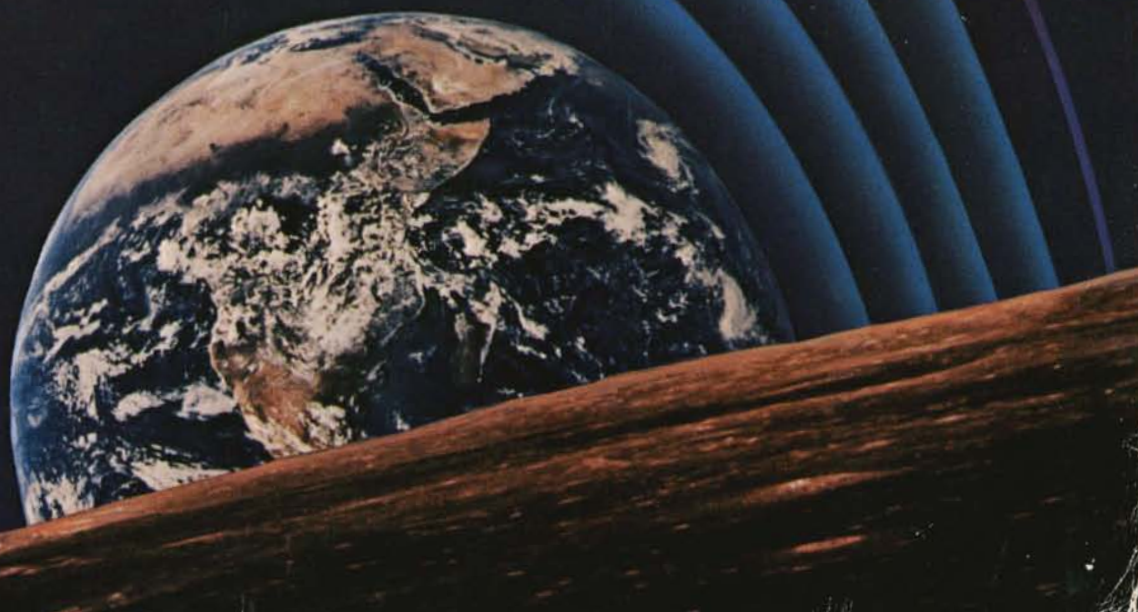
Spinoff 1980

An Annual Report

National Aeronautics and
Space Administration



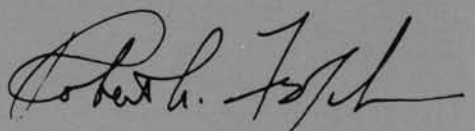
Foreword

In the National Aeronautics and Space Act of 1958, the legislative charter which established the National Aeronautics and Space Administration, the Congress directed that NASA pursue "the potential benefits to be gained from . . . the utilization of aeronautical and space activities for peaceful and scientific purposes." As we begin a new decade, it seems appropriate to reflect on how well NASA has responded to that Congressional mandate.

The operational communications and weather satellites now routinely serving mankind exemplify the many benefits accruing from practical application of space technology. This year marks the beginning of a national commitment to an operational land resources observation satellite system of exceptional benefit potential. The year will also see initiation of a new research program expected to lead to the next major beneficial capability: an operational system of ocean observation satellites.

Among other areas of benefit, NASA's space science program has provided a wealth of new scientific knowledge, immensely valuable in its own right and additionally important because it serves as a base for tomorrow's practical applications. The agency's aeronautical research effort has contributed in substantial degree to safer, more efficient, more environmentally acceptable flight. In recent years, NASA has applied its technological expertise in support of the Department of Energy's activity in developing new sources of energy and new ways of conserving it. And the secondary use, or reapplication, of the technology generated by these major programs has produced a broad range of indirect benefits—spinoffs—which collectively add up to significant gain in terms of personal convenience, human welfare, industrial efficiency and economic value.

Thus, the response to Congress' directive has been impressive. It bids to become more so in the forthcoming era of the Space Transportation System, which offers an entirely new capability for doing useful work in space. Among the many opportunities this new capability will provide, joint materials processing ventures with the private sector represent but one example of NASA's continuing commitment to vigorous pursuit of practical benefits.



Robert A. Frosch

Administrator
National Aeronautics and Space Administration

April 1980

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An Annual Report

National Aeronautics and Space Administration

Office of Space and
Terrestrial Applications
Technology Transfer Division

by James J. Haggerty

On the cover:

The artist's conception symbolizes man's outreach to other planets of the solar system, a means of learning more about our own planet Earth. The cover art commemorates "The Year of the Planets"—1979—a year of unprecedented planetary investigation during which several NASA spacecraft sent back to Earth volumes of new knowledge about Venus, Mars, Jupiter and Saturn (see Probing the Universe, page 6).

Acknowledgements:

James E. Beebe, Ph.D., Informatics Information Systems Company for coordinating the preparation of this report; Beveridge and Associates, Inc. for design and production; and William P. Taub for assistance with photography.
April 1980

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Introduction

Spinoff, in the context of this report, is the emergence of new products and processes which trace their origins to technology originally developed to meet the goals of NASA's aerospace programs. There have been thousands of such spinoffs, each contributing some measure of benefit to the national economy, productivity or lifestyle. In the aggregate, they represent a substantial dividend on the national investment in aerospace research.

By Congressional mandate, it is NASA's responsibility to promote expansion of spinoff in the public interest. Toward that end, NASA encourages withdrawals from the great bank of technology the agency has built up in 22 years of space and aeronautical research. Technology is simply knowledge, and like other forms of knowledge is transferable. Thus, the technology bank constitutes a valuable national resource, a storehouse of knowledge available for secondary application over a broad spectrum of public needs and conveniences.

Through its Technology Transfer Program, NASA seeks to broaden and accelerate the transfer process with the aim of expanding economic and other benefits to the nation. This publication is an instrument of that purpose; it is intended to heighten public awareness of the technology bank's potential for further gain and to stimulate interest among prospective users of the available technology.

Section I of this volume summarizes NASA's current mainline programs, which are producing *direct* public benefit and simultaneously contributing to *indirect* benefit—spinoff—by generating new technology which may find secondary application in the future.

Section II, the focal point of this report, contains a representative selection of spinoff products and processes, the breadth of which underlines the extraordinary degree to which spinoffs pervade everyday life.

Section III details the mechanisms NASA employs to foster technology utilization and additionally describes a related facet of the Technology Transfer Program; 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

April 1980

Spinoff 1980 **An Annual Report**

Aerospace Aims

An illustrated summary of NASA's major aeronautical and space programs, their goals and directions, their contributions to American technological growth, and the many ways in which they are producing benefits to mankind

Probing the Universe

Study of the Sun, the planets and more distant celestial bodies is producing a wealth of new knowledge about our own planet Earth

An exciting look at the surface of Venus, not visible to Earth-based optical telescopes because it is permanently cloud-shrouded, was provided last year by NASA's Pioneer Venus 1. The spacecraft's cloud-penetrating radar system showed a variety of terrain features, including mountains taller than Earth's.

Observing Io, one of the moons of the giant planet Jupiter, the Voyager 1 spacecraft photographed tremendous volcanic explosions which spewed matter a hundred miles above Io's surface. This marked the first identification of currently active volcanos elsewhere in the solar system.

Pioneer 11, Earth's first envoy to Saturn, discovered a hitherto unknown 11th Saturnian moon and uncovered the existence of two additional rings in the planet's multiple ring system.

These are a few of the great many scientifically important findings made by NASA planetary spacecraft during 1979. It was a particularly active year for planetary investigation, with several spacecraft simultaneously returning volumes of information about Venus, Mars, Jupiter and Saturn. Another chapter in the fascinating study of the solar system will be written this year—in November—when Voyager 1 flies by Saturn to amplify earlier data about the ringed planet and its moons.

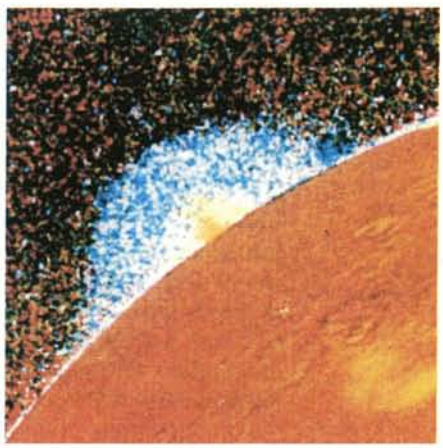
From flight missions like these, NASA is assembling a vast informational mosaic about the solar system and its intricate workings. A basic goal is to learn more about our own planet Earth through a process known as "comparative planetology"—relating phenomena on one planet to conditions on another. It is a program of immense scientific value and one which also has long-range potential for practical benefit. Greater understanding of the complex past and present processes that affect humanity's environment may in time open the door to management of these processes for mankind's benefit—controlling weather, for example.

