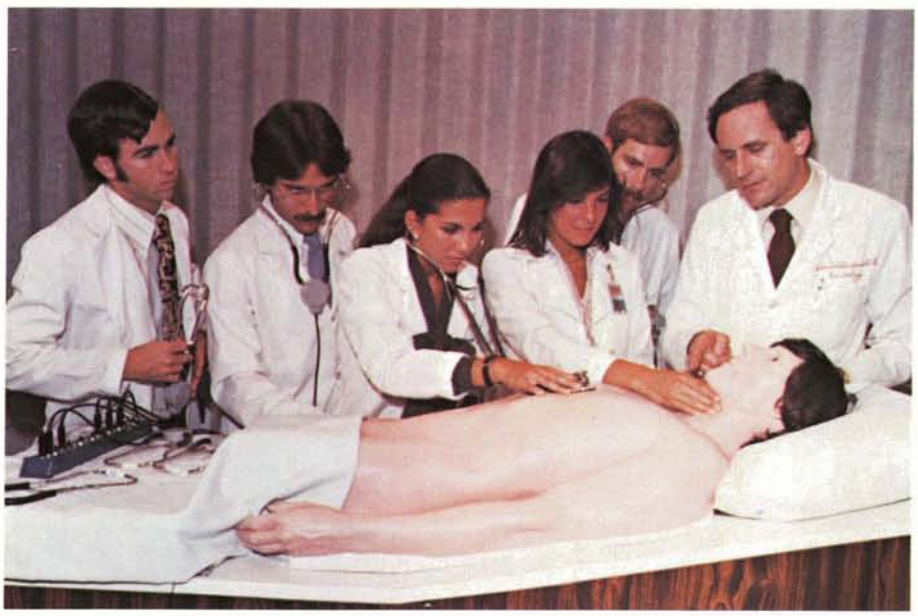


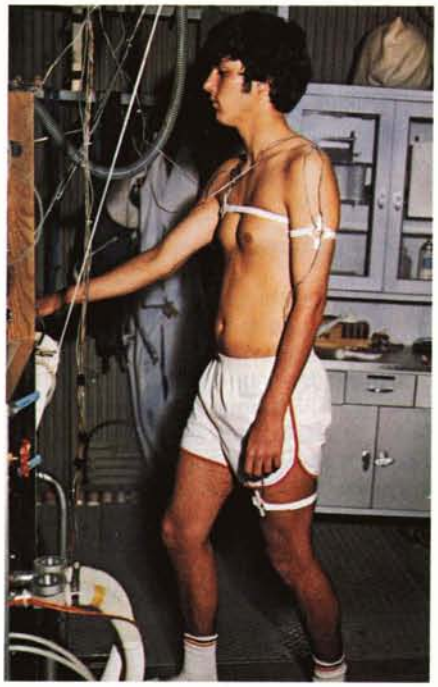
Cardiology Mannequin

Education of medical students in cardiology requires access to patients having a variety of different forms of heart disease. But bringing together student, instructor and patient is a difficult and expensive process that does not benefit the patient. An alternate approach is substitution of a lifelike mannequin capable of simulating many conditions of heart disease. The mannequin pictured below, together with a related information display, is an advanced medical training system whose development benefited from NASA visual display technology and consultative input from NASA's Kennedy Space Center.

The mannequin system represents more than 10 years of development effort by Dr. Michael S. Gordon, professor of cardiology at the University of Miami (Florida) School of Medicine. Dr. Gordon was assisted by colleagues at the medical school, by the New York firm of Messmore & Damon which builds the mannequins, and by NASA's Biomedical Applications Team, Research Triangle Institute, North Carolina. The latter group searched available NASA literature for technology useful to the development. It was able to identify applicable studies of visual information display techniques performed at Kennedy Space Center; these techniques were subsequently incorporated into the mannequin system.

The electronic mannequin simulates 40 heart disease conditions with a high degree of realism, for example, chest movement, pressure in artificial veins and arteries, and sounds of heartbeat rhythms. On the accompanying display unit, the instructor or student can push buttons to call up such information as patient histories, electrocardiograms, x-rays, blood circulation data and responses to medical and surgical treatments. The mannequin has proved a valuable educational aid at the University of Miami, Duke University Medical School, Yale University Medical School and the American College of Cardiology. The system is being produced commercially by Messmore & Damon.





Temperature Measurement Aid

NASA's Ames Research Center has designed a simple but medically-important device—one which holds temperature probes, called thermistors, to a person's skin without affecting the characteristics of the skin segment being measured. The device improves the accuracy of skin surface temperature measurements, valuable data in health evaluation.

The need for such a device was recognized in the course of life science experiments at Ames. In earlier methods, the sensing head of the temperature probe was affixed to the patient's skin by tape or elastic bands. This created a heat variance which altered skin temperature readings.

The Ames-developed thermistor holder is a plastic ring with tab extensions, shown in the upper photo on the chest, arm and leg of the patient undergoing examination. The ring holds the sensing head of the temperature probe and provides firm, constant pressure between the skin and the probe. The tabs help stabilize the ring and provide attachment points for the fastening tape or bands, which do not directly touch the sensor. With this new tool, it is possible to determine more accurately the physiological effects of strenuous exercise, particularly on the treadmill. The holder is commercially available from Yellow Springs Instrument Company, Inc., Yellow Springs, Ohio, which is producing the device under a NASA patent license.

Blood Pressure Checker

An estimated 30 million people in the United States have high blood pressure, or hypertension. But a great many of them are unaware of it because hypertension, in its initial stages, displays no symptoms. Thus, the simply-operated blood pressure checking devices now widely located in public places are useful health aids. The one pictured above, called Medimax 30, is a direct spinoff from NASA technology developed to monitor astronauts in space.

For manned space flights, NASA wanted a compact, highly-reliable, extremely accurate method of checking astronauts' blood pressure without the need for a physician's interpretive skill. NASA's Johnson Space Center and Technology, Inc., a contractor, developed an electronic sound processor that automatically analyzes blood flow sounds to get both systolic (contracting arteries) and diastolic (expanding arteries) blood pressure measurements. NASA granted a patent license for this technology to Advanced Life Sciences, Inc., New York City, manufacturers of Medimax 30.

Medimax 30 is a coin-operated self-checking device that produces blood pressure readings in only 30 seconds—and provides a printed record as well. It is extremely simple; the user puts an arm in the self-adjusting cuff and the rest is completely automatic. Medimax 30 allows the hypertension sufferer to keep ongoing blood pressure records between visits to the doctor's office. It also affords an opportunity for early detection of the disease by the many who are not aware of their problem.

Springback Foam

A decade ago, NASA's Ames Research Center developed a new foam material for protective padding of airplane seats. Now known as Temper Foam, the material has become one of the most widely-used spinoffs. Latest application is a line of Temper Foam cushioning produced by Edmont-Wilson, Coshocton, Ohio for office and medical furniture. The example pictured is the Classic Dental Stool, manufactured by Dentsply International, Inc., York, Pennsylvania, one of four models which use Edmont-Wilson Temper Foam.

Temper Foam is an open-cell, flame-resistant foam with unique qualities.

As illustrated in the before and after photos of the dental stool, the material takes the shape of impressed objects temporarily but springs back to its original shape, even after 90 percent compression. When employed as furniture cushioning, it molds to conform to body shape, evenly distributing weight over the entire contact area for comfort and working efficiency. In other applications, the material absorbs up to 90 percent of impact shocks and becomes firmer after subjected to sudden impact. Among the many applications of Temper Foam are wheelchairs and hospital pads, cushioning for off-road vehicles, and a variety of athletic equipment such as body pads, chest protectors and football helmet liners.

NASA is contributing to national productivity by providing to businesses government-developed computer programs which are adaptable to industrial use

Computer Technology for Industry

In this age of the computer, more and more business firms are automating their operations for increased efficiency in a great variety of jobs, from simple accounting to managing inventories, from precise machining to analyzing complex structures. In the interest of national productivity, NASA is providing assistance both to long-time computer users and newcomers to automated operations. Through a special technology utilization service, NASA saves industry time and money by making available already-developed computer programs which have secondary utility.

A computer program is essentially a set of instructions which tells the computer how to produce desired information or effect by drawing upon its stored input. Developing a new program from scratch can be costly and time-consuming. Very often, however, a program developed for one purpose can readily be adapted to a totally different application.

To help industry take advantage of existing computer technology, NASA operates the Computer Software Management and Information Center (COSMIC)®, located at the University of Georgia. COSMIC maintains a large library of computer programs developed for NASA, the Department of Defense, the Department of Energy and other technology-generating agencies of the government. The Center gets a continual flow of software packages, screens them for adaptability to private sector usage, stores them and informs potential customers of their availability.

COSMIC's service represents one of the broadest areas of economic benefit resulting from secondary use of technology. Programs are sold at a fraction of their original cost and in most instances users get a return many times their investment; savings sometimes amount to millions of dollars. The service has met with extraordinary industry acceptance; software packages distributed to industry number in the thousands.

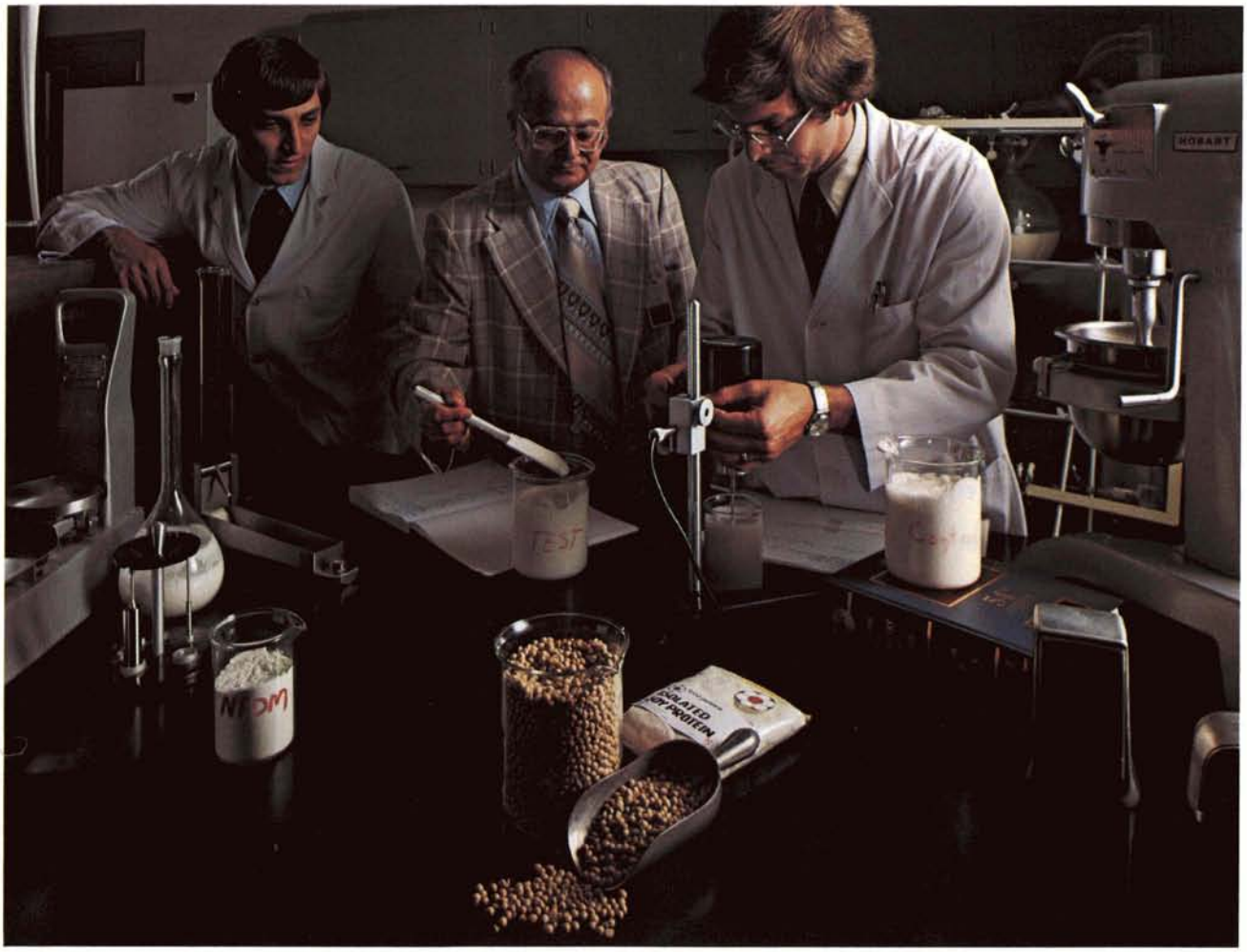
Best known and most widely used of COSMIC's packages is the NASTRAN® program, an acronym for NASA Structural Analysis Program. NASTRAN is a general purpose program which electronically analyzes a design and predicts how it will stand up under the various conditions of stress and strain it will encounter in operational service. This permits engineers to study the structural behavior of many different designs before settling on a final configuration. NASTRAN has found hundreds of industrial applications and almost invariably users report substantial time and money savings.

There are more than 1,500 other computer programs available to the private and public sectors through COSMIC. Collectively, they embrace a broad spectrum of industrial applicability. Among examples of how they are being used are two in the food processing industry:

Ralston Purina Company of St. Louis, Missouri, a diversified producer of food and animal feed, found a COSMIC program called STRCMACS a valuable aid to its own computer technology; STRCMACS is used for the conversion of other computer programs and for development of new computer systems. The company reports that it achieved significant savings by getting the software from COSMIC rather than buying a comparable program or developing a new one. Purina also effected additional savings in reduced development time.

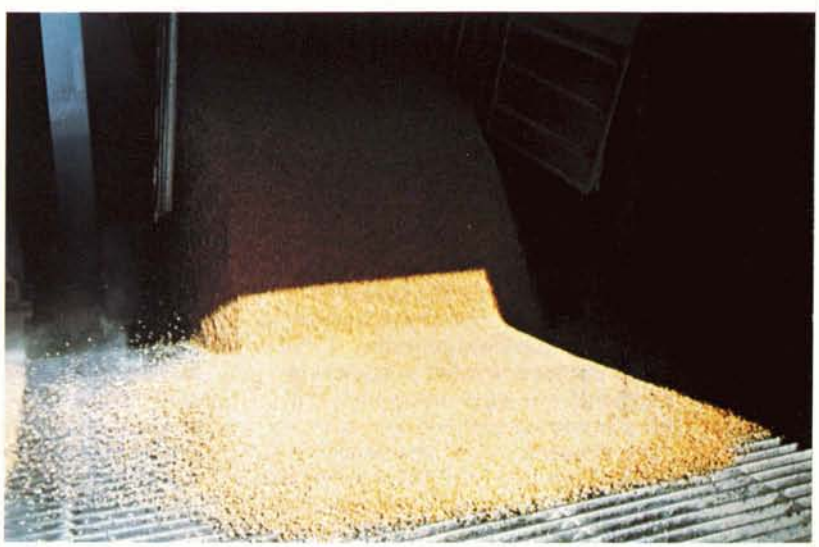
A. E. Staley Manufacturing Company, Decatur, Illinois, similarly reports monetary and time savings through use of two COSMIC programs, one called ANOVA (Analysis of Variance) and another which has no acronym for its technical title. These programs were used in research and development on management functions and on ways of processing corn and soybean products, such as corn starch, syrup, soybean oil and animal feed.