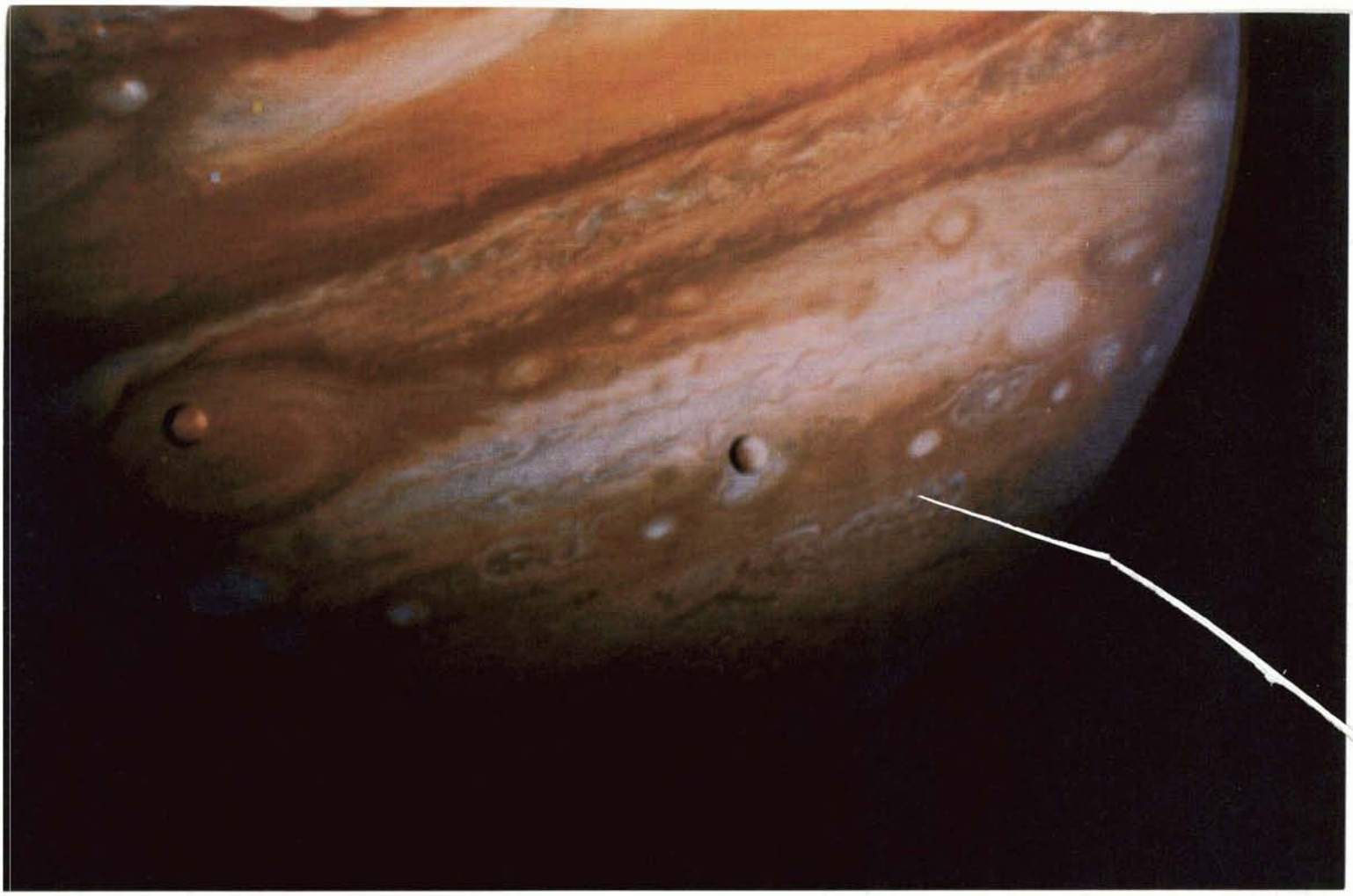
By virtue of their incredible ability to send photos and data over hundreds of millions of miles, the robot planetary explorers have gripped the world's imagination and have become the most publicly visible element of NASA's space science effort. Planetary investigation, however, is but one part of the comprehensive, four-pronged space science program, other elements of which include:

- Astrophysics research, involving observation of distant stars, galaxies and other celestial phenomena in a quest for understanding the size, scope and structure of the universe, its origin and evolution.
- Solar terrestrial research, including study of the processes that generate energy in the Sun and transport it to Earth, and the interactions of that energy with Earth's environment.
- Life sciences research, aimed at understanding the origin and distribution of life in the universe; in addition, this area of effort takes advantage of the space environment to improve knowledge in medicine and biology, and seeks to develop means whereby humans may safely perform in space over long periods of time to carry out the extraterrestrial missions contemplated for the future.

Much of the space science effort is accomplished by Earth satellites and planetary probes, but researchers employ a variety of other information-gathering tools—non-orbiting flight vehicles, such as instrumented sounding rockets, aircraft and balloons, and ground-based systems such as radio telescopes, optical telescopes and laboratory facilities. The space science program has a multitude of goals, but they have a common denominator: fitting the tiny planet Earth into the cosmic puzzle that is the origin, the evolution and the structure of the universe. The end product is knowledge, an incalculably valuable resource which will serve as a base for tomorrow's technology and perhaps for practical applications totally unimaginable today.

Taken in March 1979, this historic photo of Jupiter's moon Io shows an enormous hundred-mile-high volcanic eruption, the first ever viewed outside Earth. The illustration at right is a computer-processed blow-up of the eruption's core. This ultraviolet view shows detail not apparent in visible light, including matter extending far above the central core.





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Outer Planet Studies

Representative of thousands of photographs returned last year by two Voyager spacecraft is this dramatic view of Jupiter and two of its 14 moons—Io (left) and Europa. In an eight-month close-up study of Jupiter, the two craft sent back a wealth of photographic and instrument data, including the discovery that Jupiter —like Saturn and Uranus—has a ring. The Voyagers are now en route to Saturn for a similar reconnaissance. Voyager 1 will arrive in November of this year; Voyager 2 will encounter Saturn in August 1981, then, if all goes well, will continue on a path that will take it to Uranus, two billion miles from Earth, in 1986. A new and even more extensive investigation of Jupiter will get under way with the 1984 launch of NASA's Galileo mission, which involves two separate spacecraft. The first spacecraft will swing into orbit around Jupiter, studying the planet and its moons over a long period and amplifying the information provided by the Voyagers. The other member of the Galileo team, an instrumented probe, will descend through Jupiter's clouds and supply first-hand data on the composition of the Jovian atmosphere. Jet Propulsion Laboratory (JPL) has managerial responsibility for both Voyager and Galileo. JPL will also build the Galileo orbiter; Ames Research Center is developing the probe.

Frost on Mars

This high-resolution photo, showing a thin coating of water frost on the Utopia Plains of Mars, was returned by Viking Lander 2 last year. It is scientifically interesting because the frost appeared almost exactly one Martian year (23 Earth months) after Lander 2 photographed a similar frost layer; in each case the frost coincided with the arrival of Martian winter. Scientists believe that frost formation may be initiated by condensation of ice on dust particles in the atmosphere, which in time gain enough weight to settle to the Martian ground. Viking information indicates that the frost lasts about 100 days, then is dissipated by Sun warmth. The Viking Landers were designed to operate 90 days after touchdown on Mars, but they are still returning data after almost four years on the Red Planet. Jet Propulsion Laboratory handles Viking operations and data collection.

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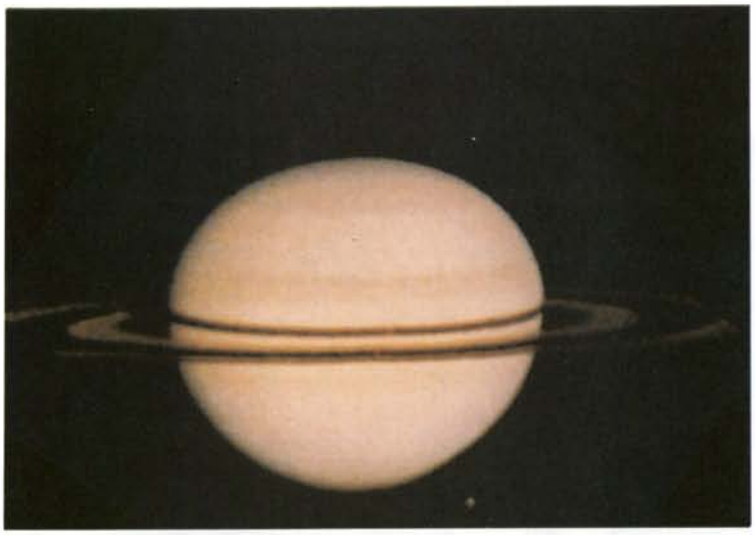
Saturn Reconnaissance

After a six-year, two billion-mile journey, the Pioneer 11 spacecraft reached Saturn last September and conducted the first close-up reconnaissance of Saturn, its rings and several of its moons. Pioneer 11 survived intense radiation in the vicinity of Saturn and a barrage of particle impacts to make a close encounter only 13,000 miles from massive Saturn, second largest planet of the solar system. The spacecraft sent to Earth volumes of instrument data and about 50 close-up photographs, information of immense scientific importance because Saturn is difficult to observe in detail from Earth due to its great distance; the close-up photos provided five to six times more detail than the best Saturn pictures acquired by Earth telescopes. Pioneer 11 also blazed a trail for Saturn-bound Voyagers 1 and 2 and significantly increased their chances for successful Saturn encounters in 1980 and 1981. In the photos below, the full view of Saturn was taken by Pioneer 11 when the spacecraft was 1.8 million miles from the planet; faintly visible below Saturn is the moon Titan. The other photo shows a portion of Saturn's ring system in detail never before seen.



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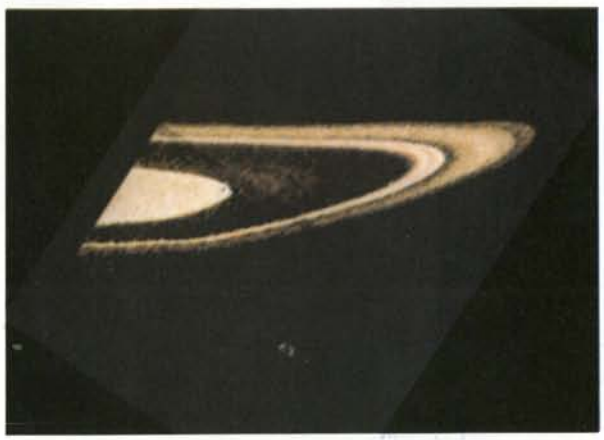

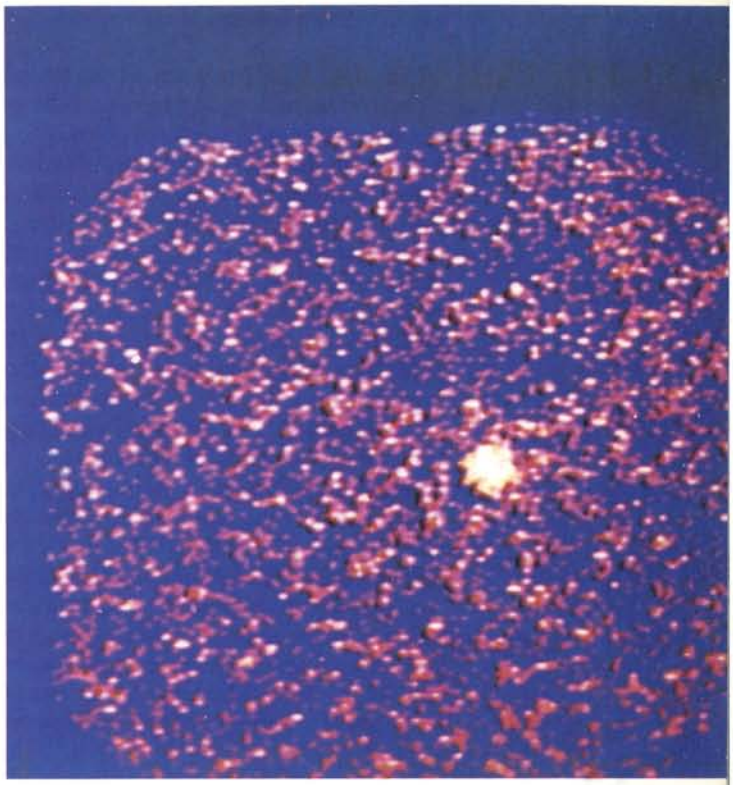

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X-ray Astronomy

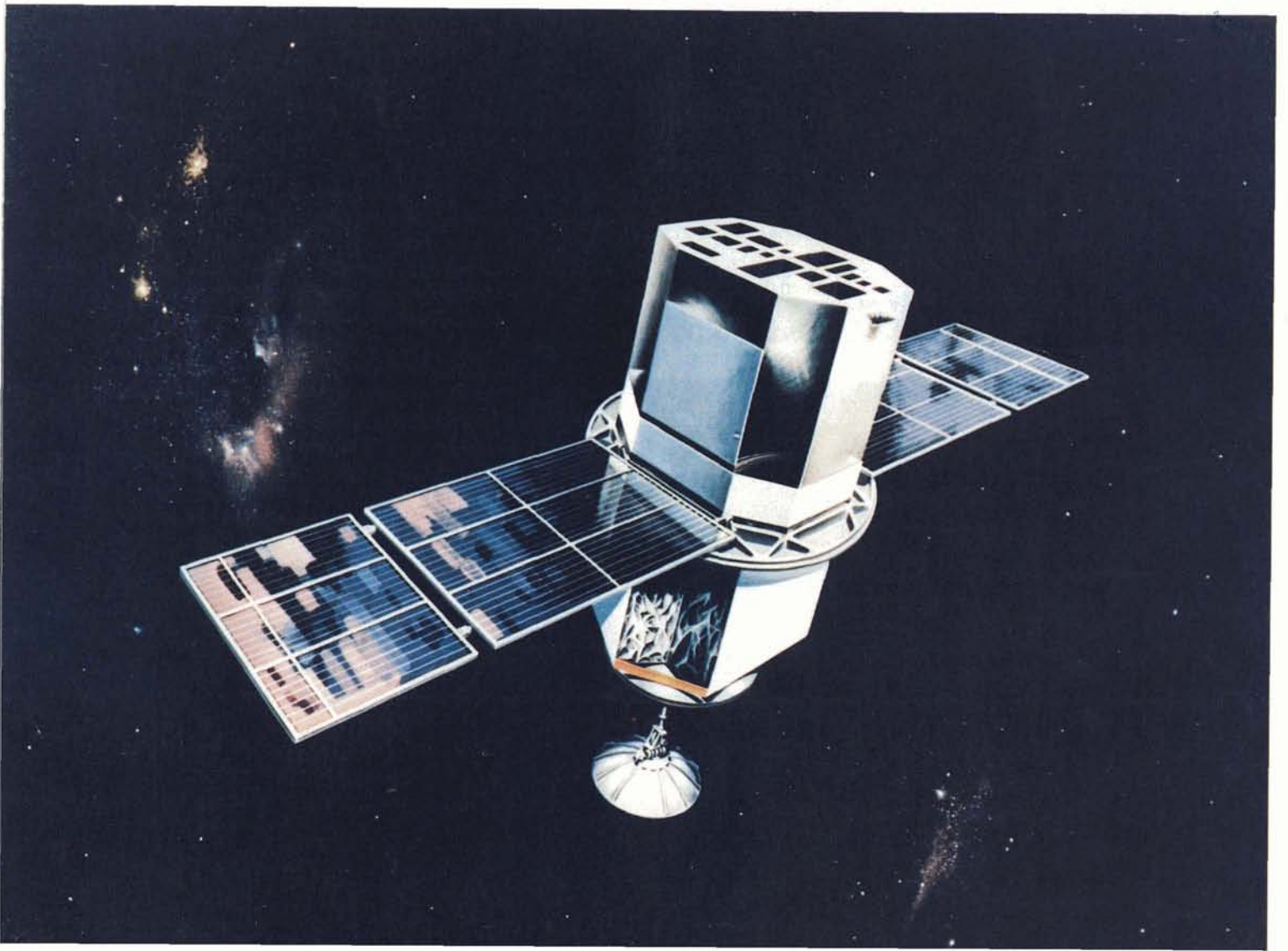
The above photo, taken by NASA's High Energy Astronomy Observatory 2 (HEAO-2), is the first picture of a rare and little understood celestial phenomenon known as an "X-ray burster." Compact objects with apparent diameters of less than 30 miles, bursters are characterized by sudden, very intense increases in x-ray brightness accompanied by tremendous emission of energy; a typical burst releases more x-ray energy in 10 seconds than our Sun does in an entire week. Burster study is one of several research fields being probed by two HEAO spacecraft, which enable scientists to study x-ray, gamma ray and cosmic ray emissions from stars and starlike objects billions of light years distant from Earth. HEAO-3, newest of the observatories, was sent into orbit last September; HEAO-2 has been operating since 1978. The initial spacecraft of the HEAO series, launched in 1977, completed its mission last year and was retired. The HEAO program is managed by Marshall Space Flight Center.

Solar Activity Research

The Sun, a ball of hot gases whose temperatures are measured in millions of degrees, undergoes periods of changing activity in the form of massive eruptions, particle discharges and intense radiation output. This activity waxes and wanes on a rhythmic 11-year cycle; it is currently at peak level. During the International Solar Maximum Year (1979-81), scientists all over the world are conducting studies—from ground and space observatories—of the Sun/Earth relationship during a peak activity period. A key tool of this effort is NASA's Solar Maximum Mission spacecraft (shown), which contains seven different instruments for monitoring solar activity. The observatory's assignment is study of solar flares, enormously forceful Sun eruptions whose sudden energy release is at times equivalent to the energy used by the entire world in many centuries. From investigations of flares and other solar activity, scientists expect to acquire a great deal of new information on how solar energy processes work. This information is also important to better understanding of energetic processes occuring on other stars throughout the universe. The Solar Maximum Mission program is managed by Goddard Space Flight Center.

Solar Polar Mission

In a project known as the International Solar Polar Mission (ISPM), two spacecraft will be Shuttle-launched in 1983 to probe a hitherto unexplored region of space. Earth itself and all spacecraft launched from Earth move through space close to an imaginary plane—called the ecliptic—which extends outward from the Sun's equator. The ISPM spacecraft will depart the ecliptic and venture into the spatial "third dimension," orbiting the Sun around its poles. The two craft (shown in artist's concept at right) will be directed first to Jupiter, whose tremendous gravity will be employed to "slingshot" them out of the ecliptic and back toward the Sun. They will arrive in the vicinity of the Sun's poles—one at each pole—late in 1986; subsequently, each will fly over the opposite pole, enabling comparative studies. Exploration in this new perspective, above and below the ecliptic, is expected to expand knowledge of the Sun's surface, its radiation and magnetic fields, and shed light on how high-velocity solar winds originating in solar polar regions can have a strong impact on Earth's environment. ISPM is co-sponsored by NASA and the 11-nation European Space Agency; each organization will provide one spacecraft. NASA's project manager is Jet Propulsion Laboratory.



9

Space Telescope

One of the most exciting of all space projects and one which has aroused wide interest among the scientific community is the Space Telescope, an orbiting astronomical observatory which will open a new door to the universe. Operating above the obscuring influence of Earth's atmosphere and employing an array of advanced equipment, it will be the most powerful astronomical telescope ever built. It will be able to detect celestial objects never before seen, objects 50 times fainter than those now observable, and it will expand the volume of the universe which can be observed by optical systems from three percent to 95 percent. With the 94-inch-diameter telescope, scientists will be able to view the universe in both the visible and ultraviolet light portions of the spectrum. Designed to operate at least through the end of the century, the Space Telescope is scheduled for delivery to orbit in 1983 and periodically visited by Shuttle crews for maintenance. Marshall Space Flight Center has management responsibility for Space Telescope development and Goddard Space Flight Center will oversee the observatory's operation.