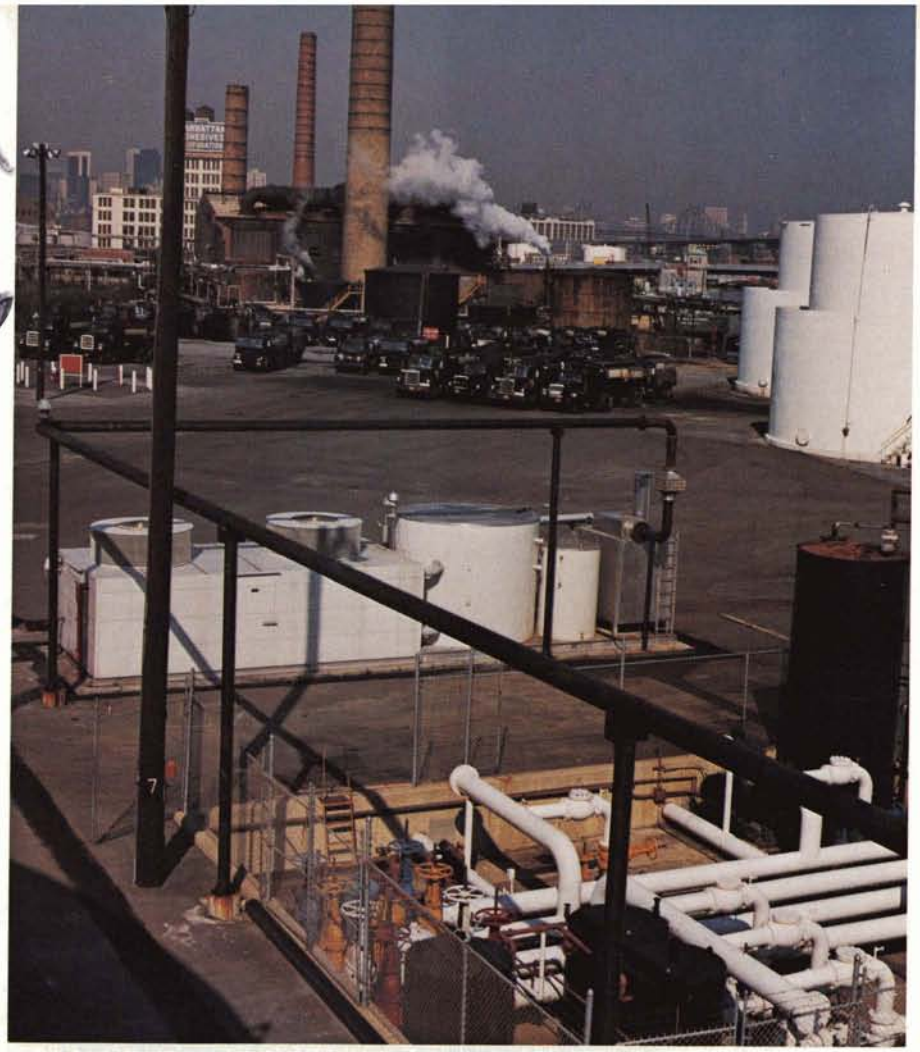
Additional examples of how COSMIC programs are contributing to industrial productivity are contained on the following pages. Other examples are listed elsewhere in this volume in the chapters on transportation and construction spinoffs.



Ralston Purina Company is conducting extensive research on the complex structure of the soybean to improve soy protein for sale to other food manufacturers. The company is one of many which have employed NASA/COSMIC computer programs in industrial operations.

In these photos, a truckload of soybeans spills down a chute at a processing facility of A. E. Staley Manufacturing Company. A leading food processor, Staley used COSMIC computer programs in research and development on ways of processing corn and soybean products.





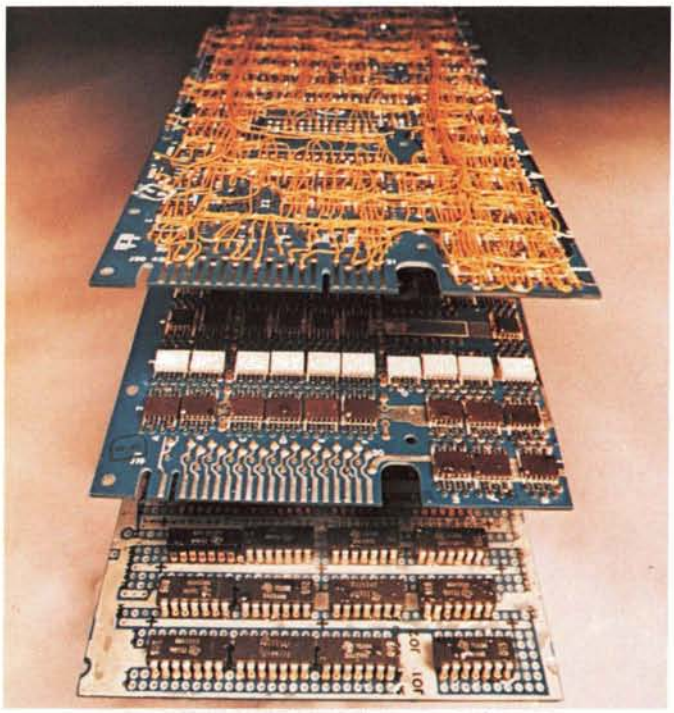
Gasoline Vapor Recovery

Gasoline is volatile and some of it evaporates during storage, giving off hydrocarbon vapor. Formerly, the vapor was vented into the atmosphere but anti-pollution regulations have precluded that practice in many localities, so oil companies and storage terminals are installing systems to recover hydrocarbon vapor. Recovery provides an energy conservation bonus in that most of the vapor can be reconverted to gasoline.

Two such recovery systems are shown in the accompanying photographs (mid-photo at right and in the foreground below). They are actually two models of the same system, although configured differently because they are customized to users' needs. They were developed and are being manufactured by Edwards Engineering Corporation, Pompton Plains, New Jersey. NASA technological information proved useful in development of the equipment.

The Edwards system collects hydrocarbon vapor and channels it through pipes to a condensing unit, a series of refrigerated coils, in which the vapor is converted to liquid. The resulting product, a mixture of water and gasoline, drains into a separator unit, which removes the water and leaves reusable gasoline. The company says that gasoline recovery can pay for the cost of the system in one to two years in cases—such as at dockside where tankers and barges are loaded—involving almost continuous use of the equipment.

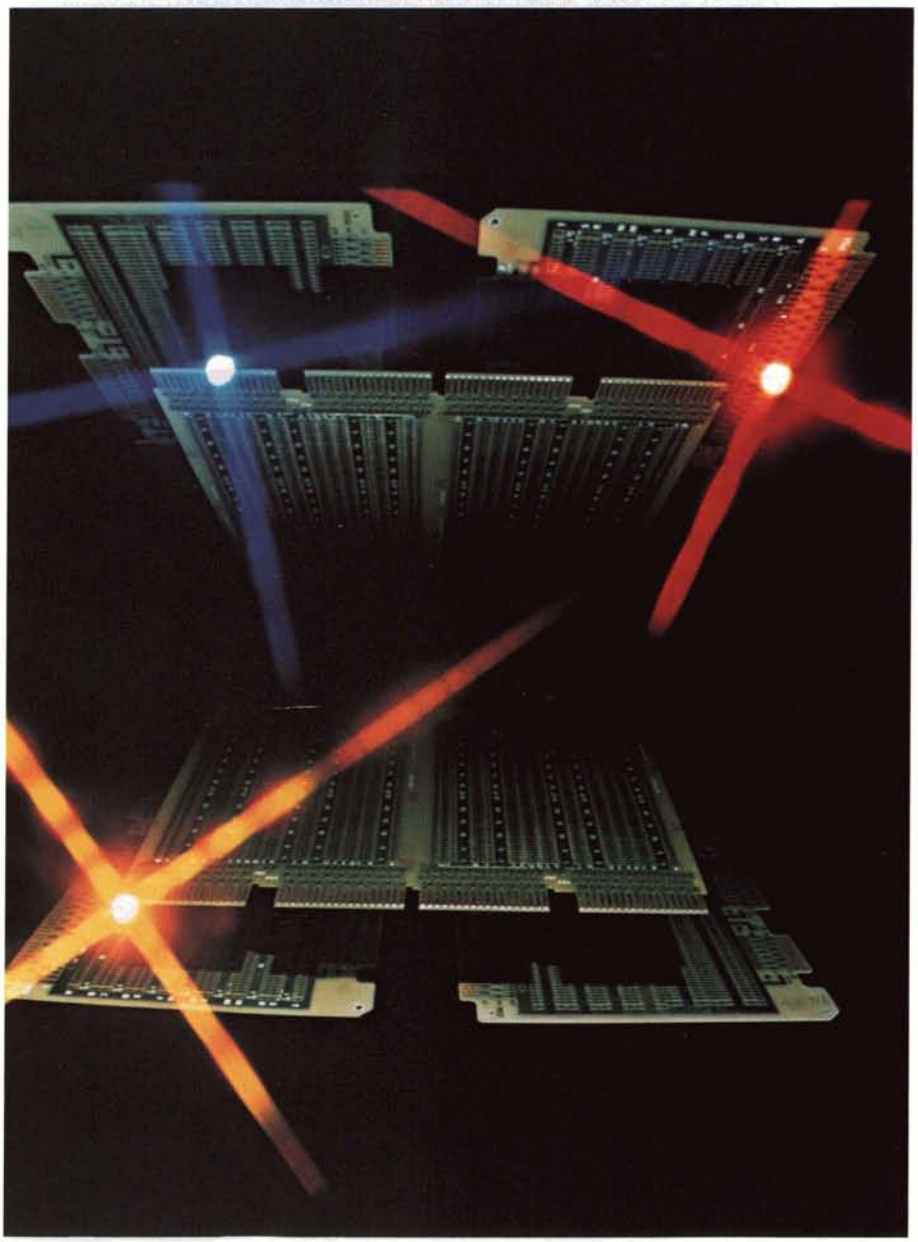
In developing the system, Edwards Engineering fabricated some components in its own plant and used commercially available equipment for other parts. One such part was a compressor for the condensing unit, which operates at temperatures of more than 100 degrees below zero Fahrenheit. The compressor posed a major development problem; it had never before operated at such temperatures and lubricating oil froze. After trying several oils without success, Edwards' vice president-engineering learned of a NASA handbook on lubricants. Compiled by Marshall Space Flight Center, the handbook is a comprehensive consolidation of technical information about commercially available lubricants, their characteristics, specifications and applications. Edwards obtained the handbook and used it to select a suitable low-temperature oil and to find a supplier for the oil. The problem was solved and Edwards is now producing 15 varying-capacity models of the vapor recovery system. The company has sold 90 units to major oil and chemical companies and is developing a new, smaller model for use at retail gas stations.



Electronic Packaging Techniques

A characteristic of aerospace system design is that equipment size and weight must always be kept to a minimum, even in small components such as electronic packages. The dictates of spacecraft design have spawned a number of high-density packaging techniques, among them methods of connecting circuits in printed wiring boards by processes called stitchbond welding and parallel gap welding. These processes help designers compress more components into less space; they also afford weight savings and lower production costs.

Odetics, Inc., Anaheim, California, an aerospace-oriented company which produces tape recording equipment for spacecraft, developed advanced stitchbonding and parallel gap welding processes for spacecraft applications, including equipment aboard the Space Shuttle, Spacelab and several unmanned satellites. Called Multi Link, Odetic's space-originated welding concepts have found their way into a number of commercial applications; for example, the circuit boards pictured are part of a microfilm storage and retrieval system produced by Odetics. Commercial demand for these processes resulted in establishment of a separate element of the Odetics company, called the Multi Link Division, which provides automated electronic packaging services for Odetics' own commercial products and for such other customers as Xerox, Dalmo Victor, Sperry Sun and Sierra Research.



Spinoff 1979

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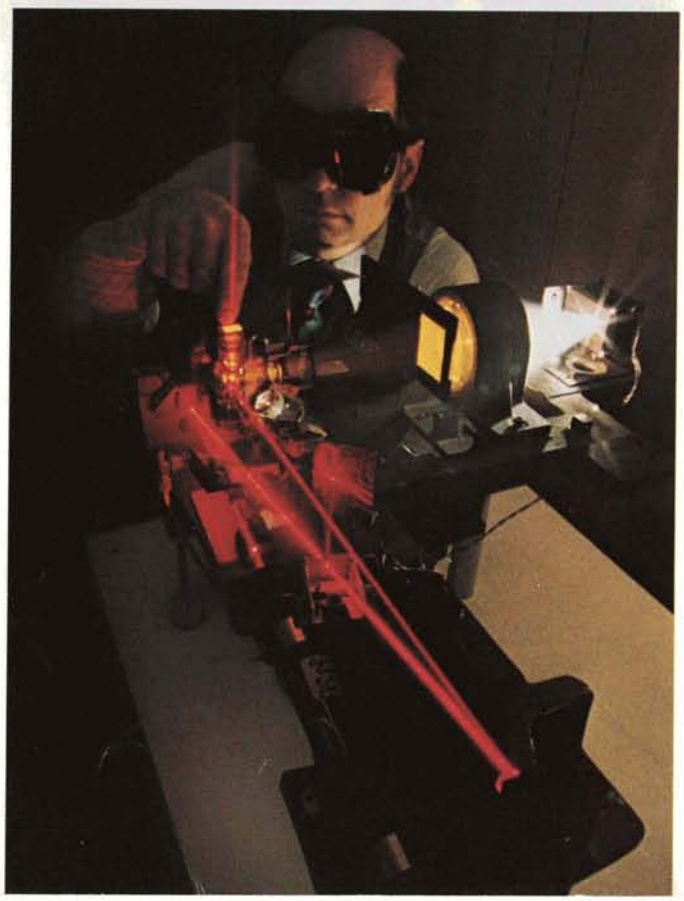
#10

Turbine Manufacture

The machinery pictured is a set of Turbodyne steam turbines which power a sugar mill at Bell Glade, Florida. A NASA-developed computer program called NASTRAN aided development of these and other turbines manufactured by Turbodyne Corporation's Steam Turbine Division, Wellsville, New York. An acronym for NASA Structural Analysis Program, NASTRAN is a predictive tool which advises development teams how a structural design will perform under service use conditions.

Turbodyne uses NASTRAN to analyze the dynamic behavior of steam turbine components, achieving substantial savings in development costs. One of the most widely used spinoffs, NASTRAN is made available to private industry through NASA's Computer Software Management Information Center (COSMIC) at the University of Georgia.



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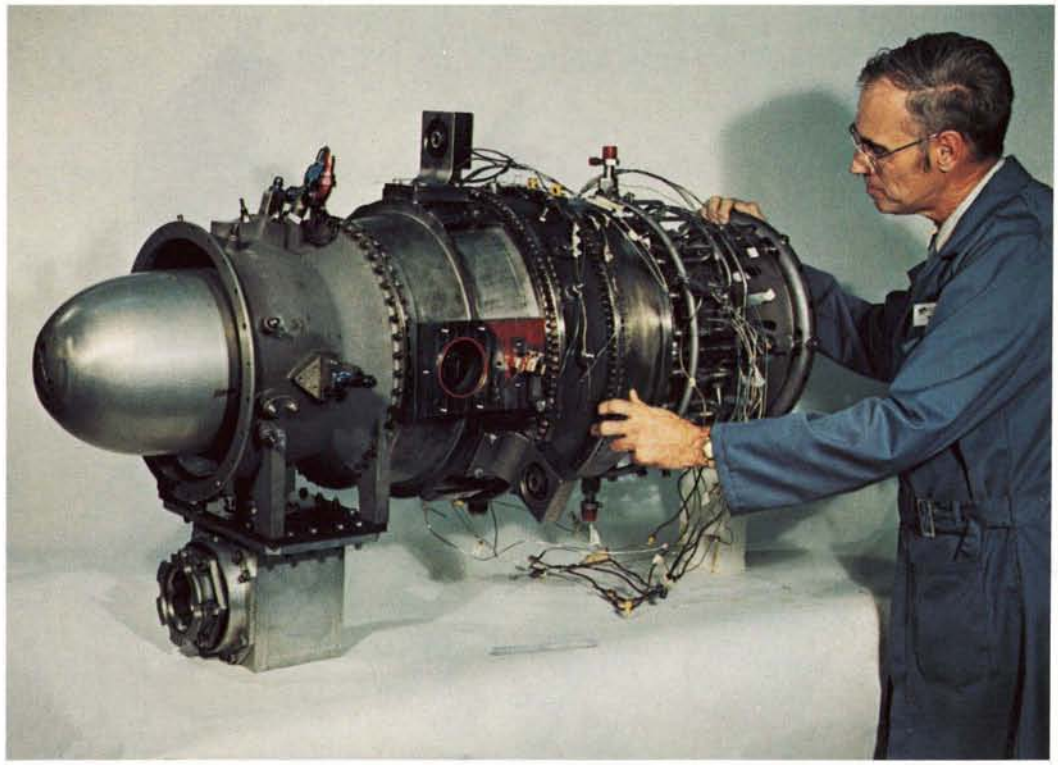
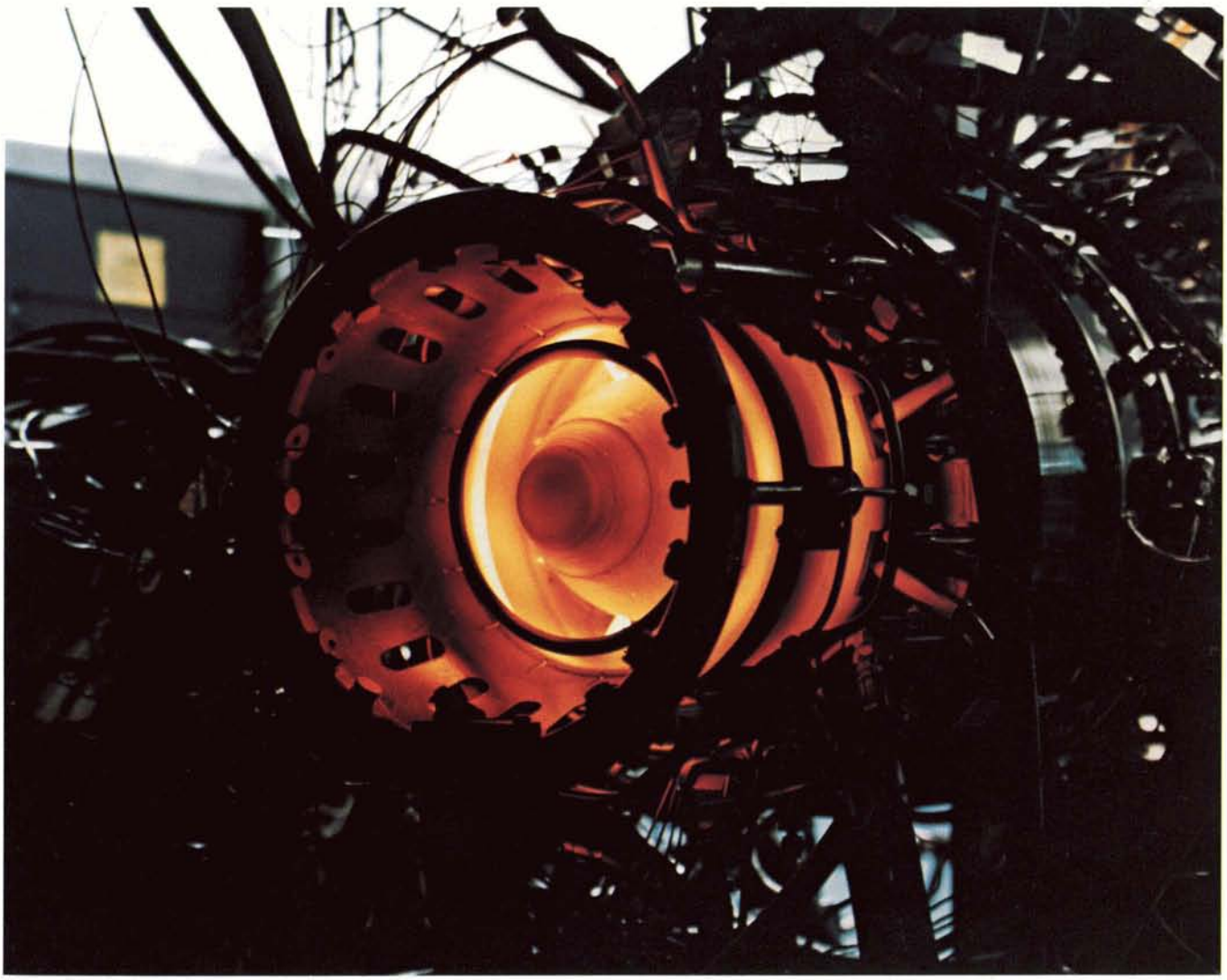
Laser Research