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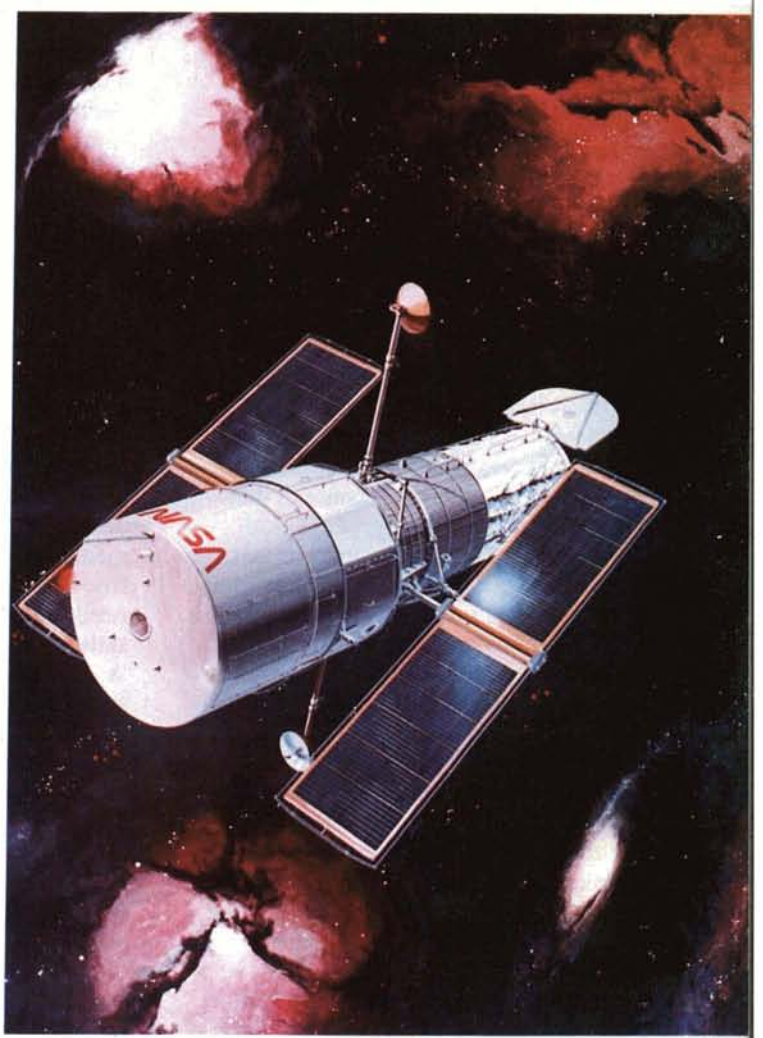


The Space Connection

A link to orbit, the Space Transportation System will give NASA a new range of capability for pursuing beneficial opportunities in space

Would you be interested in an automobile made of lighter-yet-stronger materials which, because it is lighter, would use less fuel and which, because it is stronger, would last half a million miles? Such a car would be possible if automakers had available a certain type of metal alloy. It is not now available because the metallic combination will not "mix" in the presence of Earth's gravity. But it could be produced in the gravity-free environment of orbital space.

This is one of many possibilities being examined by industrial researchers, who see in the forthcoming debut of the Space Shuttle what one national magazine termed "the key to opening the next industrial revolution." The Shuttle is the first and principal element of a Space Transportation System which will enable assembly in orbit of human-habitable space factories. Such facilities would turn out a new range of products impossible to process on Earth because of the influences of air and gravity—for example, a variety of superior construction and manufacturing materials for Earth use; pure glass, free of container contamination, for laser, optical and electronic applications; flawless crystals for improved electronic systems; and an entirely new class of high-purity, more effective pharmaceuticals.

Space construction capability offers a number of other advantageous applications. One structure being planned is a large orbiting platform, stationary with respect to Earth, housing many different types of payloads now contained in individual satellites; it would reduce the number of objects in orbit, lessen radio interference and allow multiple-system servicing on a single visit of a maintenance vehicle. Another example is an orbital "farm" of superpowered antennas which would offer vast improvement in global communications, perhaps such innovations as low-cost space-relayed electronic mail or long-range voice communication by wrist radio. A possibility of enormous potential is a network of orbital power stations beaming Sun-generated electricity to Earth. Some of the early Shuttle missions will be devoted to technology development for these and other large orbital structures.

In its initial form, the Space Transportation System will consist of the Space Shuttle, the Spacelab manned laboratory which fits into the Shuttle Orbiter's cargo bay, and two types of upper stages; the latter are propulsion systems for boosting certain payloads to higher altitudes after they are Shuttle-delivered to low Earth orbit.

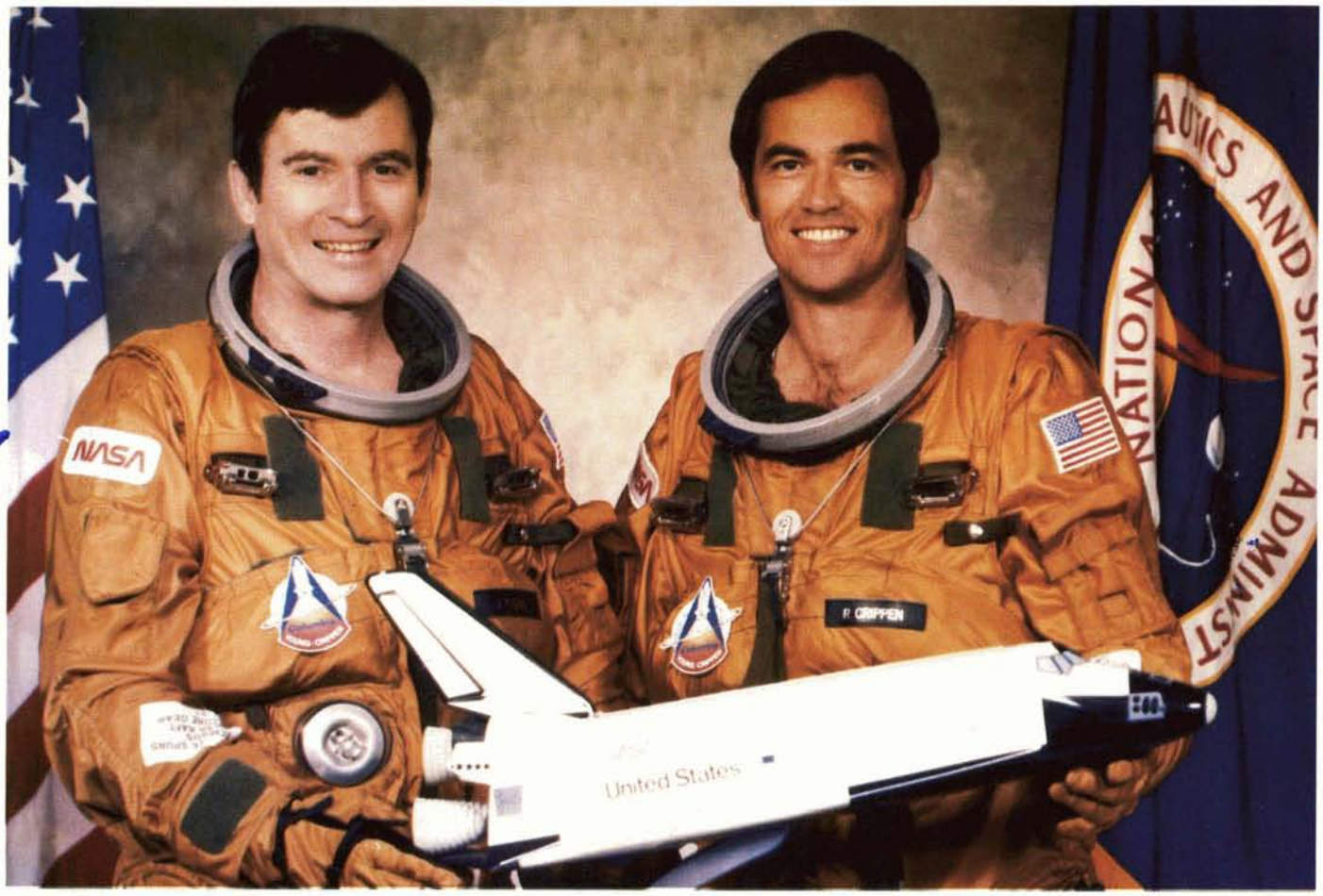
Among additions planned for later development are robot systems for maintenance and construction tasks; free-flying power modules for electrical needs greater than the Shuttle can satisfy; orbital transfer vehicles, or "space tugs," for transporting cargo and people from low to high orbits; and a heavy lift vehicle for space construction work, a Shuttle-derived system capable of delivering payloads much heavier or of greater dimensions than the Shuttle can accommodate. The Shuttle itself will undergo evolutionary improvements in weight-lifting and durational capabilities; on early flights it will operate in space for about seven days but later its "stay-time" will be increased to 30 days or more.

Keynotes of the Space Transportation System are flexibility and economy. Flexibility includes the system's use for delivering payloads to any desired orbit or into interplanetary trajectories, servicing satellites in space or retrieving them for rework on Earth. Additionally, the Shuttle Orbiter can serve as a laboratory for human-directed experiments in space, as a space construction base and as an Earth-to-orbit ferry for support of future manned space facilities.

The fact that the Shuttle's main components—the Orbiter and its solid rocket boosters—can be recovered, refurbished and re-used is the primary factor in the system's economy; reusability eliminates the need for costly one-shot launch vehicles and reduces the cost of orbiting payloads substantially below current levels. But Shuttle economy goes further: orbital repair or retrieval of satellites extends their useful lives and saves replacement costs.

The operational advent of the Space Transportation System will inaugurate a new era of space operations, an era characterized by routine, economical access to orbit and a much broader capability for pursuing the many significant benefits that space affords.

Ready for launch, the Space Shuttle consists of three main elements: the Orbiter, manned segment of the system; two recoverable solid boosters which team with the Orbiter's main engines to produce launch thrust; and the huge, expendable central fuel tank, which feeds the Orbiter's engines during the ascent phase.