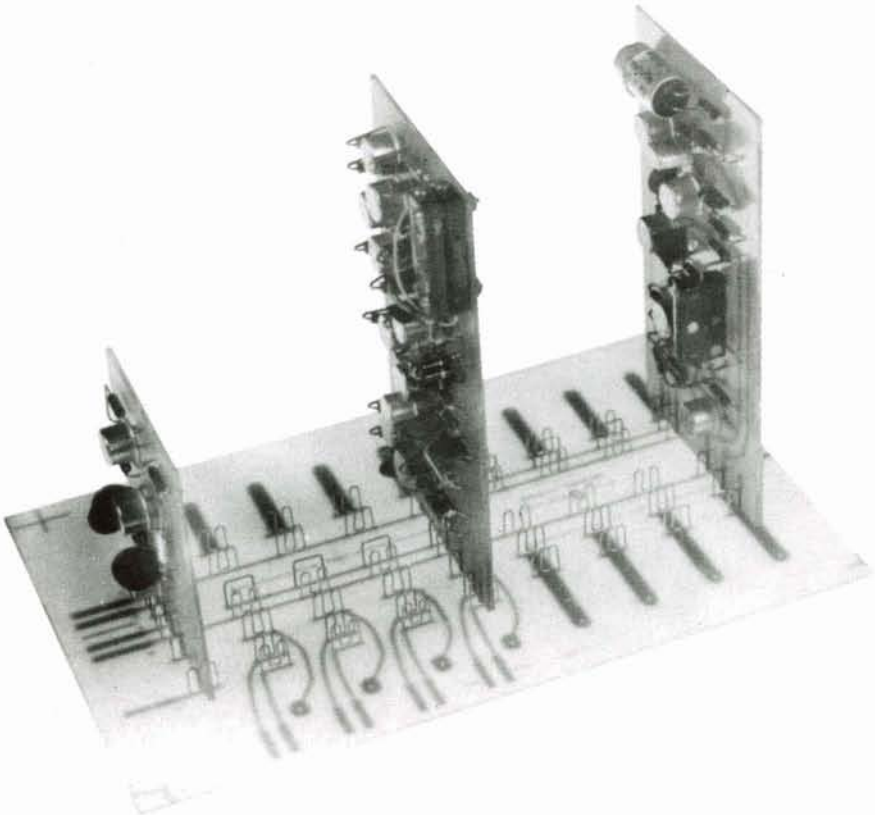
Eastman Kodak Company, Rochester, New York is a broad-based firm which produces photographic apparatus and supplies, fibers, chemicals and vitamin concentrates. Much of the company's research and development effort is devoted to photographic science and imaging technology, including laser technology. Eastman Kodak is using a COSMIC computer program called LACOMA in the analysis of laser optical systems and camera design studies. The company reports that use of the program has provided development time savings and reduced computer service fees.

Engine Design

Shown in static view and in operation on a test stand, the engine pictured is an advanced aircraft propulsion system being developed by Teledyne CAE, Toledo, Ohio, manufacturer of turbofans, turbojets and turbomachinery. In the design and analysis phases of this and other engines, the company makes extensive use of COSMIC's NASTRAN computer program. NASTRAN serves as an analytical tool for design of many engine components, such as those glowing in the test stand photo. Teledyne CAE also uses two other COSMIC programs in studies of engine airflow. Use of the three computer programs affords significant annual savings.



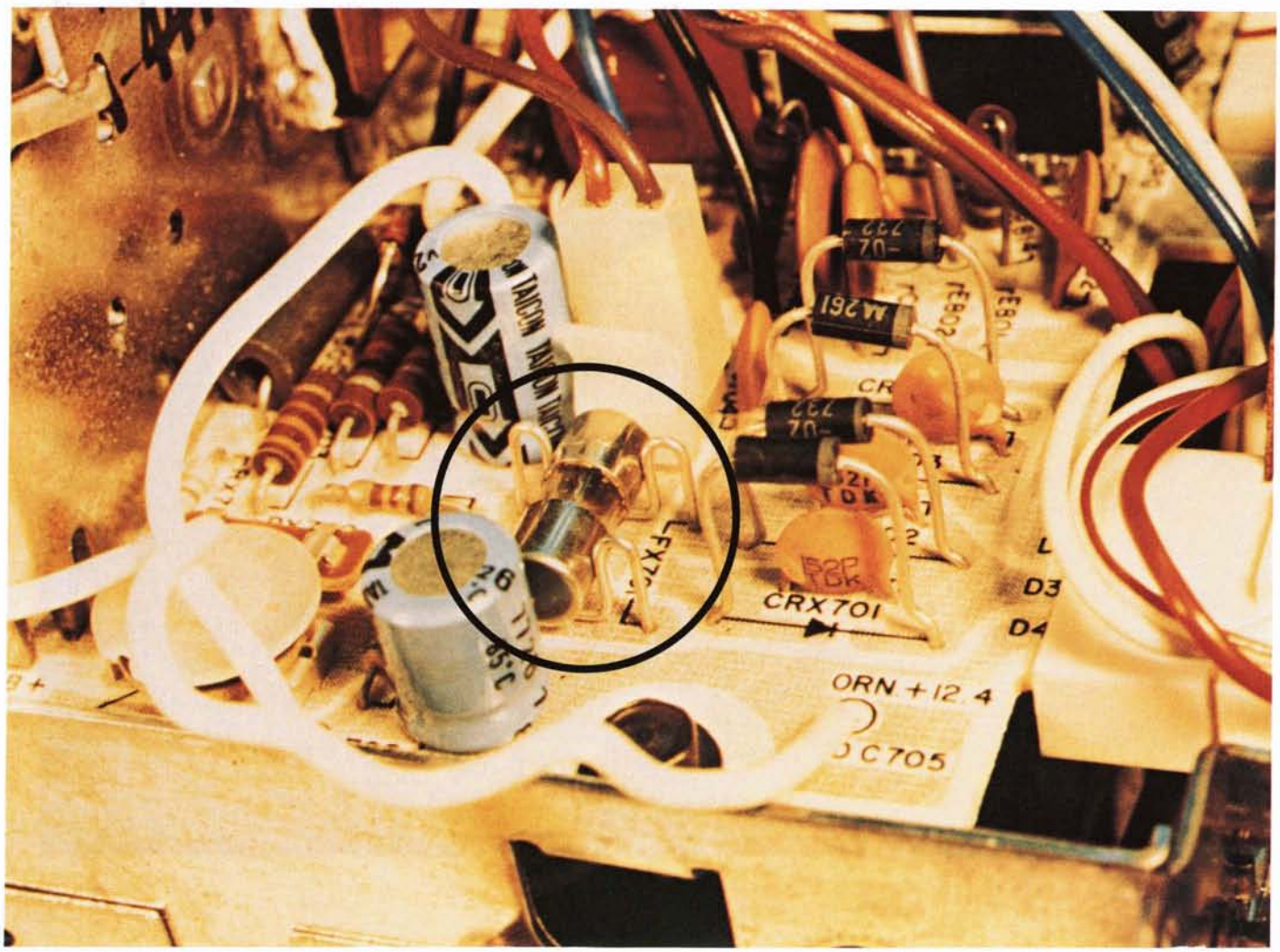




Circuit Connectors

The U-shaped wire devices in the upper photo are Digi-Klips®; aids to compact packaging of electrical and electronic devices. They serve as connectors linking the circuitry of one circuit board with another in multi-board systems. Digi-Klips were originally developed for Goddard Space Flight Center to meet a need for lightweight, reliable connectors to replace hand-wired connections formerly used in spacecraft. They are made of beryllium copper wire, noted for its excellent conductivity and its springlike properties, which assure solid electrical contact over a long period of time.

Used on a number of satellites, Digi-Klips were developed for NASA by Components Corporation, Denville, New Jersey. The company is now producing the connectors for a vari-



ety of commercial applications, such as household appliances, telephone systems, computers, aircraft and automotive equipment. Offshoots of the original Digi-Klips are the company's Fuse Clips, which are used on all black and white Zenith television sets. The lower photo shows a display of Zenith TVs in the showroom of The Zamoiski Company, Baltimore area distributors. At lower left is a view of the circuitry of one Zenith model, with typical Fuse Clips circled.

®Registered trademark. Components Corporation

Rotation Measurement

In aircraft turbine engine research, certain investigations require extremely precise measurement of the position of a rotating part, such as the rotor, a disc-like part of the engine's compressor which revolves around a shaft at extremely high speeds. For example, in studies of airflow velocity within a compressor, researchers need to know—for data correlation—the instantaneous position of a given spot on the rotor each time a velocity measurement is made. Earlier methods of measuring rotor shaft angle required a physical connection to the shaft, which limited the velocity of the rotating object.

Seeking better instrumentation, NASA's Lewis Research Center developed an Electronic Shaft Angle Encoder which measures the angular position of a rotating shaft in about one microsecond; the device picks up an electrical pulse generated by the rotating machinery, computer processes the information and presents a coded reading on a display window. The fact that it does not require physical connection allows use of the device with the highest-speed machinery in existence; thus it is possible to obtain accurate measurements of very high speed rotations that cannot be accomplished by other means. The Lewis-developed device is being produced by Real Time Systems Inc., Mount Vernon, New York, as the Model 371 Shaft Angle Encoder shown above. The encoder has commercial application in monitoring the performance of industrial turbines as an aid to preventive maintenance or problem diagnosis.

Among spinoffs for commercial, home and consumer use is a novel video-computer system for creating unusual graphic designs

Moon Technology for a New Art Form

Howard Sochurek, a New York free lance artist, is using an "electronic palette" to create extraordinary visual effects. His work is gaining wide acceptance in commercial art circles and, Sochurek acknowledges, he is indebted to NASA research, which provided both the inspiration and the basic technology for his exciting new art form.

Sochurek uses video-computer equipment to convert ordinary photographs into spectacular graphic designs or "electronic paintings." His technique is based on an image enhancement process originally developed for NASA's Johnson Space Center as an interpretive aid in analysis of moon photos.

In the early days of the Apollo program, NASA employed telescopic photography for preliminary consideration of possible Apollo lunar landing sites. The photos acquired provided good general views of lunar features, but without known reference points it was difficult to determine certain essential details, for example, the height of a large boulder or the depth of a moon crater. To get such information, NASA and its contractors developed a technique known as "density slicing," which refers to the density scale of a photograph or the tones from pure white to pure black with gradations of gray in between.

The keystone of the density slicing process is an instrument called a densitometer, which can "see" many subtle gradations not visible to the human eye. This instrument was integrated into a computerized system which analyzed the tonal density of a moon photo, assigned a color code to each of the various shades, and created on a video monitor a new picture in which each color represented a particular measurement, such as height or depth. Density slicing, applied to telescopic photos and later to close-up views acquired by unmanned spacecraft, provided the foundation for NASA's extensive study and selection of safe Apollo landing sites.

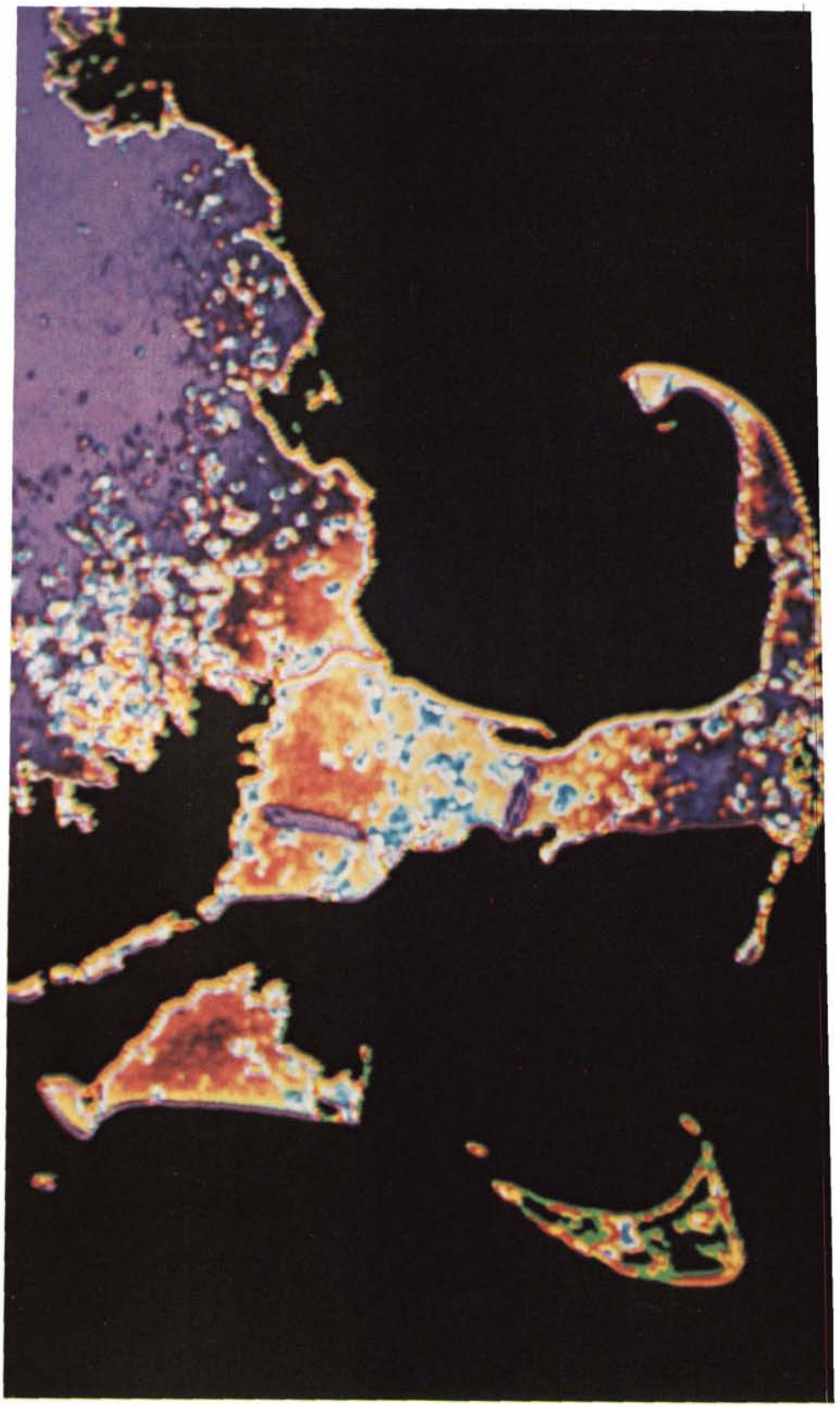
Howard Sochurek, a former award-winning *Life* photographer who had covered many aerospace assignments, heard of the NASA technique at a convention of the Aviation/Space Writers Association. He followed up with a visit to Johnson Space Center, where he witnessed a demonstration of the NASA system. The possibilities for a new art form excited him, but he wanted a variation of the basic technology. NASA's original system assigned a particular color to a particular density; for artistic breadth, Sochurek wanted a system which could put *any* color into *any* density. He discussed the matter with Spatial Data Systems, Inc., a Goletta, California firm which was adapting density slicing technology to commercial use in such areas as medical x-ray analysis. Sochurek bought the necessary video-computer equipment from the company, which customized it to his specifications.