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Astronaut Training

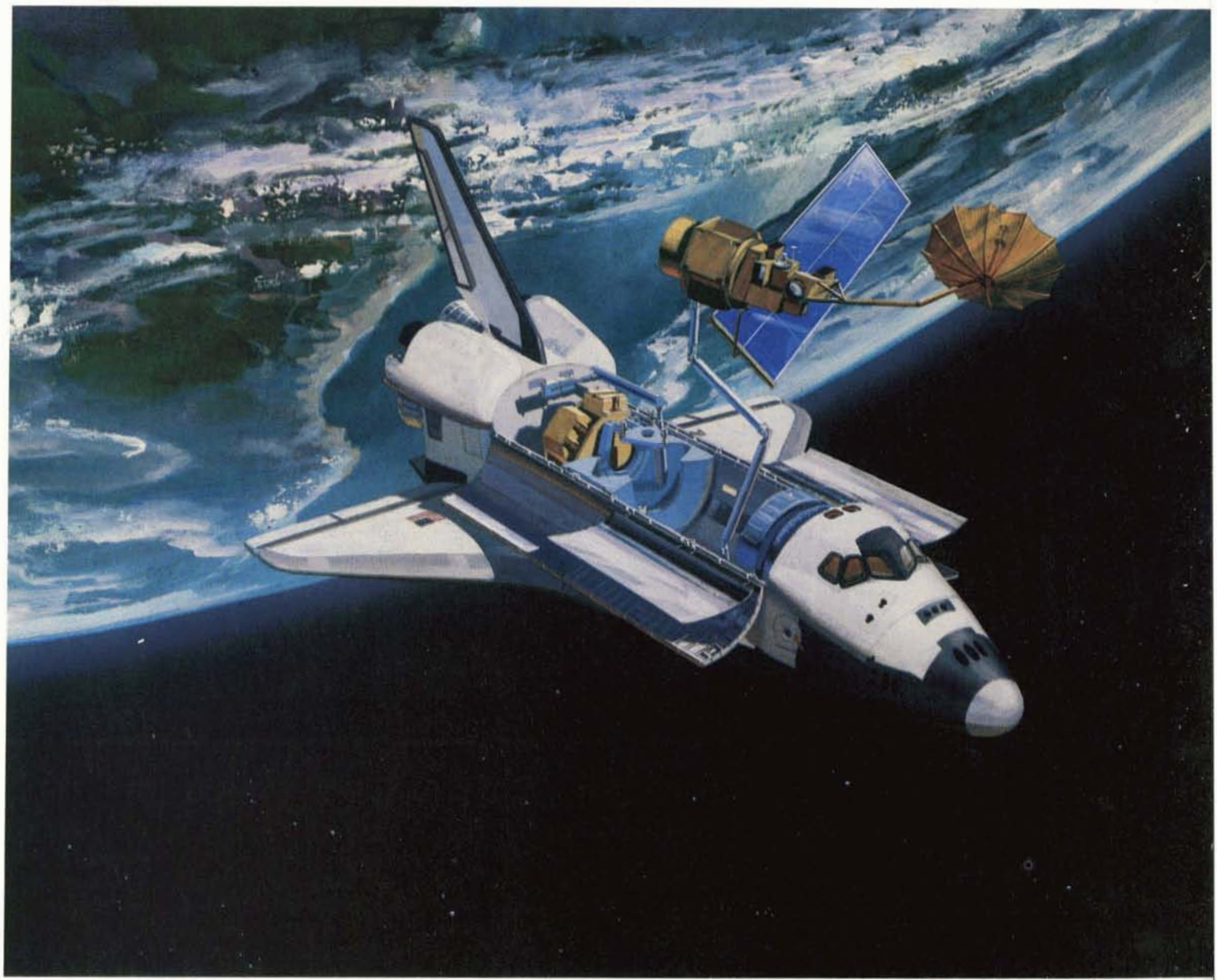
In the upper photo are astronauts John W. Young (left) and Robert L. Crippen, who will be commander and pilot, respectively, of the Orbiter *Columbia* on the first orbital flight of the Space Shuttle system. In the lower photo, Young (in the left seat) and Crippen are running through a checkoff list preparatory to "flying" a Shuttle mission in Johnson Space Center's Shuttle simulation facility. Flight simulations represent one of many activities in a comprehensive training program aimed at preparing NASA astronauts for Shuttle operations, which differ in many respects from prior manned space missions.

There are currently 62 qualified astronauts in the training program. Their number will be augmented annually by new selections from a pool of astronaut candidates, who will be chosen on the basis of their performance during a year of preliminary training and evaluation. Shuttle crews will be composed of two types of astronauts: pilot astronauts, who control the vehicle, and mission specialists. The latter are scientists and engineers who handle a number of assignments relative to payload deployment and retrieval, experiment activities and other aspects of Shuttle operations. Also undergoing training are a number of payload specialists who are not part of NASA's regular astronaut corps; they are scientific investigators, including a number from foreign countries, who will conduct experiments on Spacelab missions.

Shuttle Payloads and Users

A major part of the Space Shuttle's activity will be delivery of payloads to orbit in the manner illustrated by the artist's concept shown. The Orbiter, whose spacious cargo bay can accommodate one large spacecraft or as many as five smaller satellites, will deliver its payload to a predetermined point in orbit. The Orbiter crew will then open the cargo bay doors and use the Remote Manipulator System, a 50-foot triple-jointed robot arm, to extract the payload from the cargo bay and release it in space a safe distance from the Orbiter. Also used to retrieve payloads for on-the-spot servicing or for return to Earth, the manipulator is being developed by a Canadian industrial team under the direction of the National Research Council of Canada.

A tentative assignment list for the first two and a half years of Shuttle operational service shows that the bulk of the payloads will be new versions of the types of satellites launched in recent years. Additionally, the Shuttle will deliver such new developments as a NASA satellite network for more precise tracking and improved data acquisition from operational spacecraft; a commercial communications satellite system designed specifically for transmission of business data; some advanced scientific and applications experiments; and the first eight units of the Spacelab orbiting laboratory. The primary users over this initial service span will be NASA and the Department of Defense. Among other users are the National Oceanic and Atmospheric Administration, the European Space Agency, a number of foreign nations and the operators of several commercial communications satellite systems. For these and future customers, NASA will provide launch, delivery and related services on a reimbursable basis.



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Get Away Specials

On some Shuttle launches of primary payloads, there will be leftover space in the Orbiter's cargo bay. NASA is taking advantage of this space availability to allow Shuttle use by experimenters who could not afford the cost of orbiting a primary payload—small companies, educational institutions, research organizations and individuals. At "Get Away Special" rates of $4,300 to $14,350, (1979 dollars), researchers can put aboard the Orbiter small self-contained payloads of their own design weighing up to 200 pounds. Housed in NASA-supplied cylindrical canisters like the one pictured, these payloads are carried into orbit, exposed to the space environment in the open cargo bay, and returned to Earth for analysis. The aim of this program is to stimulate broader interest in space research among the large segment of the scientific community not engaged in development of primary payloads; by attracting a new group of investigators, NASA hopes to expand the national space capability for future years. Managed by Goddard Space Flight Center, the Get Away Special program is already a success; NASA has received "earnest money"—down payments—for more than 300 secondary payloads.

A Get Away Special example is illustrated below. A group of Camden, New Jersey high school students is measuring an experiment to make sure it fits within the dimensions of a canister mockup. Part of an RCA-sponsored educational project known as Orbit '81, the experiment includes an ant colony and monitoring instruments to be placed aboard a Shuttle flight for study of the effects of orbital weightlessness on the ants.

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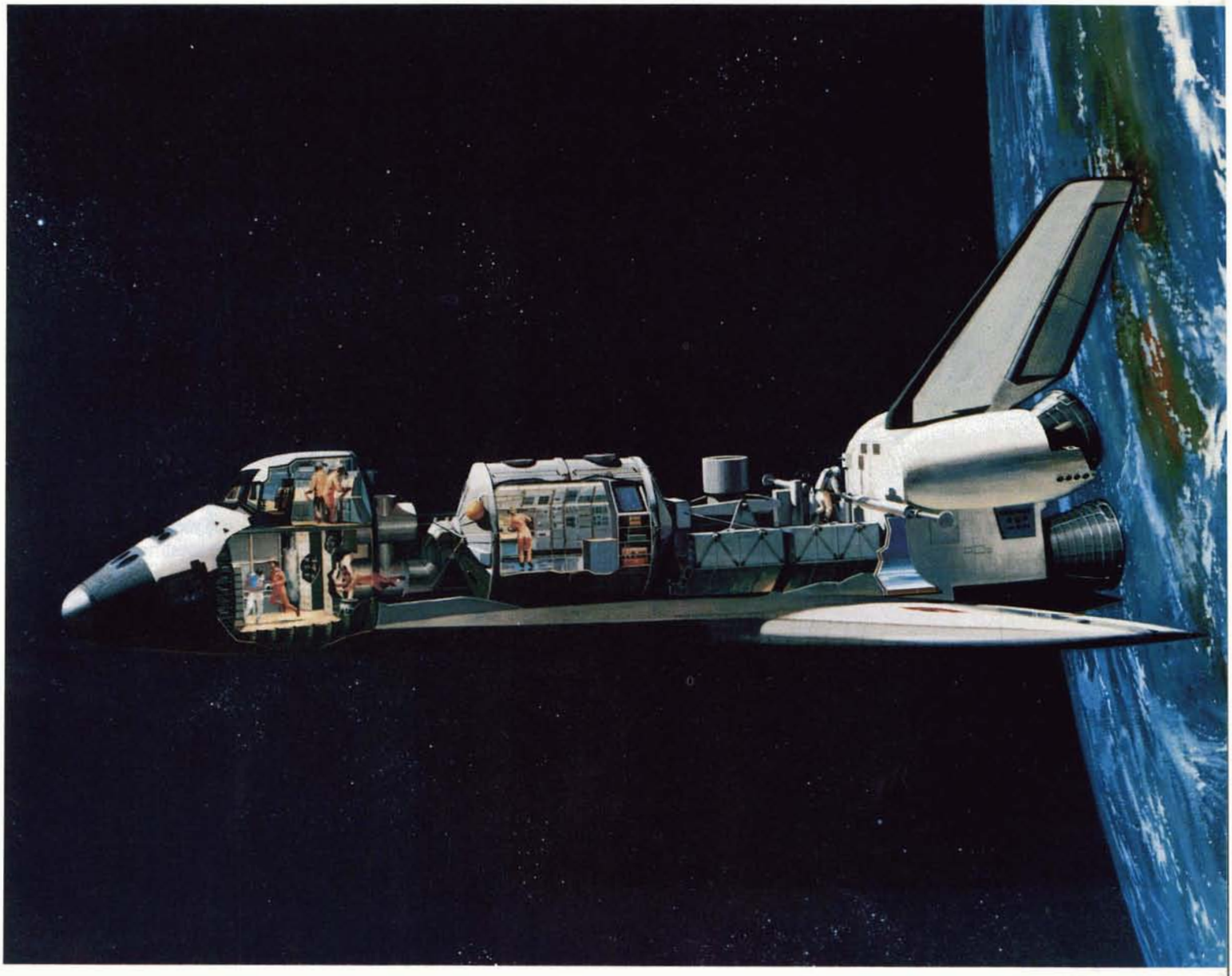