At work, Sochurek sits before a video monitor and a computer keyboard. The image to be converted—a photo, a slide, a pen and ink sketch, a painting or even a three-dimensional object—is placed under a high resolution TV camera. The camera scans the image and an analyzer separates it

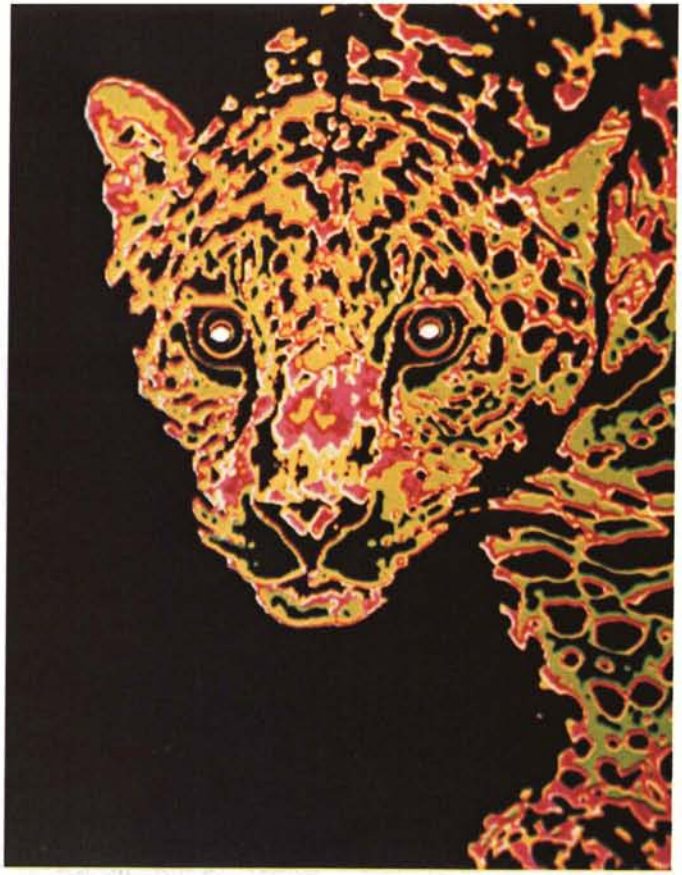
according to the various densities; the separated image then appears on the video monitor.

Now Sochurek begins to "paint" by means of his electronic palette, which offers literally millions of color combinations. By punching keys, he assigns a color to each density value of the image. He has a wide choice, ranging from brilliant primary colors to subtle pastels, with a variety of hues and tints within each basic color. Studying the resulting color image on the monitor, he can then change all or any part of it by punching in new color combinations. The process is repeated until Sochurek feels that he has achieved the desired effect. Then, with a simple push of the "print it" button, the system transfers the finished art work to film.

The appeal of Sochurek's electronic painting is attested by a large and growing list of clients, including industrial firms, advertising agencies, publishing companies and other art users. His work has appeared on the covers of national magazines, on book jackets and posters, in brochures and reports. Other applications range from unusual animal graphics for a hospital children's ward to office murals which present eye-catching views of a company's product line developed from unexciting photos of cast iron industrial equipment. Electronic art technology is still advancing, Sochurek says, and he sees many new applications in the future for the space-inspired process.



The illustration at right is an artistic impression of a satellite image covering an area of the northeastern United States around Cape Cod, Massachusetts. It is an "electronic painting" by New York artist Howard Sochurek, who uses a process based on NASA image-enhancement technology developed for interpretation of lunar photos.



The art works pictured were created by photo-artist Howard Sochurek, whose "palette" is an electronic system derived from NASA technology. Sochurek's technique involves use of video-computer equipment to convert basic images, such as photographs, into unusual graphic designs. The electronic equipment allows extraordinary choice of color and composition, but the final effect is the product of the artist's creative ability.

Woodburning Heaters

On Apollo missions, the Lunar Module served as home and operating base for astronauts exploring the lunar surface. Since the moon has no layer of atmosphere to filter the sun's rays, the Lunar Module was exposed to extremely high daylight temperatures. To help cool the spacecraft, NASA employed a protective exterior coating capable of casting off, rather than absorbing, the sun's radiant energy. NASA selected an existing high temperature coating called Pyromark and asked the manufacturer to improve it to space-use specifications. Developed by Tempil Division of Big Three Industries, South Plainfield, New Jersey, Pyromark proved effective on the Lunar Module and it is similarly used on the Space Shuttle.

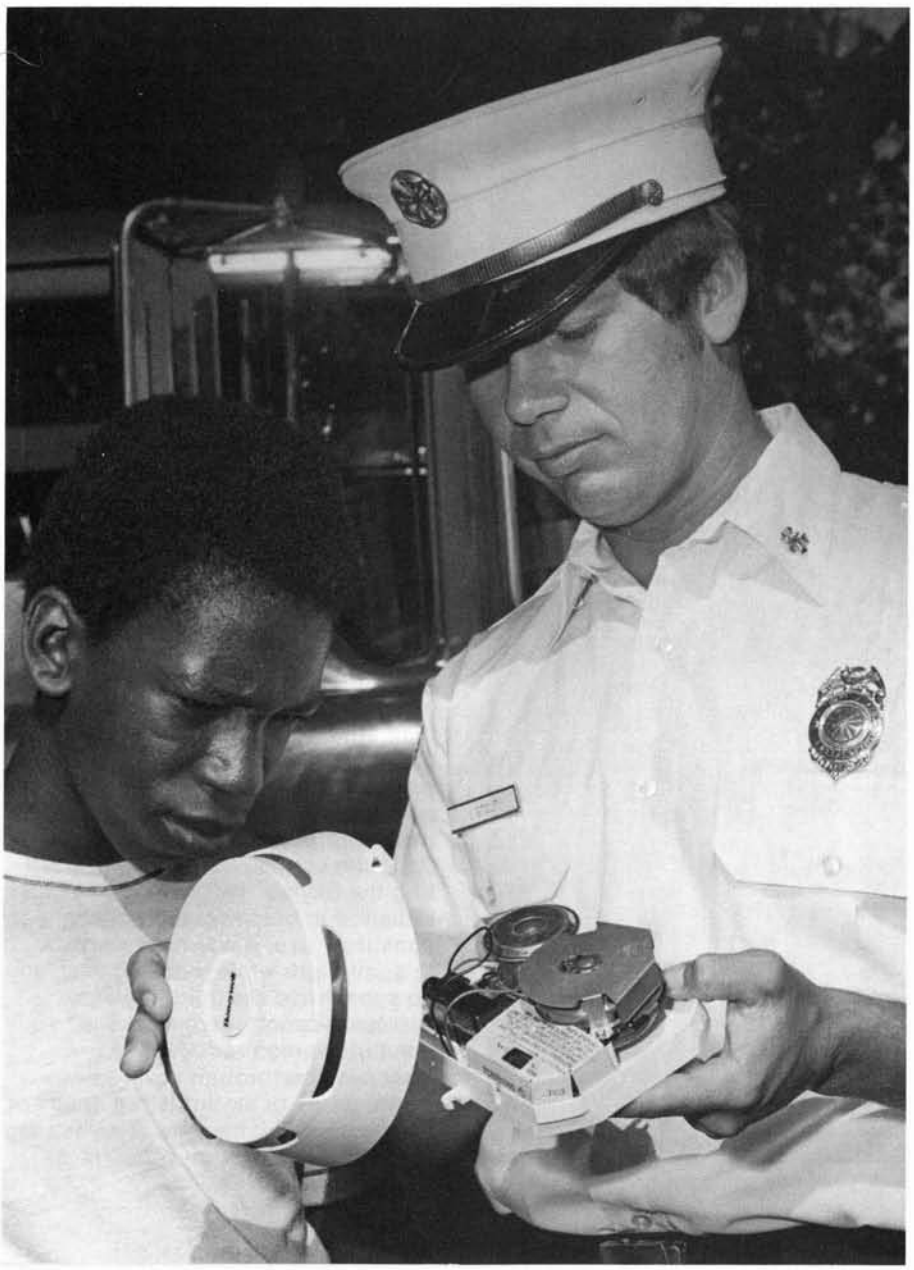
The characteristics which make Pyromark useful in spacecraft protection are similarly beneficial in other high temperature applications. Pyromark is used as a protective coating for a number of commercial products, including those shown in the accompanying photos.

The upper photo shows a high-efficiency woodburning heater that fits into a home fireplace. Manufactured by Aeroheator Company, Inc., Fairfax City, Virginia, it has a patented heat exchanger that recirculates heated air from the upper ducts back into the room with less waste of energy; the heat does not go up the chimney. Temperatures up to 1,800 degrees Fahrenheit are generated within the Aeroheator, so it is coated with Pyromark to protect the metal from heat damage; the high temperature paint also protects the exterior finish from everyday abrasions.

Pyromark is used for the same purposes on the Geomid woodburning stove shown in the lower photo. Manufactured by Transmetal Inc., Mt. Vernon, Washington, the four models of the Geomid line are uniquely shaped for efficiency as well as decor appeal. The wider-at-the-top shape, along with interior design features, promotes favorable airflow patterns inside the stove, thus enabling the Geomid to heat a larger area with a smaller firebox.

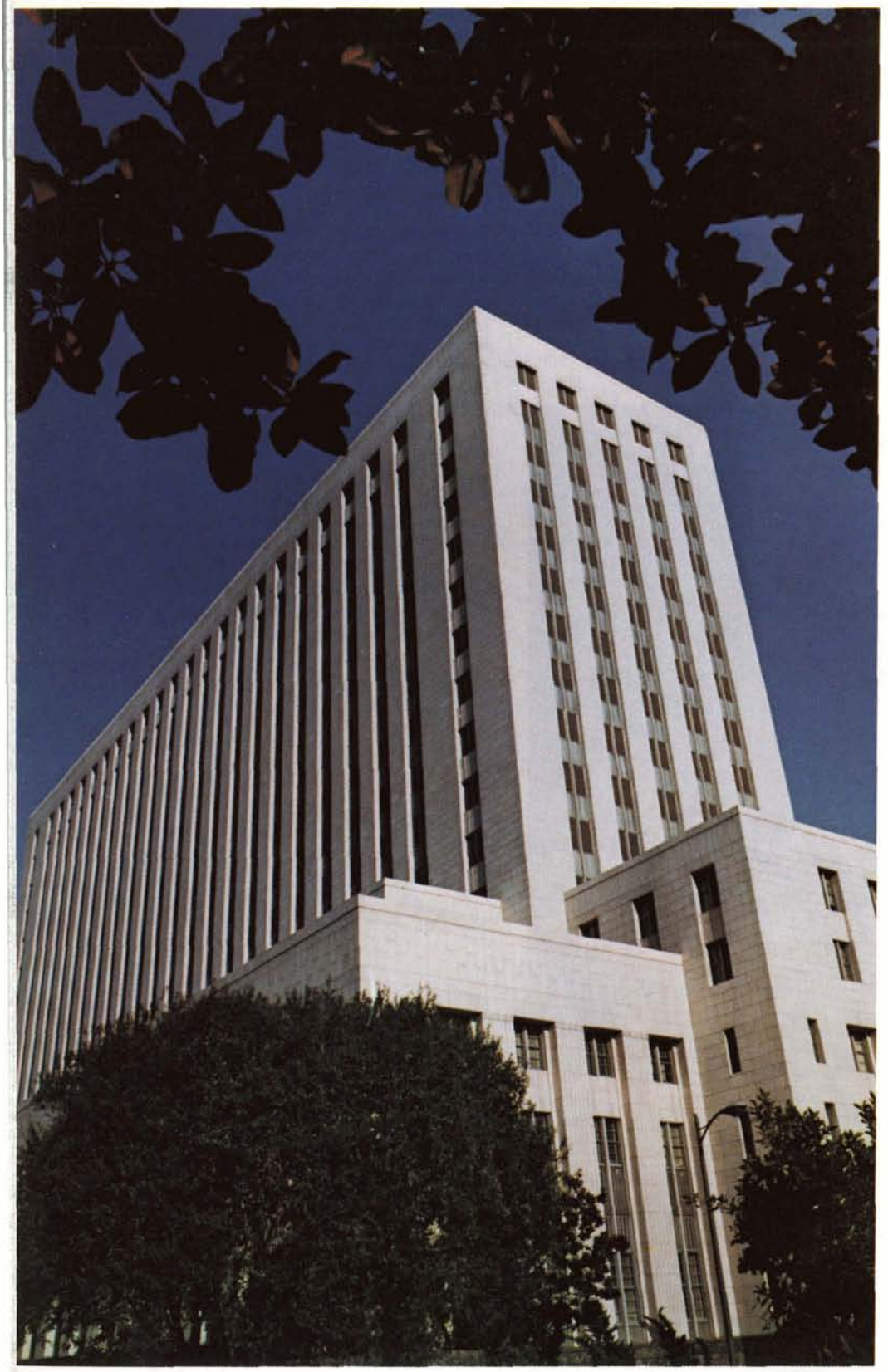
Smoke Detector

In the photo, Fire Chief Jay Stout of Safety Harbor, Florida, is explaining to young Richard Davis the workings of the Honeywell smoke and fire detector which probably saved Richard's life and that of his teen-age brother. Alerted by the detector's warning, the pair were able to escape their burning home. The detector in the Davis home was one of 1,500 installed in Safety Harbor residences in a cooperative program conducted by the city and Honeywell Inc.



Marketed commercially by Honeywell Consumer Products, Minneapolis, Minnesota, the detector incorporates technology developed by Honeywell Inc. for a sophisticated smoke and fire detection system used in NASA's Skylab, a long-duration orbital laboratory which was active in the mid-seventies.

The Honeywell AC/Battery Backup Smoke and Fire Detector normally operates on home electrical current, but it also has a continuously self-recharging nickel-cadmium battery which automatically takes over if home power fails. An ionization chamber senses incipient combustion and actuates an alarm horn which emits a loud, piercing warning signal. The unit has a sensitivity switch which permits the homeowner to fine-tune the detector, in order to avoid nuisance alarms such as those triggered by cooking. A special feature is a do-it-yourself testing system that allows the user to make sure all elements of the detector are working properly simply by pushing a button.

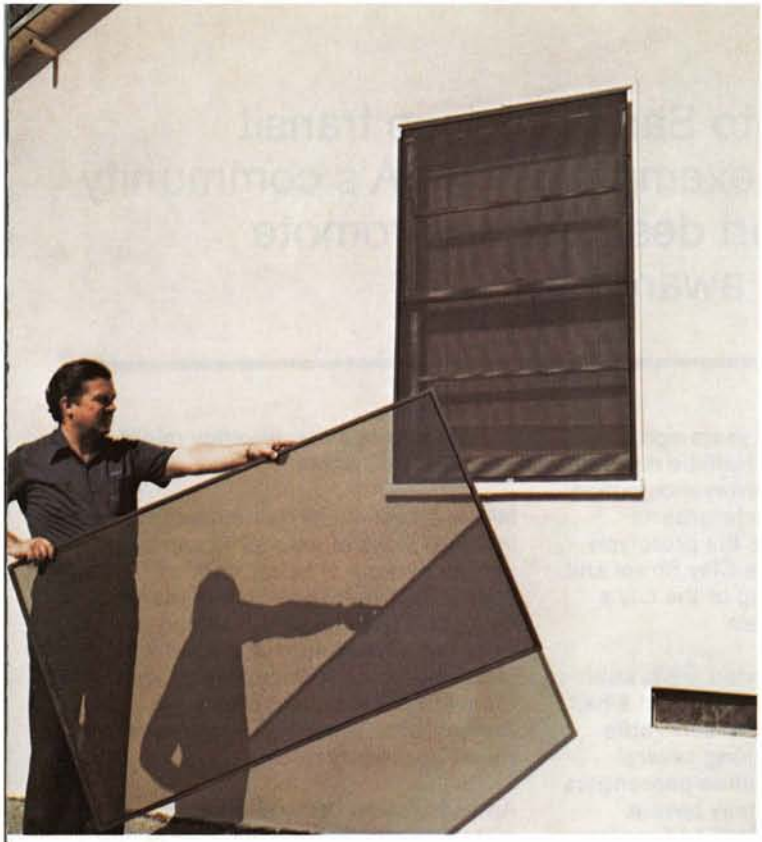


Solar Screen

On each of the windows of the large building pictured—Los Angeles Federal Courthouse—is a spinoff product called a Coughlin Solar Screen, the purpose of which is to block unwanted heat and glare. Manufactured by Coughlin Solar Screen Company, Inc., Valencia, California, the screens keep out 70 to 80 percent of the heat that would normally penetrate window glass, thus substantially reducing air conditioning costs.

Efficacy of the screens is attested by General Services Administration approval for use on federal buildings. They are also available for home use. The home screen (above right) looks like tinted glass, but actually it is finely-woven fiberglass fabric designed to admit light while blocking heat. Available in six colors and guaranteed by the manufacturer for 10 years, the screens have winter as well as summer utility; their tight weave provides an exterior layer of insulation and also reflects some interior heat back into the room.

This spinoff stemmed not from aerospace hardware technology but from adaptation of a problem-solving concept employed as an emergency measure in NASA's Skylab program of 1973-74. Skylab, a manned orbital laboratory, was equipped with a thermal shield to protect the laboratory from the intense solar radiation of space and also to stop penetration by micrometeorities. During launch of the laboratory, the shield was ripped off. Without its protection, Skylab experienced extremely high internal temperatures, making it all but uninhabitable. The problem was solved when astronauts erected a large aluminized mylar "blanket" to cover the unprotected area. Daniel T. Coughlin conceived the idea of adapting the Skylab "fix" to blocking solar radiation in homes and buildings. For consumer use, it was necessary to admit light while blocking heat, so he substituted the tightly woven, corrosion-proof fiberglass. The resulting screen reduces light transmission through covered windows, doors or skylights but does not impair visibility; the view is something like that seen through sunglasses.



Light Controller

Artificial lighting is designed to provide the light intensity necessary if there were no other source of illumination. But many rooms, particularly those in large-windowed office buildings, get a substantial amount of sunlight during the day. An automatic system which considers available sunlight and adjusts the artificial lighting level accordingly can trim energy costs appreciably. Such a system was developed by NASA's Kennedy Space Center. International Technology Corporation, Satellite Beach, Florida, obtained a NASA patent license for the technology, refined the design, and is now producing commercially an improved version known as the Automatic Lighting Controller.

In the photo, the small wall-mounted device at upper left is a photocell sensor which measures the intensity of combined sunlight and artificial light. The sensor communicates its information to the light controller in the box at left of the typewriter (the unit shown is a display model; normally the control box would be centrally located and out of sight). The controller automatically switches lights in various parts of the room to maintain a predetermined lighting level. The third element of the system, on the wall below the sensor, is the switch which turns the system on; by removing the switchplate, the user can adjust lighting intensity to his desired level. According to the manufacturer, use of the light controller can, in some cases, reduce electrical usage by 90 percent on a given day.

The system's capability was demonstrated in a two-year NASA test program and the Automatic Lighting Controller is being further evaluated by the National Bureau of Standards (NBS). Under NBS contract, International Technology Corporation installed the system at the Bureau's Center for Building Technology, Gaithersburg, Maryland.

Assistance to San Francisco transit authorities exemplifies NASA's community service effort designed to promote technology awareness

New Life for the Cable Cars

More than a hundred years ago, Scottish inventor Andrew Hallidie devised a horseless public conveyance pulled along by a moving underground cable. In 1873 he rode the prototype down San Francisco's Clay Street and that was the beginning of the city's famed cable car system.

This relic of the Victorian era is still going strong today. At nine and a half miles per hour, some 40 cars rattle and clang their way along several routes, carrying 10 million passengers a year over the city's hilly terrain. Parts have been repaired and replaced hundreds of times, but most of the cable cars are the same vehicles that were operating before the turn of the century. Over the years there have been many proposals to abolish the antique railway in the interests of safety or cost-effectiveness. Each time San Franciscans have risen wrathfully to defeat the proposal; to them the cable railway is a venerable symbol of San Francisco's colorful past, a landmark as much a part of the city's character as the precipitous hills or the scenic bay.

Now the San Francisco Municipal Railway, or "Muni," has launched a program to update the system by applying 20th century technology to a 19th century concept. The idea is to extend the service life of the cable cars while retaining their historic flavor. The basic principle of locomotion—in which a "gripman" in the car operates a long-handled gripping device to grasp the moving cable—will remain the same. The cars, some new, some rebuilt, will look exactly like the originals. But modern technology will be applied in areas not visible to the passengers, in order to upgrade the system's safety and efficiency. NASA technological expertise is playing a part in the rejuvenation effort.

Muni requested NASA input through the NASA Technology Application Team at SRI International, Menlo Park, California. Accordingly, Ames Research Center assigned an engineering/safety group to conduct a study and make recommendations as to how advanced technology might improve the system.

NASA-Ames' major recommendations involved ways of extending cable life in the interests of safety and economy. Other recommendations included redesign of the cable-gripping device, substitution of modern braking mechanisms, improvements in cable pulleys and other components, and new inspection and repair procedures.

Ames followed up by designing and installing new equipment to lengthen cable life, which averages only about two months. These cables—four of them for four different car routes—are endless belts, like ski lift cables, running from the downtown car barn to the end of each line. When a cable is installed, the loop is closed by splicing the ends together in a 72-foot-long splice. The splice is the weakest part of the cable and a source of problems. When the car operator applies his grip while over a splice, the resulting friction sometimes causes the splice to "unbraid" and fail; this means shutting down the line until the splice can be repaired. Even when unbraiding does not occur, gripping a splice shortens cable life by friction wear. Worn cables are a safety hazard and must be replaced, which is expensive at $1.60 a foot for 10,000 to 20,000 feet of cable.

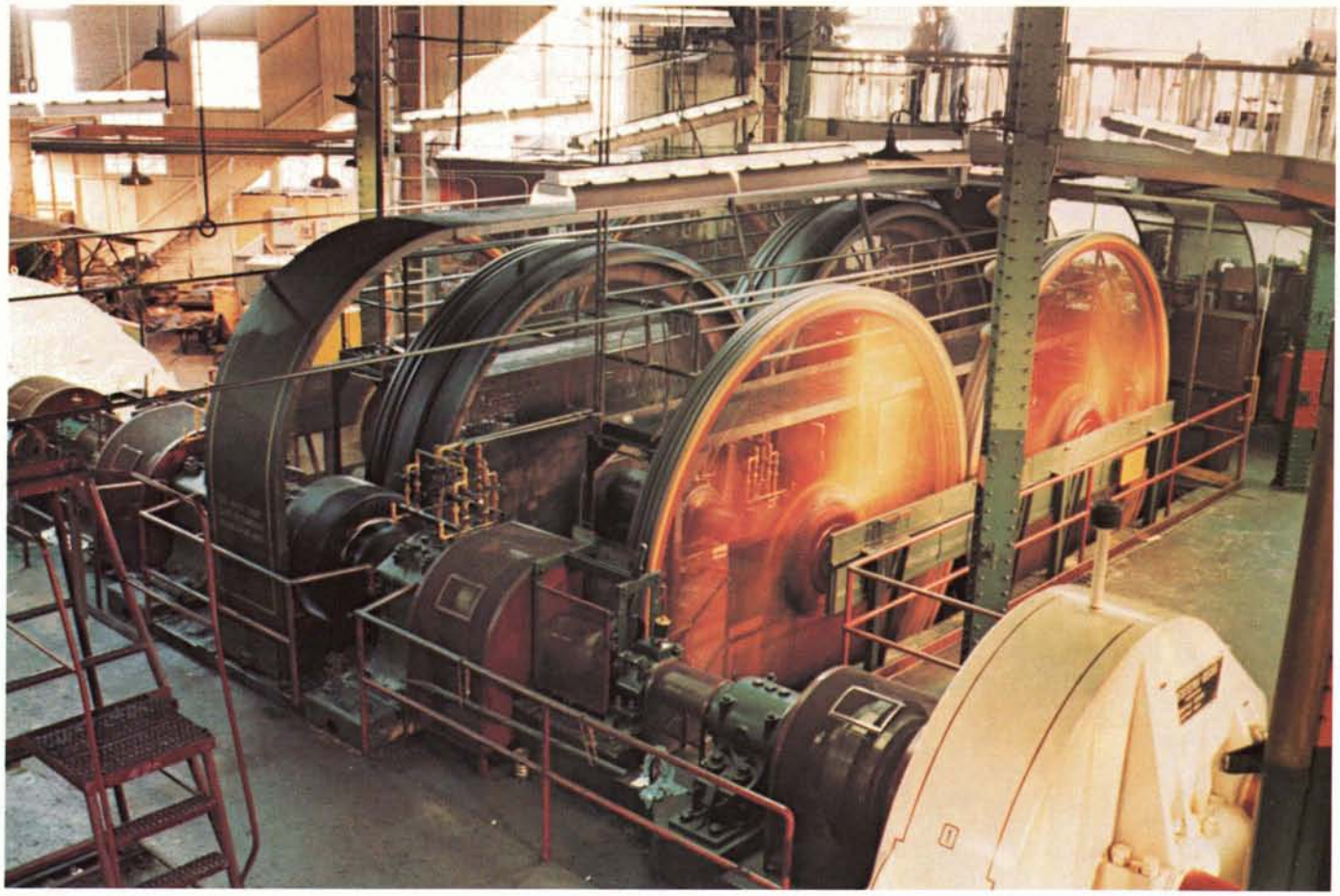
These problems occur because the gripman does not know when his car is over a splice, so the Ames team devised and installed a prototype system which alerts him. Applying magnetometer technology developed for space programs, Ames magnetized a section of the cable in an area just ahead of the splice. A magnetism sensor was mounted on the operator's gripping device. As the spliced segment of the moving cable approaches a cable car, the sensor detects the magnetic field ahead of it and triggers a whistle-like signal to the gripman for the several seconds it takes the splice to pass by. Thus, the gripman can delay gripping until the warning signal stops, thereby curbing the unbraiding problem and generally

San Francisco's century-old cable car system is being modernized and NASA is participating in the rejuvenation program. The cable car effort is an example of NASA's work with communities, which involves demonstrations of beneficial technology applications.

reducing wear in the most vulnerable part of the cable.

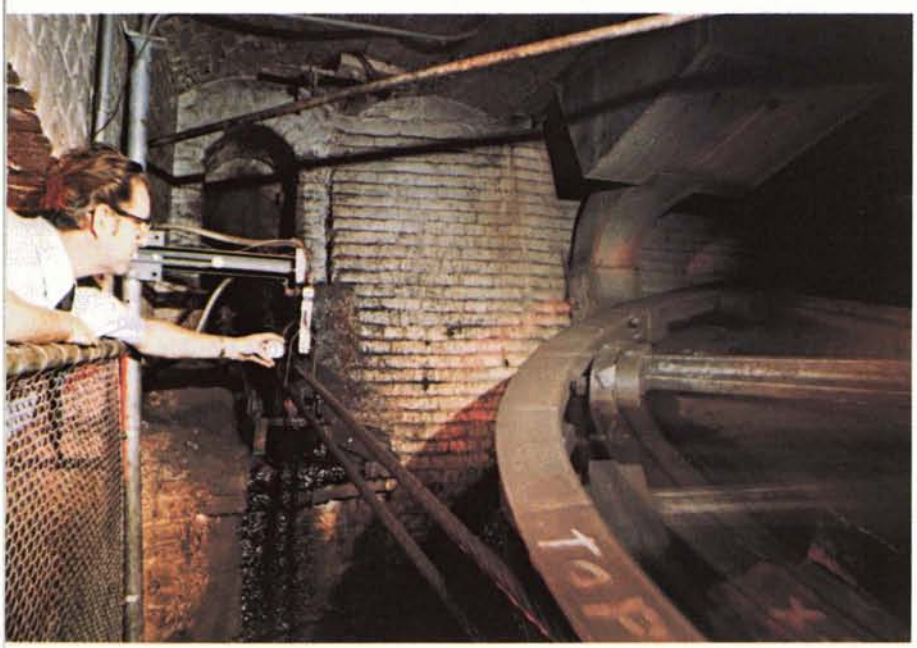
In addition, Ames installed similar sensors—one for each of the four cable lines—at the cable-winding facility in the car barn. When a spliced section approaches the winding drum, the sensor actuates a bell to notify maintenance personnel; a light signal tells them which line to watch. In this manner, Muni technicians can make periodic inspections of the splices without constantly standing at the winding facility waiting for a splice to appear. Ames is continuing to monitor these improvements and is working on another, a new, friction-easing grip in which the cable slides easily through rollers rather than through the "nutcracker" clasping mechanism currently in use.

The cable car project exemplifies a special area of NASA's technology utilization effort: service to communities through demonstrations of advantageous technology. In the interests of broadening technology awareness, NASA provides technological assistance to community groups, state and local governments, medical institutions and other organizations. In this type of work, NASA seeks to show how the application of new technology may help solve major problems or produce better ways of meeting public needs. Development of equipment for demonstrations may later result in some product spinoff, but that is not the primary goal. The principal aim is to inspire community sponsorship of beneficial technology applications. The following pages contain other examples of NASA community service projects.



The large spools in the upper photo are cable winding drums in the Muni car barn. Each of the four cable lines passes through the winding facility, where Muni technicians make periodic inspections of the cable splices. But since the cables are two to four miles long, waiting for a splice to appear is a time-consuming process. To eliminate long waits and make better use of technicians' time, NASA-Ames installed a sensory alert system, shown undergoing a checkout in the lower photo. Sensors—one for each of the four lines—detect the approach of a splice and actuate a bell to notify maintenance personnel, simplifying the visual inspection process. In developing sensors for both the winding facility and the cable car grip, NASA-Ames applied magnetometer technology originally developed for space programs.

In the cable car barn, through which the moving cables pass, an Ames Research Center engineer is testing a magnetism sensor, part of a NASA-designed system for reducing cable wear. A similar sensor on the car operator's grip detects magnetism in spliced areas of the cable and warns the gripman to delay gripping, thus easing friction on the most vulnerable part of the cable.



In the photo, technicians of the San Francisco Municipal Railway—"Muni"—are exchanging a cable car's grip, used by the operator, or "grip-man," to clasp the moving cable which pulls the car along. NASA's Ames Research Center is improving the grip design.

Solving a Corrosion Problem

The ferry pictured is one of two operated by the Golden Gate Transit Authority between San Francisco and Marin County, California. These ferries are the subject of an interesting NASA community service problem solution. The problem was that the aluminum hulls of the modern ferries were experiencing excessive corrosion, which, unchecked, could have in time caused perforation of the hulls. Golden Gate officials consulted a number of industrial sources, but were unable to find what was causing the corrosion.

The Authority requested NASA assistance through the SRI International Technology Application Team, and an Ames Research Center engineer was assigned to investigate. He was able to pinpoint the problem.

At night, or during periods of maintenance, the ferries are tied up at the Transit Authority's San Francisco dock. At such times, the ferries' generators are idle, so electricity is supplied from an on-shore source through a cable plugged into the ship's hull (lower photo). Safety regulations designed to prevent electrical shock to people on board require a grounding line. At the San Francisco dock, a copper line connected to a copper rod implanted in the ground served this purpose.