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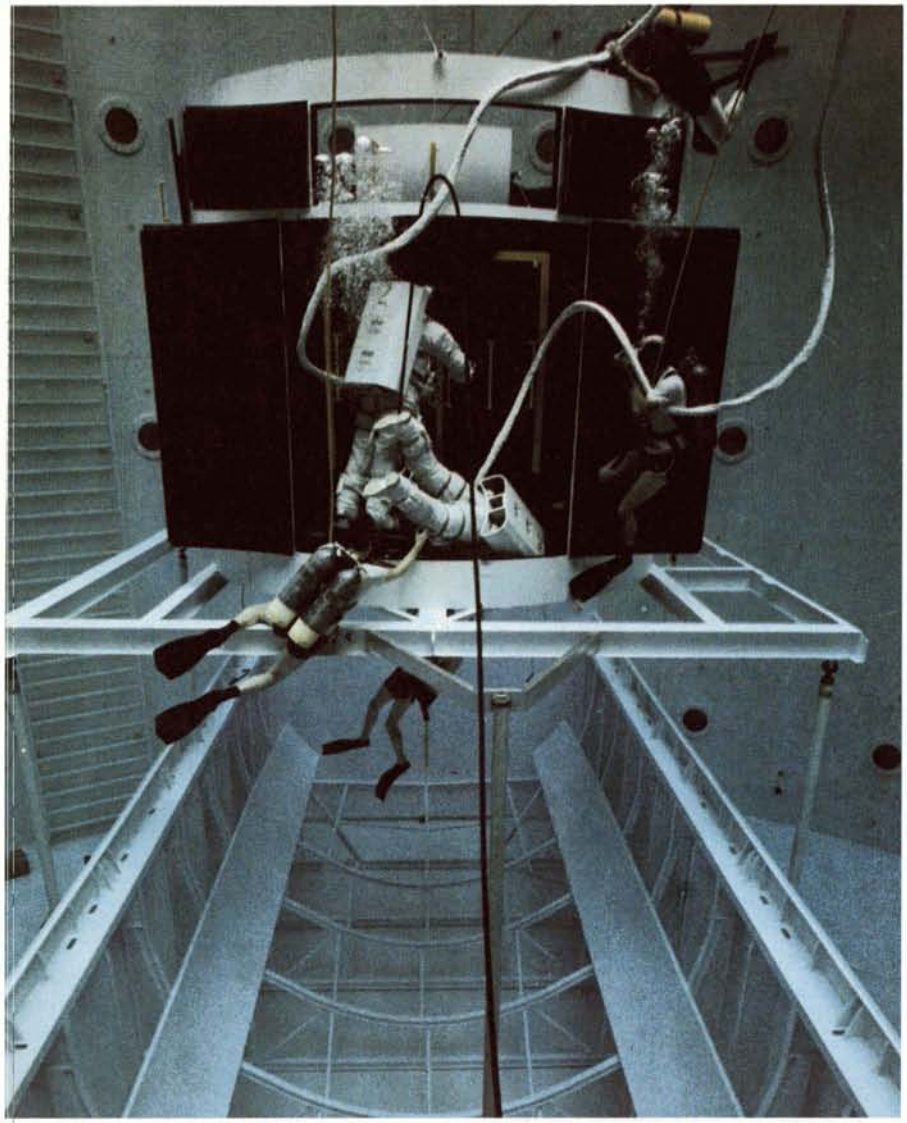
Spacelab

A complete orbital laboratory that fits into the cargo bay of the Shuttle Orbiter, Spacelab will make possible a variety of human-directed experiments in the space environment—for example, astronomical observations not obscured by Earth's atmosphere, Earth resources surveys, research on materials processing in space, or life science studies of man and other organisms under weightless conditions. The Spacelab system includes a pressurized module, where up to four non-astronaut investigators can work in shirtsleeve environment, and an unpressurized pallet containing the instruments and other equipment appropriate to the type of research being conducted. To make more room for experiments, some missions will be flown without the pressurized module; in such cases the investigators will control the instruments from the Orbiter's flight deck. Spacelab is being developed by the 10-nation European Space Agency, whose activities are being coordinated by Marshall Space Flight Center.



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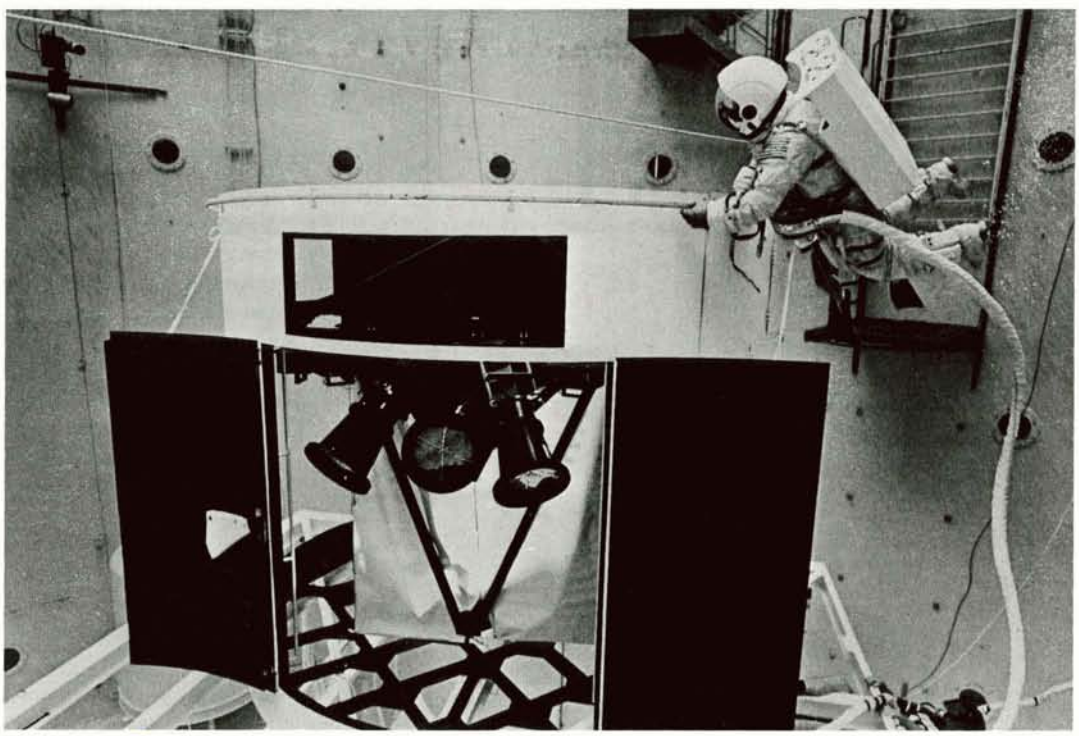
On-orbit Servicing

The Space Shuttle offers a means of servicing satellites in orbit, thereby extending their useful lives and substantially reducing replacement costs. On such operations, the Shuttle Orbiter will fly to a rendezvous with the satellite, retrieve it and stow it in the cargo bay; space-suited astronauts will enter the unpressurized bay through an airlock tunnel to perform required maintenance.

The accompanying photos illustrate research under way at Marshall Space Flight Center's Neutral Buoyancy Simulator, a huge water tank facility which provides a close approximation of the zero gravity environment in which satellite servicing teams will operate. In the photos, a full-scale mockup of a portion of NASA's Space Telescope is submerged in the tank; astronauts Bruce McCandless and George D. Nelson (in space suits) are evaluating the difficulty and time required for various tasks, such as unlatching access doors and replacing scientific instruments (the scuba divers pictured are safety monitors). Tests like this will determine what special tools are needed for on-orbit servicing and will help satellite designers make provisions for easiest in-space removal and replacement of components.