The corrosion problem, it turned out, stemmed from the process called electrolysis. When two different metals are in contact, an electrical potential is set up between them; when the metals are surrounded by an electrolyte, or a conducting medium, the resulting reaction causes corrosion, often very rapid corrosion. In this case the different metals were the copper grounding system and the ferry's aluminum hull; the dockside salt water in which the hull was resting served as the electrolyte. After identifying the source of the trouble, the Ames engineer provided a solution: a new wire-and-rod grounding system made of aluminum like the ferry's hull so there would no longer be dissimilar metals in contact. Ames research on the matter disclosed that the problem was not unique to the Golden Gate ferries. It is being experienced by many pleasure boat operators who are probably as puzzled about it as was the Golden Gate Transit Authority.

Poultry Industry Energy Research

The poultry industry, a multi-billion-dollar business in the United States, uses great amounts of energy in such operations as broiler growing, feed manufacturing, poultry processing and packing. Higher costs and limited supply of fuels common to the industry are predicted, so poultry producers are seeking ways to reduce energy expenditure. NASA is providing assistance to Delmarva Poultry Industry, Inc., an association of some 4,000 growers and suppliers in one of the nation's largest poultry production areas. Delmarva is the East Coast peninsula that includes Delaware and parts of Maryland and Virginia.

The upper right photo shows a weather station in the Delmarva area (wind indicator on the pole, other instruments in the elevated box). The station is located at the University of Maryland's Broiler Sub-station, Salisbury, Maryland, where the university conducts research on poultry production and processing. The sub-station is investigating ways of conserving energy in broiler production and also exploring the potential of solar collectors as an alternative energy source. For these studies, it is essential that researchers have continuous data on temperature, pressure, wind speed and direction, solar intensity and cloud cover. Equipment to acquire such data was loaned and installed by NASA's Wallops Flight Center, Wallops Island, Virginia.

In a related project, Wallops Flight Center is helping Delmarva Poultry Industry establish a seasonal wind profile for the area. The intent is to assess the future potential of wind turbine power systems, now being developed by NASA and the Department of Energy, for reducing costs of Delmarva feed manufacturers. The Center provided and installed wind measuring equipment at a typical site adjacent to the Chesapeake Food Feed Mill, Princess Anne, Maryland. The equipment will gather data over a two year period.

Briefcase Communicator

In the photo at bottom right, a U.S. Park Police officer is demonstrating a battery-powered communications system, sufficiently compact to be packed in a briefcase-size container, which can send and receive signals over great distances by means of satellite relay. Key to the system's efficacy is the high-powered transmitting and receiving equipment aboard such NASA satellites as the Applications Technology Satellite-6 (ATS-6) and the joint U.S.-Canadian Communications Technology Satellite (CTS); this enables the briefcase communicator to pick up satellite-relayed signals by means of the small hook-on antenna shown instead of the more elaborate ground equipment customarily needed. Developed by NASA's Goddard Space Flight Center, the communicator is intended for use in emergency situations. It has utility, for example, in disasters, such as floods and hurricanes, where power failure disrupts conventional communications; for on-the-spot transmissions from major accident sites; or in remote areas where no other means of communication exists.

The system's usefulness was demonstrated last summer in a field exercise conducted at Baltimore/Washington International Airport by the Maryland Institute for Emergency Medical Services. The exercise, one of several similar demonstrations, simulated a major accident and assumed that large numbers of "burn patients" required immediate medical treatment on the scene. The briefcase communicator, used in conjunction with the ATS-6 satellite, provided an on-the-spot method of consulting burn-specialist physicians hundreds of miles away in Boston and Chicago. It was used by emergency medical technicians to describe verbally, and to show via slow-scan TV, the conditions of the "patients." In a real emergency, patients would be treated at the scene by medical technicians remotely directed by specialists.

Jimmy Gerlach, 11, benefited from application of the same technology. Jimmy is afflicted with another rare disease which causes scaling of the outer skin layer. This results in lack of normal heat loss mechanisms and prevents Jimmy from exercising or participating in many everyday activities. Until recently, Jimmy was forced to spend much of his time in air-cooled environments. Responding to a request from Jimmy's father, Ames Research Center designed a personalized portable cooling unit and upper body garment. The battery-powered backpack modeled by Jimmy in the lower photo contains a fluid reservoir and a pump which circulates cool fluid through a network of panels in the garment. Now Jimmy is able to ride a bicycle and join in other outdoor activities.

Liquid-Cooled Garments

Astronauts working on the surface of the moon had to wear liquid-cooled garments under their space suits as protection from lunar temperatures which sometimes reach 250 degrees Fahrenheit. In community service projects conducted by NASA's Ames Research Center, the technology developed for astronaut needs has been adapted to portable cooling systems which will permit two youngsters to lead more normal lives.

Fifteen-year-old Karen MacKenzie (upper photo) was confined to bed or ice-baths for several years due to a disease known as "burning limb syndrome." The disease causes severe pain in the limbs and only cooling brings relief. At the request of Karen's physician, a NASA-Ames team headed by Dr. Bill Williams (shown in photo with Karen) designed a pump-chilling system which circulates cool water through a garment wrapped around Karen's thighs. The cooling garment relieves Karen of pain and prevents further tissue deterioration. Attached to her wheelchair, the system gives Karen the mobility she was so long denied.

Cancer Therapy

The patient shown is undergoing cancer radiation treatment in a hospital-like atmosphere—but he is not in a hospital. The treatment room is at NASA's Lewis Research Center, Cleveland, Ohio. It is a converted portion of the Center's cyclotron facility, originally designed for radiation studies related to nuclear propulsion for aircraft and spacecraft. Under an agreement between the Center and the Cleveland Clinic Foundation, the 50 million volt cyclotron is now being used to evaluate the effectiveness of "fast neutron" therapy in the treatment of cancerous tumors.

One of several alternatives to conventional x-ray radiation—the objective of which is to damage cancer cells so that they cease to grow and divide—fast neutron radiation penetrates tissue in a manner similar to x-rays but has theoretical advantages in treatment of some tumors. Still largely an investigative technique, neutron therapy is employed when a patient has a tumor that has not spread and which cannot effectively be treated by such conventional procedures as surgery, x-ray, cobalt or chemotherapy. Encouraging results at London's Hammersmith Hospital inspired similar research in the United States; the Lewis/Cleveland Clinic facility is one of four places in the U.S. where clinical trials are being conducted.

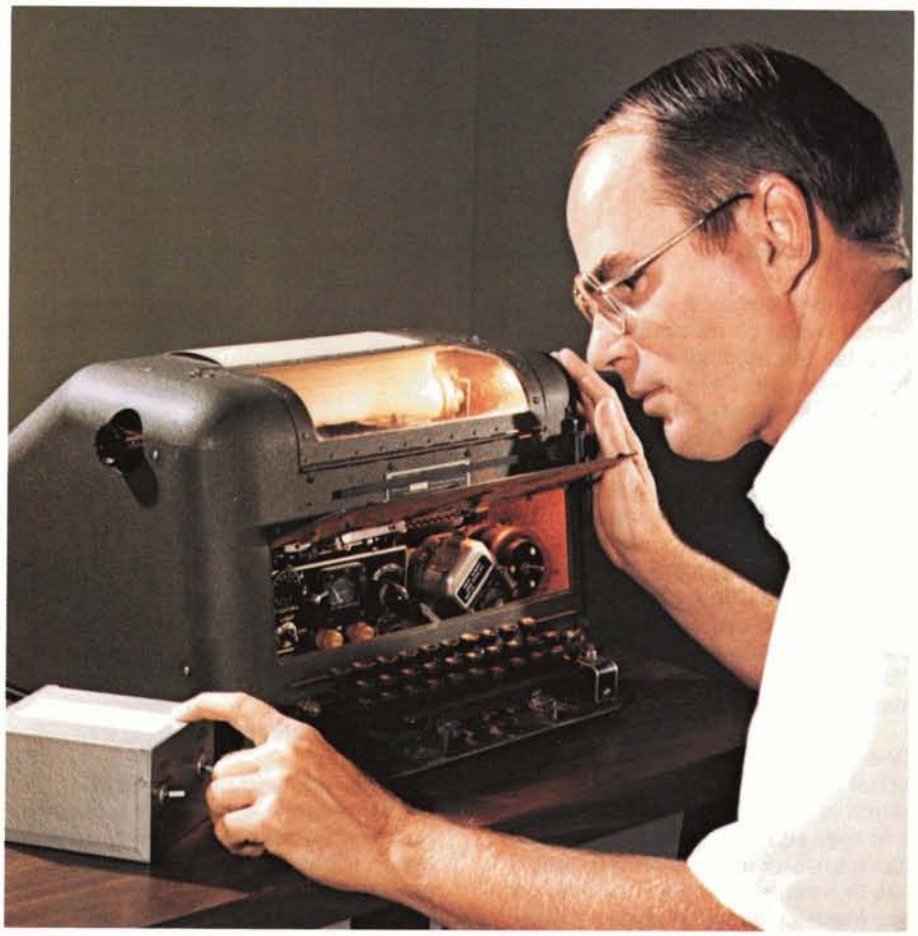
The cyclotron generates neutron radiation by bombarding a beryllium target, causing a nuclear reaction which yields fast neutron particles. Conversion of the Lewis cyclotron to medical use involved modification of the neutron beam; calibration of the instrument to provide the exact prescribed radiation dosage; construction of a properly shielded treatment room; and provision of associated facilities. Conversion and therapy costs are funded by Cleveland Clinic Foundation under a grant from the National Cancer Institute.

Foldable Walker

Paraplegics, who number about 100,000 in the United States, depend on crutches for their mobility on level ground. But crutches are ineffective on stairways; for climbing or descending, the paraplegic needs a stable pair of rails to push against. Aluminum metal walkers are designed for use on level surfaces, hence they have little utility on stairs; and, although lightweight, they are too heavy to be carried by the paraplegic while walking on crutches. There exists a need for a walker specifically designed for stair use and made of material much lighter than aluminum.

Engineers at Langley Research Center teamed with Dr. Ernest Harrison of the Mississippi Methodist Rehabilitation Center in a community service project involving development of a very light walker that is foldable for easy carrying. The prototype stair-walker is based on composite materials being developed by NASA for aircraft and spacecraft. The material selected was a graphite-epoxy composite which is stronger yet 50 percent lighter than aluminum. The developers made the front legs eight inches longer than the rear legs to fit the uneven surfaces of a stairway.

Dr. Cynthia Morris (shown in photos), a professor at American University, Washington, D.C. and a paraplegic, has been evaluating the composite foldable walker for more than a year. She reports that it is light enough to carry while walking on crutches, it forms a stable platform to assist her in ascending and descending stairs, and it has significantly improved her mobility and independence.



Teletype Tester

In the United States, more than 12,000 homes of deaf people are equipped with a system that enables the deaf to communicate by telephone. It consists of a teletype machine hooked up to an "acoustic coupler." The deaf person taps out a message on the teletype keyboard and the acoustic coupler converts teletype pulses into audio signals that can be sent over phone lines. At the other end, another coupler reconverts the signals to activate the teletype's printer and provide a readable message.

Though a boon to the deaf, the system presents a problem when something goes wrong. It is difficult to pinpoint the trouble because of the multiple units involved—the teletype's keyboard or its printer, the coupler's sending circuit or its receiving circuit. Finding the trouble is time-consuming and it usually involves removing the equipment from service, leaving the deaf person temporarily without communication. Seeking an answer to this difficulty, NASA's Biomedical Applications Team at Research Triangle Institute, North Carolina, circulated a problem statement to NASA field centers. Langley Research Center responded by developing a compactly-packaged portable Teletype Test Unit.

Shown at left in the upper photo, the unit generates perfect test signals like those sent or received by the teletype system's various components. By testing each component separately, a technician can quickly identify the defective part; often he can adjust it without removing the equipment from service. The unit also serves as a tool for preventive maintenance, providing a perfect signal source for adjusting circuits or machinery. Langley Research Center has produced several prototypes which are undergoing evaluation at Greensboro, North Carolina, at the Atlanta (Georgia) Association for the Deaf, and at Gallaudet College, Washington, D.C.

Composite Javelin

In the photo at right, a unique, advanced type of javelin is undergoing "flight test." The javelin was designed to meet specifications laid down by the International Amateur Athletic Federation, but it has better stability than conventional javelins, according to college athletes who tested it. Its development incorporated aerodynamic design techniques and a composite material developed by NASA's Langley Research Center for aircraft and spacecraft.

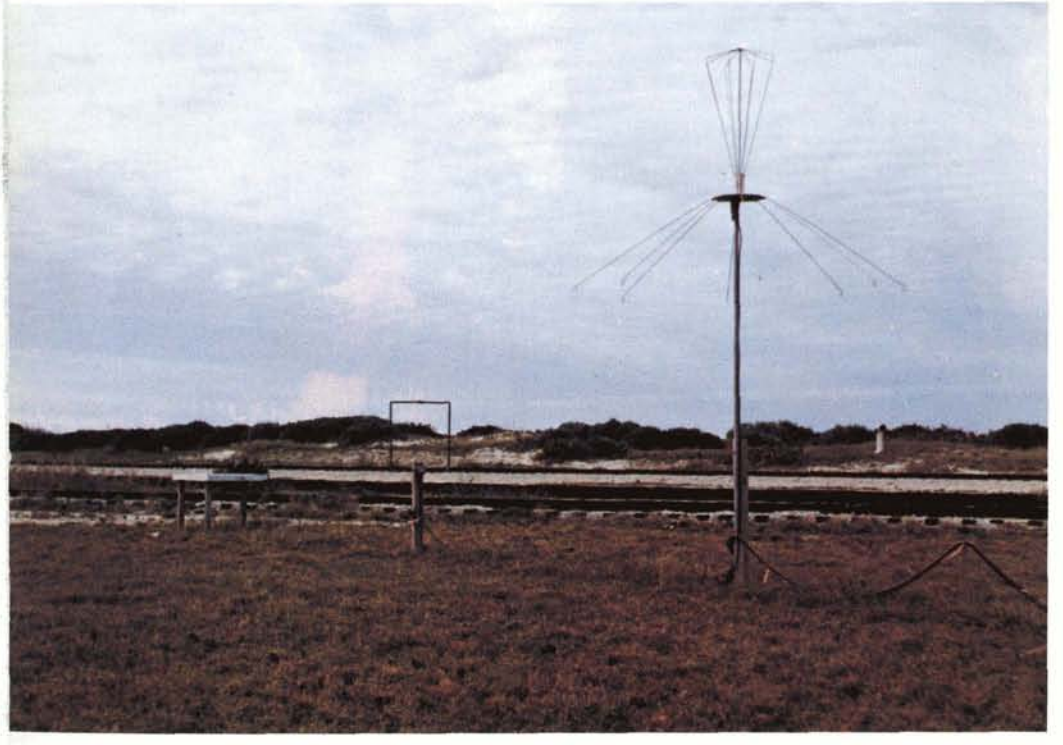
The javelin was developed as a spare-time project by two aerospace engineers—NASA-Langley's Bill Brooks and General Electric Company's Victor Saffire. At the Montreal Olympics, they noticed that javelins in flight made eccentric wobbling motions—called flutter—although different athletes were throwing different javelins. They concluded that greater shaft stiffness would reduce flutter and improve performance, but increasing stiffness with conventional materials would cause an unacceptable weight increase. Their answer was use of an advanced epoxy graphite composite material to provide the requisite stiffness within weight limitations.

The developers acquired some left-over surplus epoxy graphite and obtained the assistance of Graphite Technology, Santa Ana, California, which fabricated test shafts. In the photo at left Saffire (right) holds one of the composite javelins while Irving Mondschein, track and field coach at the University of Pennsylvania and a participant in the test program, compares conventional and composite javelins. The tests confirmed the predicted improved stability of the composite javelin. As an added development, the designers placed a threaded joint at the javelin's center of gravity, permitting its disassembly into two sections for ease of transportation. Brooks and Saffire are now working on a similar development for pole vaulting.

Lightning Detector

The antenna pictured below is part of a NASA-developed system for pinpointing the location and altitude of lightning activity in the atmosphere. Developed by Kennedy Space Center, it is called the Lightning Detection and Ranging (LDAR) system. Its original purpose was to give space launch controllers additional information on which to base launch or no launch decisions. It may also have utility in civil aviation. Last summer, NASA and the Federal Aviation Administration jointly conducted—at Patrick Air Force Base, Florida—tests of LDAR's potential as an aid to air traffic control. The results are being evaluated.

LDAR came into being as a result of an incident on an early Apollo moon mission, when a lightning strike just after launch knocked out the spacecraft's main electrical power system. The strike caused momentary loss of spacecraft instrumentation and necessitated readjustment of the instruments. As a result of this, Kennedy instituted an active program of lightning detection and measuring systems development—one of which was LDAR. It was used developmentally on both the Skylab and Apollo-Soyuz manned missions.