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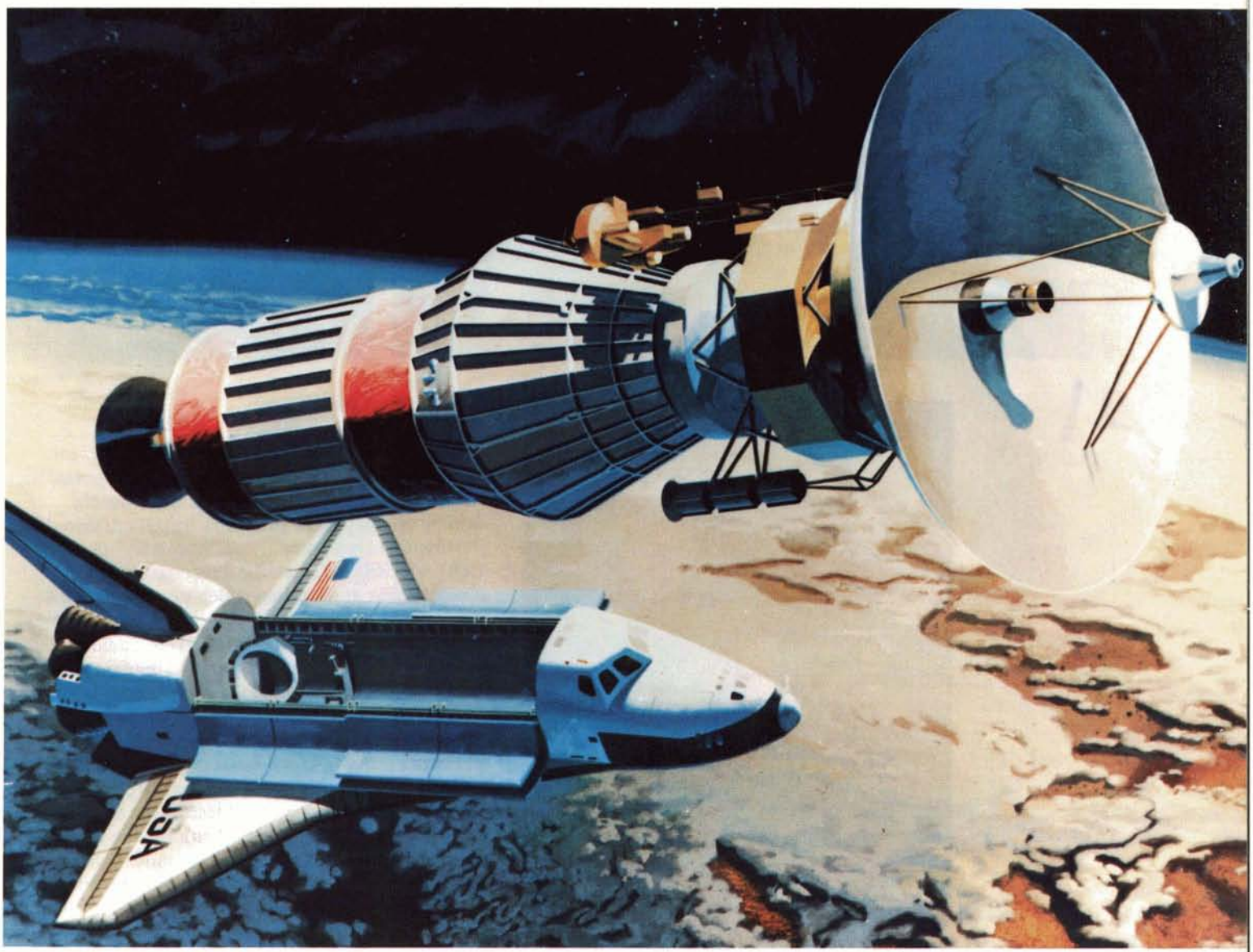
Upper Stages

The Shuttle Orbiter is designed to operate at altitudes below 500 miles, but many payloads must be sent into higher orbits. For example, the "geosynchronous" satellite—one whose movement is synchronized with Earth's rotation so that the satellite holds a fixed position relative to Earth—must orbit at 22,300 miles. For delivery of this type of payload, the Space Transportation System includes upper stage propulsion units which are carried in the Orbiter's cargo bay affixed to the satellite. Delivery of high altitude satellites or planetary spacecraft is a two-step operation. First the Orbiter flies into low Earth orbit, extracts the combined payload/upper stage and releases it in space. Then the rocket propulsion system of the upper stage is ignited to boost the payload to higher orbit, or, in the case of the planetary probe, into deep space trajectory. Initially, NASA will employ two types of upper stages, both powered by solid rockets. In the photo is the Inertial Upper Stage, being developed by the Department of Defense; it will be used to boost heavy payloads (up to 5,000 pounds) into geosynchronous orbit, or to accelerate planetary spacecraft to the high velocity needed to escape Earth's gravity. For high-altitude boost of lighter satellites, NASA is developing the Spinning Solid Upper Stage. Looking to future requirements, NASA is planning a high-energy orbital propulsion system capable of sending 50,000 pounds to synchronous orbit.



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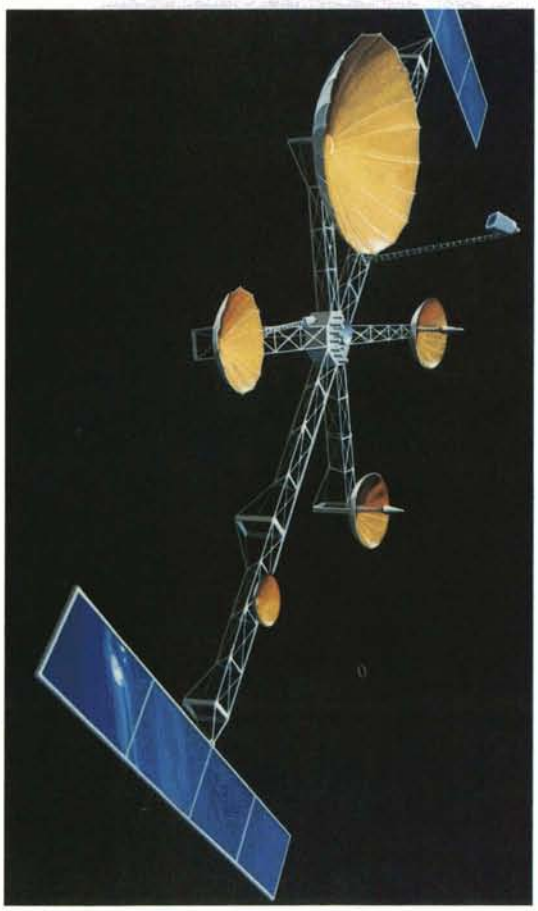

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Space Construction

The Space Transportation System's capability for erecting large structures in orbit offers vast potential for pursuing entirely new areas of space benefit. Among many types of structures being considered for development is an unmanned "stationary" platform (left), a facility for scientific data collection and direct benefit applications which would house in a single orbiting package the equipment and functions that now require a number of different satellites. Another contemplated structure is a human-habitable space factory which would allow processing in the weightless space environment of products not producible on Earth because of the negative influence of Earth's gravity. A long-range possibility of enormous benefit potential is a network of very large space-based power stations capable of harnessing the Sun's energy for conversion to Earth-use electricity; the upper illustration shows one such station under construction.

For building such structures, the Shuttle Orbiter—or a later Heavy Lift Vehicle—would serve in a dual capacity, as a materials delivery system and as a construction base. Energy for construction tasks would be supplied by orbiting power modules.

NASA and its contractors are studying and developing technology for several different methods of assembling structures. One approach involves Shuttle delivery to orbit of fully-equipped modules which would be docked together to form a facility of any desired size. In another approach, platform com-

ponents would be pre-assembled on Earth, collapsed into compact packages for transport and automatically expanded to original form on arrival in orbit.
A third technique involves in-space fabrication of large construction girders by means of a Shuttle-contained beam building machine, the prototype of which (below) has already been developed by an aerospace manufacturer under contract to Marshall Space Flight Center. Known as the Automated Beam Builder (ABB), the prototype is being used for ground demonstrations, for testing beam specimens, and for assembling a number of beams into platforms. It works this way: spools of extremely light aluminum sheet or composite material are fed into the computer-controlled ABB, which automatically rolls, bends, cuts and welds the material to produce a complete triangular beam up to six miles long. Early in the 1980s, a lighter-weight flight version of the ABB will be mounted aboard the Space Shuttle Orbiter, in the manner shown in the bottom illustration, for in-space demonstrations. The job of joining beams and other components would be accomplished in part by robot systems and in part by extravehicular astronauts. NASA is considering a number of other space platform deployment and erection experiments when the Space Shuttle enters operational service.

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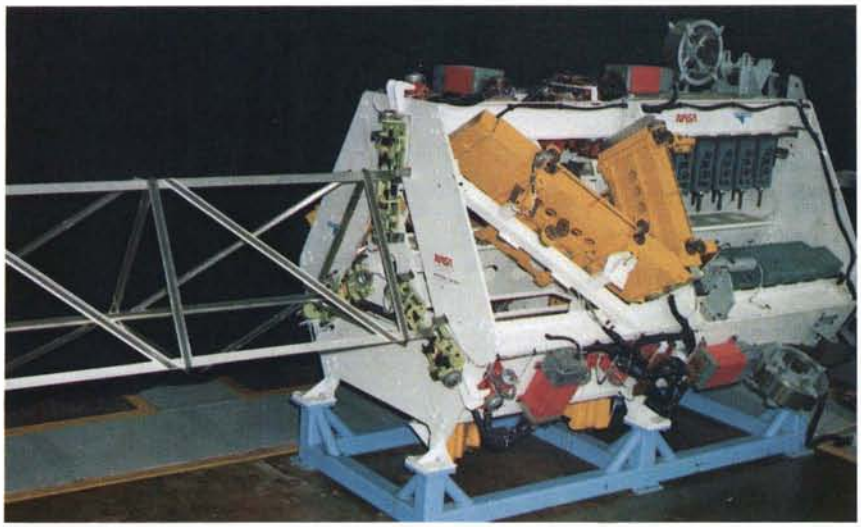