Lightning can be hazardous to airliners and general aviation aircraft, particularly during approaches to airports, because it could effect electronic equipment aboard the airplane. Additionally, hail and severe updrafts or down drafts, potentially troublesome, are usually associated with thunderstorm electricity. Pilot reports of lightning and thunderstorms provide some warning to other aircraft, but they identify general areas of electrical activity whereas LDAR can provide specifics as to location. LDAR has the capability of detecting electrical charge build-up in thunderstorms before the storm reaches the lightning stage. Recent developments have shown that LDAR can indicate the areas of maximum turbulence in a thunderstorm. With precise information as to the locations and altitudes of electrical discharges, air traffic controllers could route aircraft away from trouble zones.

LDAR consists of four receivers like the one below, together with computer processing and display equipment. One receiver is located at a central station and the other three are sited at points several miles away. Each receiver picks up signals emitted by electrical discharges in parts of the sky where thunderstorms are building up. The system measures the arrival times of the signals at each station. From this information, the computer can determine the points at which the signals originate. Zones of electrical activity are shown as "blips" on a display terminal, which indicates their distance, altitude and bearing from the control center.

Technology Transfer

A description of the mechanisms
by which NASA encourages new uses
of aerospace technology
and facilitates its application

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In a nationwide effort, NASA seeks to increase public and private sector benefits by broadening and accelerating the transfer of aerospace technology

Putting Technology to Work

The wealth of aerospace technology generated by NASA programs is an important resource, a foundation for development of new products and processes with resultant contribution to expanded national productivity. In a dormant state, however, the technology has only potential benefit. One of NASA's jobs is to translate that potential into reality by putting the technology to work in new applications.

NASA's instrument is its Technology Transfer Program, the aim of which is to increase the return on the national aerospace investment by identifying new ways to employ aerospace technology and by making the technology more readily available to prospective users. The program involves two major areas of effort: 1) facilitating broader application of remote sensing technology and 2) fostering technology utilization, or encouraging re-use of technology emerging from NASA's mainline programs.

Satellite remote sensing, although a relatively new technology, offers extraordinary benefit potential in a great many areas—for example, agricultural inventories; land, water and forest resources management; exploration for minerals and new energy sources; wildlife habitat analysis; selection of sites for public and industrial facilities; and a variety of environmental applications. NASA seeks to bring about wider use of remote sensing technology by generating greater awareness of the benefit potential and by providing assistance to organizations interested in developing their own capabilities in this promising field.

In another element of the program—technology utilization—NASA promotes secondary application of aerospace technology by disseminating information on the technology available for transfer, by assisting industry in the transfer process, and by adapting existing aerospace technology to the solution of public sector problems.

Focal point of the program is the Technology Transfer Division, a component of NASA's Office of Space and Terrestrial Applications headquartered in Washington, D.C. The division coordinates the activities of a nationwide network of technologists, who provide a link between the developers of aerospace technology and those who might effectively employ it either in remote sensing operations or in non-aerospace re-applications.

NASA employs a variety of mechanisms to meet the objectives of the Technology Transfer Program. Amplified on the following pages, they include:

- Liaison and awareness activities with regard to remote sensing applications, whereby NASA establishes relationships and maintains two-way communications with the user community.
- Regional remote sensing activities, wherein NASA conducts technology demonstrations of remote sensing applications to assist both new and experienced users in the effective employment of remotely acquired data.
- Industrial applications centers, channels through which industrial firms and other organizations interested in secondary utilization of technology may avail themselves of NASA scientific, technical and management information and expertise.
- A specialized center which provides aerospace-developed and other computer programs adaptable to the needs of industry and government agencies.
- Applications engineering projects, in which NASA undertakes adaptation of existing technology to specified needs of government agencies and public sector institutions.
- Application teams, multidisciplinary groups of technologists who provide technology-matching and problem-solving assistance to public sector organizations.
- Publications and announcement media, designed to acquaint potential users with available technologies emanating from aerospace research and development programs.

User Liaison

Satellite remote sensing is a means of acquiring enormous amounts of information about Earth's surface. The principal advantage of this new but increasingly proven technology is that, in many applications, it can provide more information on a more timely basis and at lower cost than other data-gathering methods. It is an effective tool for inventorying and analyzing natural resources and it is being used for such purposes by both private sector and government organizations, the latter including federal, state, regional and local agencies. Remote sensing offers vast potential benefit, and one element of NASA's Technology Transfer Program seeks to expand these benefits by establishing liaison with users and prospective users to generate greater awareness of the technology.

NASA promotes awareness of the technology through symposia, workshops, publications and direct contact with personnel of agencies which might employ remotely-sensed data to advantage. Where real interest and opportunities exist for transfer of the technology, NASA assists the user in learning how to extract useful information from satellite-acquired data tapes and images, and how to put the information to work in the user's environment. In some cases, NASA aids user development by conducting cooperative projects involving demonstrations of specific applications; the intent is to build user confidence that the technology can be applied advantageously and cost-effectively.

NASA maintains continuing two-way communications with active users. NASA technologists stay abreast of advances in remote sensing technology and keep user organizations informed of new capabilities. Users, in turn, advise NASA of results and difficulties in employing satellite data; this "feedback" serves to guide NASA program planning.

Remotely-sensed information is particularly valuable to state policy makers and management officials, who have special need for comprehensive, up-to-date information on which to base management and planning decisions involving vast natural and man-made resources. Eight states already have operational capabilities for extracting and employing information from space-acquired data; nearly all other states have some degree of remote sensing involvement. NASA maintains direct contact with state officials and also makes use of two other national channels as an aid to identifying user needs and priorities and for acquiring feedback. These channels are the National Conference of State Legislatures and the National Governors Association. For information on the remote sensing activities of these organizations, contact:

Paul Tessar, Director, Remote Sensing Project, National Conference of State Legislatures, 1405 Curtis Street, Denver, Colorado 80202; Peggy Harwood, Staff Associate, Council of State Planning Agencies, National Governors Association, 444 North Capitol Street N.W., Washington, D.C. 20001.

Regional Activities

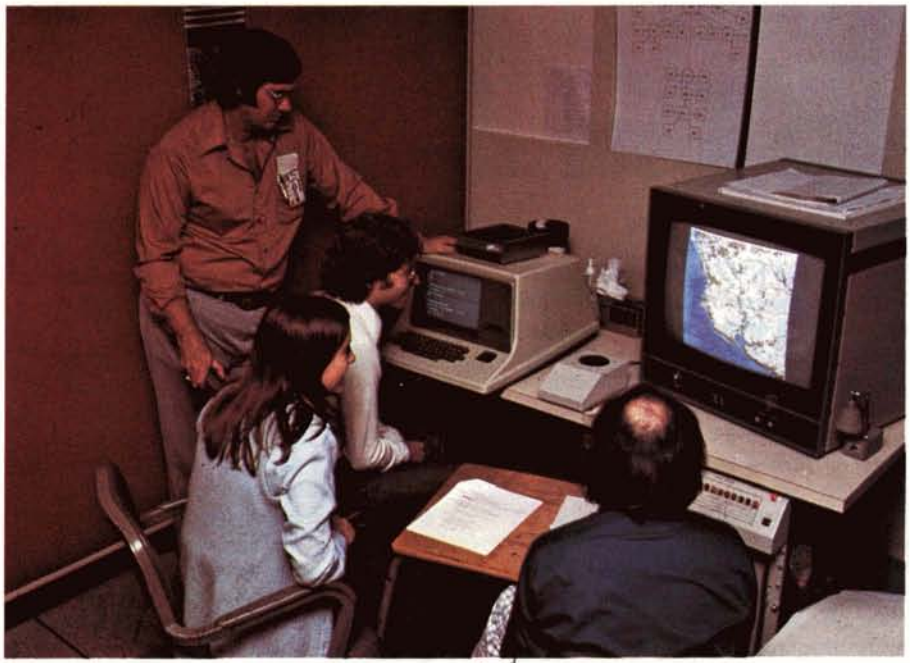
To encourage the transfer of remote sensing technology and facilitate its broader use, NASA operates the Regional Remote Sensing Applications Program. User assistance is organized on a geographical basis, with principal activities concentrated in three of NASA's field centers (see accompanying map).

Ames Research Center (ARC), Moffett Field, California deals with user organizations in 14 western states, including Alaska and Hawaii. National Space Technology Laboratories (NSTL), Slidell, Louisiana serves 17 states in the midwest, south and southeast. Goddard Space Flight Center (GSFC), Greenbelt, Maryland is responsible for user liaison in 19 eastern/northeastern states plus Puerto Rico and the Virgin Islands. Each of the regional centers has the full range of equipment and know-how needed to assist both new and experienced users in making use of remotely-acquired data and information extraction techniques. When necessary, they draw upon the resources and expertise of the other NASA centers.

The regional centers provide training, conduct small scale demonstration projects and offer technical assistance to on-going users. An initial training phase involves basic orientation to acquaint decision makers and other user personnel with remote sensing capabilities, applications and limitations. In a more advanced course, technicians of user organizations get "hands-on" training and experience in data analysis techniques through participation in demonstration projects. Demonstrations selected are based on well-proven, low-risk applications suitable for operational use in resource management programs—for example, land use classification, agricultural resources assessment and water resources inventory.

Organizations which elect to develop capabilities for using satellite data sometimes face problems in successfully applying the data to specific needs and in assessing their hardware and software requirements. Therefore, NASA provides continuing assistance to users to help them become self-sufficient in applying remote sensing technology. Regional activities to date have focused on state government applications, but NASA is now also begining to address the somewhat different needs of sub-state governments—such as counties—and encouraging greater private sector involvement in supporting users of the technology.

For more detailed information about the Regional Remote Sensing Applications Program, contact the NASA Headquarters or Regional Center personnel listed on page 115.



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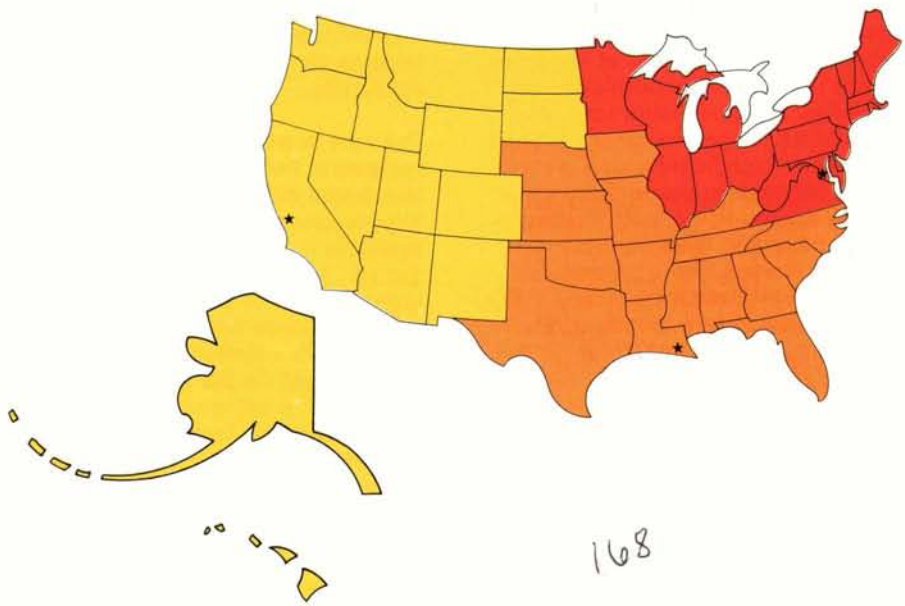

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Technology Applications

One facet of NASA's Technology Transfer Program is its applications engineering effort, which involves the use of NASA expertise to redesign and reengineer existing aerospace technology for the solution of problems encountered by federal agencies or other public sector institutions.

Applications engineering projects originate in one of three ways. Some stem from requests for NASA assistance from other government agencies; others are generated by NASA technologists who perceive possible solutions to public sector problems by adapting NASA technology to the need. NASA also employs six application teams, each team composed of several scientists and engineers representing different areas of expertise. These teams contact public sector agencies, medical institutions, and trade and professional organizations to uncover significant problems which might be susceptible to solution by application of NASA technology. Located at research institutes and universities, the application teams concentrate their efforts in the fields of health care, public safety, transportation and industrial productivity.

A technology application example is Project FIRES, a multi-year program jointly sponsored by NASA and the U.S. Fire Administration (USFA) of the Department of Commerce. FIRES is an acronym for Firefighter's Integrated Response Equipment System; the project involves application of advanced materials and design concepts to municipal firefighters' protective clothing and hand-held equipment.

Firefighter protective gear has gone basically unchanged for half a century. Current gear is burdensome (nearly 80 pounds) and it does not adequately protect against the many hazards encountered in fire suppression activities. Project FIRES represents a systematic approach to providing fire personnel protective gear of significantly reduced weight which offers maximum protection and greater ease of movement. The aim is to reduce the incidence of injuries, heat exhaustion and fatigue, important from a financial as well as a humanitarian standpoint because injury/disability benefits constitute large expenditures of municipal resources.

The new protective gear is being developed in two phases: an interim system based on existing technology and a more advanced ensemble to be available in the latter part of the next decade. In the above photos, the interim system—which includes helmet and gloves not shown—is pictured at left; developed by Marshall Space Flight Center with contractor assistance, it will be ready this year for performance tests by USFA and selected municipal firefighting organizations. The advanced ensemble, now in design status, is at right.

Another technology application example is the NASA Automated Water Monitoring System. This project derived from a NASA/Department of Housing and Urban Development program for design of a closed utility system for a 500-unit garden apartment complex. The utility system involves on-site power generation with use of recovered waste heat for residential heating/cooling and for water processing. To assure the safety and quality of treated water used for various purposes throughout the utility system, NASA initiated development of the automated water monitoring system at Johnson Space Center. Ames Research Center is now responsible for development and program management. This system employs 21 sensors to measure 17 water conditions, such as temperature, chemical composition, and the presence of hydrocarbons and bacteria.

The system is installed in a van (interior shown at right) and is undergoing test at a Santa Clara Valley Water District water reclamation facility (far right) near Palo Alto, California. Samples are drawn from several treatment points in the reclamation process and piped to the van for test. The whole operation—sampling, sensor calibration and control, data acquisition/analysis and water quality reporting—is automated and computer-controlled. A cost benefit study indicates that the NASA system offers significant potential savings in comparison with conventional water monitoring procedures.

A third example, pictured at upper right, is an implantable human tissue stimulator, designed to provide relief

Outtake available

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to thousands of patients with common disorders treatable by electric stimulation, such as back, leg and arm pain, cancer pain and multiple sclerosis. Existing stimulation systems require an external power source and a transmitting coil; they are cumbersome, uncomfortable, inconvenient and often unreliable.

NASA developed the implantable tissue stimulator in cooperation with Johns Hopkins University, several major medical centers and industrial participants. Designed for minimal size and weight, low power consumption and high reliability, the device has an internal power source—a nickel-cadmium power system rechargeable from the surface of the skin. An outgrowth of technology developed for spacecraft electronics, the device allows a physician to adjust stimulation according to the treatment needs of a particular disorder. He does so by use of the command programmer pictured, which operates in a manner similar to the way radio commands are sent to orbiting satellites from a ground transmitter.

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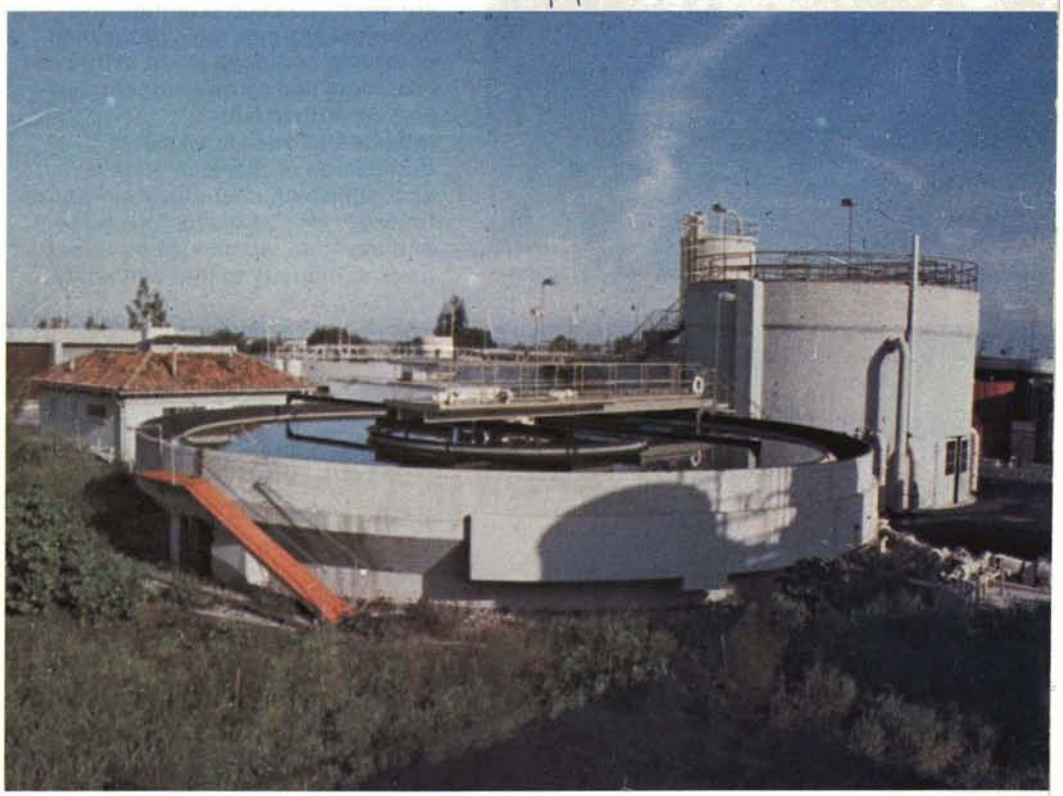

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Industrial Applications Centers

To promote technology transfer, NASA operates a network of applications centers whose job is to provide information retrieval services and technical assistance to industrial and government clients. The network consists of seven Industrial Applications Centers (IAC) and two State Technology Applications Centers (STAC) located at university campuses across the country, each serving a geographical area. 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 ongoing NASA research and engineering with client interests.

The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval. Through the applications centers, clients have access to some 10 million documents, one of the world's largest repositories of technical data. More than 1.5 million of these documents are NASA reports covering every field of aerospace activity. In addition, the data bank includes the continually updated contents of 15.000 scientific and technical journals, plus thousands of reports compiled by industrial researchers and by government agencies other than NASA.
Intended to prevent wasteful duplication of research already accomplished, the Industrial Applications Centers endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems. By taking advantage of IAC services, businesses can save time and money and the nation benefits through increased industrial efficiency and productivity.

Staffed by scientists, engineers and computer retrieval specialists experienced in working with companies, the IACs provide three basic types of services. To an industrial firm contemplating a new research and development program or seeking to solve a problem, they offer "retrospective searches"; they probe the data bank for relevant literature and provide abstracts or full-text reports on subjects applicable to the company's needs. IACs also provide "current awareness" services, tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields with a minimal investment of time. Additionally, IAC applications engineers offer highly skilled assistance in applying the information retrieved from the data bank to the company's best advantage. The IACs charge a nominal fee for their services.

The experimental State Technology Applications Centers supplement the IAC system. They facilitate technology transfer to state and local governments, as well as to private industry, by working with existing state mechanisms for providing technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state. In effect, the STAC program focuses on areas not normally served by the IACs, especially in the less industrialized states and among small businesses.

For further information on the nature of applications center services, contact the director of the nearest IAC or STAC listed on pages 115 and 116.

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Publications

An essential step in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This is accomplished by means of several types of publications.

The National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. These reports provide input to NASA's principal technology utilization publication, *Tech Briefs*. Issued quarterly, *Tech Briefs* provides current awareness of problem-solving tools for its more than 45,000 industrial subscribers. Each issue contains information on approximately 100 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

A special feature of *Tech Briefs* is a section on "New Product Ideas," innovations stemming from NASA research that appear to have particular promise for commercial application. Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on a particular product or process described in the publication. Innovations reported in *Tech Briefs* last year generated more than 65,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader secondary use of NASA technology.

Subscription to *Tech Briefs* is free to engineers in U.S. industry, business executives, state and local government officials and other potential users of aerospace technology. The publication may be obtained by writing to the Director, Technology Transfer Division, NASA Scientific and Technical Information Facility. Post Office Box 8756. Baltimore/Washington International Airport. Maryland 21240.

NASA also publishes the announcement bulletin *Computer Program Abstracts* (see item at right) and a variety of special publications. The latter are reports, technical handbooks and data compilations designed to acquaint the non-aerospace user with NASA advances in various states of the art. Examples include new developments in welding and soldering, lubricants and lubricating techniques, human factors engineering, sterilization and decontamination. Many of these publications are available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Others may be obtained from the National Technical Information Service, Springfield, Virginia 22161. A list of titles is available from the Director, Technology Transfer Division, at the address listed earlier.

Software Center

Like hardware technology, computer programs have secondary applicability; programs developed for one purpose can often be adapted to another. To help industrial firms, government agencies and other organizations take advantage of this type of technology transfer, NASA operates the Computer Software Management and Information Center (COSMIC), located at the University of Georgia.

COSMIC collects, screens and stores computer programs developed by NASA and other technology-generating agencies of the government. The center's library contains more than 1,500 programs, which perform such tasks as structural analysis, electronic circuit design, chemical analysis, design of fluid systems, determination of building energy requirements and a variety of other functions. COSMIC offers these programs at a fraction of their original cost and the service has found wide acceptance.

Availability of potentially adaptable programs is announced in the NASA publication *Computer Program Abstracts*, which may be obtained through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. For additional information about COSMIC's services, contact the director at the address listed on page 116.

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NASA's Technology Transfer Network

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, together with regional coverage of state and local governments engaged in technology transfer activities.

★ *NASA field center Technology Utilization Officers:* manage center participation in regional technology utilization activities.

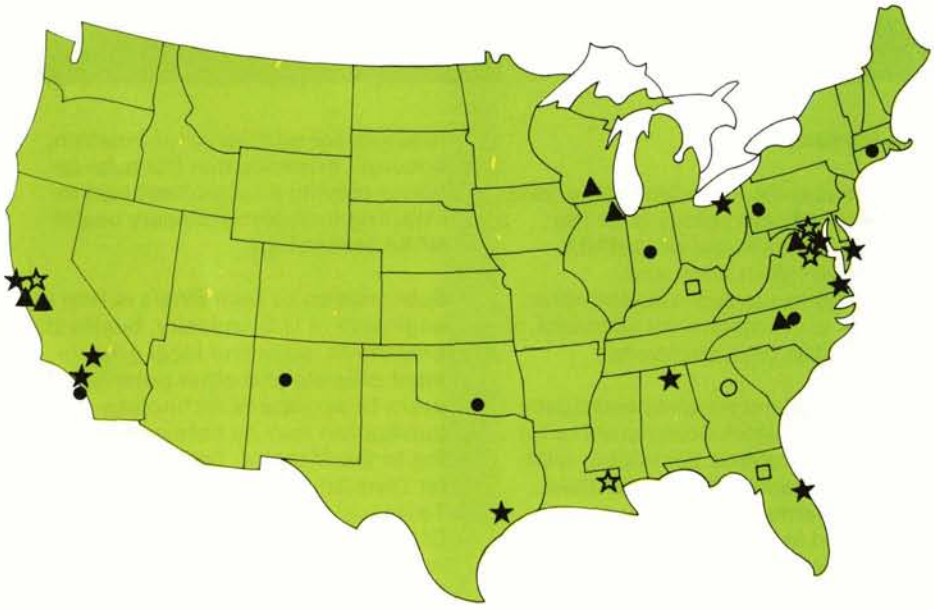
☆ *Regional Remote Sensing Applications Centers:* provide training, conduct demonstrations and offer technical assistance to users of remote sensing data.

● *Industrial Applications Centers:* provide information retrieval services and assistance in applying relevant technical information to users needs.

□ *State Technology Applications Centers:* provide technology transfer services similar to those of the Industrial Applications Centers, but only to state governments and small businesses within the state.

○ *The Computer Software Management and Information Center (COSMIC):* offers government-developed computer programs adaptable to secondary use.

▲ *Application teams:* work with public agencies in applying aerospace technology to solution of public sector problems.



The following pages list key technology transfer personnel and addresses of the various facilities. For information of a general nature about the Technology Transfer Program, address inquiries to the Director, Technology Transfer Division, NASA Scientific and Technical Information Facility, Post Office Box 8756, Baltimore/Washington International Airport, Maryland 21240.

NASA Field Centers

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, California 94035

Technology Utilization Officer: *Charles C. Kubokawa*
Phone: (415) 965-5554

Hugh L. Dryden Flight Research Center
National Aeronautics and Space Administration
Post Office Box 273
Edwards, California 93523

Technology Utilization Officer: *John C. Drane (acting)*
Phone: (805) 258-3311, Ext. 787

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 344-6242

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas 77058

Technology Utlization Officer: *John T. Wheeler*
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899

Technology Utilization Officer: *Raymond Cerrato*
Phone: (305) 867-2780

Langley Research Center
National Aeronautics and Space Administration
Langley Station
Hampton, Virginia 23655

Technology Utilization and Applications Programs Officer:
John Samos
Phone: (804) 827-3281

Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135

Technology Utilization Officer: *Paul Foster*
Phone: (216) 433-4000, Ext. 6422

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Director, Technology Utilization Office: *Aubrey D. Smith*
Phone: (205) 453-2224

NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Technology Utilization Officer: *John C. Drane*
Phone: (213) 354-6420

Wallops Flight Center
National Aeronautics and Space Administration
Wallops Island, Virginia 23337

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, Ext. 2201

Regional Remote Sensing Applications Centers

National Space Technology Laboratories
Earth Resources Laboratory
1010 Gause Boulevard
Slidell, Louisiana 70458

Director, Southern Regional
Remote Sensing Applications Center: *Roy Estess*
Phone: (504) 255-6472

Goddard Space Flight Center
Greenbelt, Maryland 20771

Head, Eastern Regional
Remote Sensing Applications Center: *Philip Cressy*
Phone: (301) 344-7658

Ames Research Center
Moffett Field, California 94035

Chief, Technology Applications Branch: *Dale Lumb*
Phone: (415) 965-5900

NASA Headquarters
Technology Transfer Division
Office of Space and Terrestrial Applications
Washington, D.C. 20546

Manager, Regional Remote
Sensing Applications Program: *Richard H. Weinstein*
Phone: (202) 755-7450

Industrial Applications Centers

Aerospace Research Applications Center (ARAC)
1201 East 38th Street
Indianapolis, Indiana 46205

E. G. Buck, director
Phone: (317) 264-4644

Knowledge Availability Systems Center (KASC)
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Allen Kent, acting director
Phone: (412) 624-5211

New England Research Application Center (NERAC)
Mansfield Professional Park
Storrs, Connecticut 06268

Daniel Wilde, Ph.D., director
Phone: (203) 486-4533

North Carolina Science and Technology Research Center (NC/STRC)
Post Office Box 12235
Research Triangle Park, North Carolina 27709

Peter J. Chenery, director
Phone: (919) 549-0671

Technology Applications Center (TAC)
University of New Mexico
Albuquerque, New Mexico 87131

Stanley Morain, Ph.D., director
Phone: (505) 277-3622

Western Research Applications Center (WESRAC)
University of Southern California
University Park
Los Angeles, California 90007

Robert Mixer, Ph.D., acting director
Phone: (213) 741-6132

Kerr Industrial Applications Center (KIAC)
Southeastern Oklahoma State University
Durant, Oklahoma 74701

Robert Oliver, Ph.D., director
Phone: (405) 924-0121, Ext. 413

State Technology Applications Centers

NASA /Florida State Technology Applications Center
State University System of Florida
311 Weil Hall
Gainesville, Florida 32611

Robert A. Ramey, Ph.D., director
Phone: (904) 392-6626

NASA/University of Kentucky State Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, Kentucky 40506

William R. Strong, manager
Phone: (606) 258-4632

COSMIC

112 Barrow Hall
University of Georgia
Athens, Georgia 30602

Harold G. Hale, Jr., director
Phone: (404) 542-3265

NASA Biomedical Application Teams

Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709

Doris Rouse, director
Phone: (919) 541-6256

Stanford University School of Medicine
Cardiology Division
Biomedical Technology Transfer
701 Welch Road, Suite 3303
Palo Alto, California 94303

Donald C. Harrison, M.D., director
Phone: (415) 497-5935

Advisory Center for Medical Technology & Systems
University of Wisconsin
1500 Johnson Drive
Madison, Wisconsin 53706

William N. Fetzner, Ph.D., director
Phone: (608) 263-2735

NASA Technology Application Teams

Public Technology Inc.
1140 Connecticut Avenue, N.W.
Washington, D.C. 20036

Tom Smith, acting director
Phone: (202) 452-7700

SRI International
333 Ravenswood Avenue
Menlo Park, California 94026

Tom Anyos, Ph.D., director
Phone: (415) 326-6200, Ext. 2864

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

Edmund R. Bangs, director
Phone: (312) 567-4191

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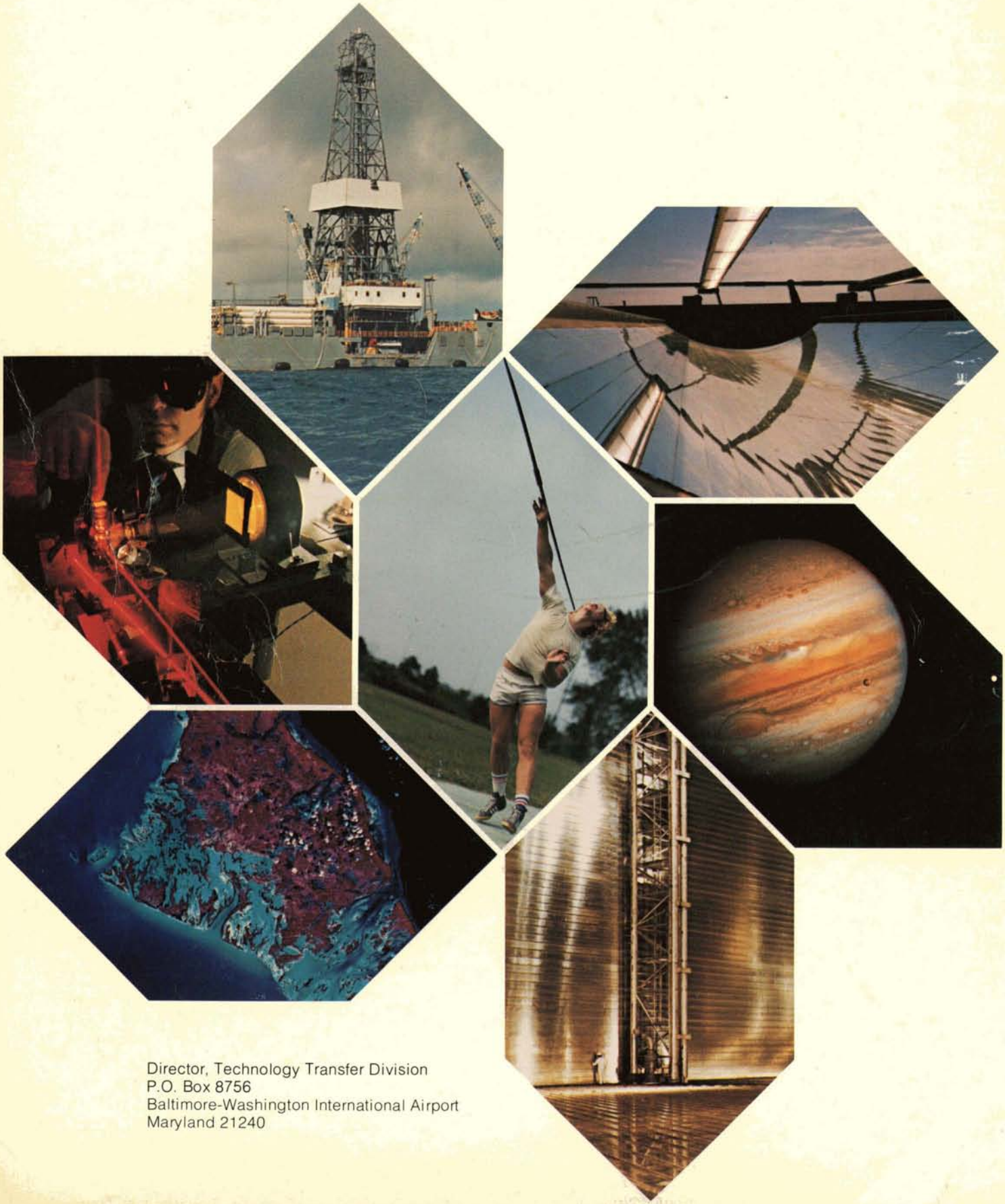
NASA

National Aeronautics and
Space Administration



Director, Technology Transfer Division
P.O. Box 8756
Baltimore-Washington International Airport
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