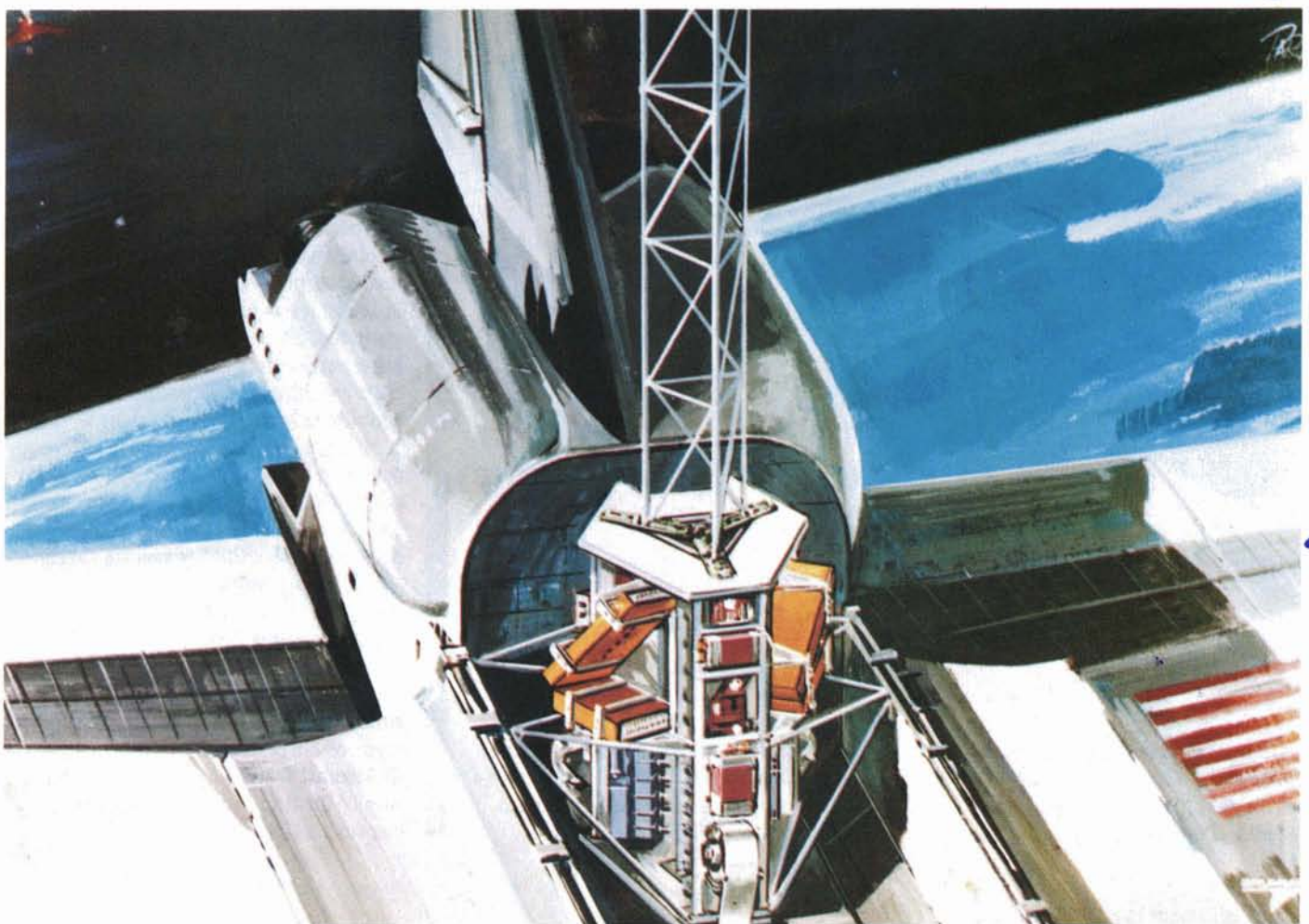

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Trailblazing Future Flight

Reducing fuel consumption is a primary goal of NASA's aeronautical research program, which seeks better performance, efficiency, safety and environmental characteristics for tomorrow's airplanes

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Advanced technology turbine-driven propellers with reshaped blades could provide jetlike speeds with sharply reduced fuel consumption. The conceptual aircraft above, a design resulting from a NASA/contractor study, is a propeller-driven version of the L-1011 TriStar jetliner.

Depending on its size, a commercial jetliner burns from 1,000 to more than 3,000 gallons of fuel each hour it flies, and it flies, on the average, eight to nine hours a day. The cost of jet fuel has quadrupled in the past seven years—and it is still climbing. Fuel costs, which account for almost 25 percent of airline operating expenses, have become one of the airline industry's most pressing problems. They are cutting sharply into airline earnings and causing increases in passenger ticket prices and the rates shippers pay to move air cargo.

Curbing jetliner fuel consumption is a major aim of NASA's aeronautical research. Researchers have identified technologies which collectively could cut civil transport fuel consumption in half when applied to newly designed aircraft, a potential boon of enormous significance. It would not only benefit airline operators and users, it would also help the nation's economy through large-scale energy savings and reduced reliance on foreign oil.

An obvious target of NASA's Aircraft Energy Efficiency program is the engine. Researchers are conducting tests to find out why certain engine parts deteriorate and which worn parts waste fuel, with an eye to extending the effectiveness of these parts. A longer range effort involves development of components for a new generation of more fuel-efficient turbofan engines. NASA is also redesigning the propeller, which lost favor in commercial service largely because propeller tip speed limitations restricted airplane speed. New multi-bladed, reshaped propellers promise high efficiencies at jetliner speeds and altitudes. Since the turboprop engine inherently offers better fuel economy than jets, the reborn propeller could provide substantial fuel savings.

A less obvious area of fuel-efficiency research is aerodynamics. Generally, aerodynamic improvements reduce air drag and thereby save fuel because of decreased demand for engine thrust. Among drag-reducing advances being investigated are new "supercritical" wings; winglets, vertical extensions of the wing; and a technique known as "laminar flow control," which involves smoothing the turbulent, drag-inducing layer of air next to the airplane's skin.

Aircraft weight-trimming is another way of cutting fuel consumption, because a lighter airplane eases the

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engine's workload. Researchers believe that greater use of composite materials, generally stronger but lighter than metals, can decrease aircraft structural weight by 25 percent. Additional fuel savings are possible through a new computer-coordinated flight control system known as "digital fly-by-wire." This system increases aircraft stability, which in turn reduces structural loads and aircraft weight.

Some of these advances will be incorporated in the new generation of American-built jetliners which will enter commercial service in the early 1980s. Others require additional years of research. Fuel-saving investigations offer bonus value, because techniques for improving aircraft energy efficiency produce corollary benefit in passenger comfort and safety, in noise abatement and in reduced engine emissions.

In other avenues of aeronautical research, NASA is investigating a wide range of aviation needs and problems. In studies, laboratory work, wind tunnel simulations and experimental flight programs, NASA is developing technology for advanced rotorcraft and jet V/STOL (Vertical/Short TakeOff and Landing) aircraft for tomorrow's air transportation system; for general aviation planes, all civil aircraft other than commercial transports; future large cargo aircraft; high-performance military aircraft; environmentally acceptable and operationally efficient commercial supersonic cruise aircraft; and, looking well into the future, the someday hypersonic transport.

In addition to these vehicle-related programs, NASA is conducting research of a general nature aimed at advancing aerodynamics, propulsion, materials and structures, aviation electronics and knowledge of the human factors involved in flight. Another area of effort seeks improvement of the air transportation system by solving such problems as aircraft noise, airport congestion and bad weather operations. A common thread through all these investigations is a continuing quest for greater safety in all types of flight vehicles.

This comprehensive aeronautical research program generates public benefit in a number of ways. It makes flight safer for all who fly; it eases the environmental impact of the airplane by curbing noise and pollutants; and it benefits passengers, shippers and operators by helping to reduce airline operating costs. Additionally, NASA-developed technology made available to manufacturers enhances the competitive position of the American aircraft industry in the international marketplace, with attendant benefit to the U.S. economy.

In tests at Dryden Flight Research Center, NASA and the Air Force are evaluating "winglets"—shown above and below—on a KC-135 cargo/tanker aircraft. Developed by Langley Research Center, winglets increase lift and reduce air drag, thereby cutting fuel consumption.

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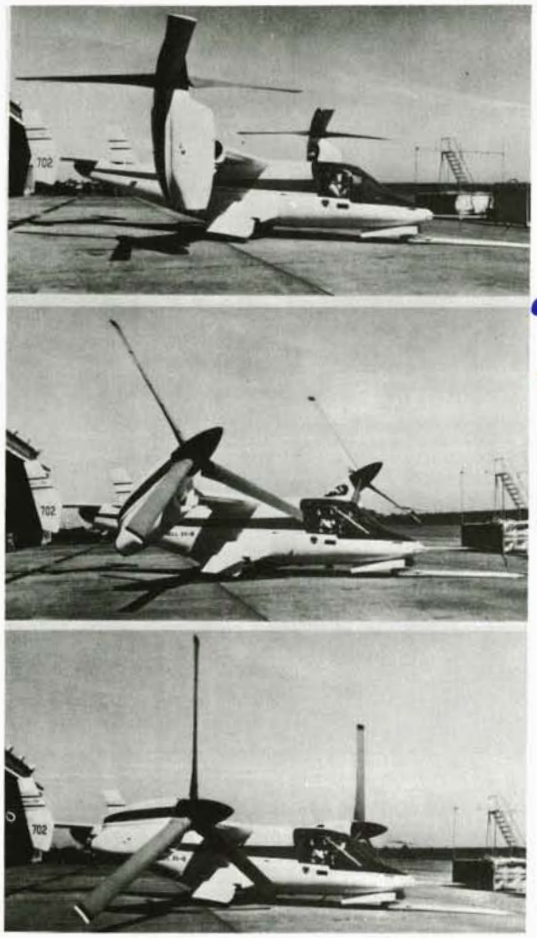

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Rotorcraft Research

A candidate for tomorrow's air transportation system is the VTOL (Vertical TakeOff and Landing) transport, which combines the vertical lift advantages of the helicopter with the greater forward speed of the fixed-wing airplane. In flight test status is an experimental vehicle for investigating one VTOL concept, the XV-15 Tilt Rotor Research Aircraft shown at left. A joint NASA/Army project, the XV-15 has helicopter-like rotors for vertical takeoff and landing; once airborne, the rotors tilt forward for cruise flight at about 350 miles per hour. The XV-15 passed a major milestone in its flight test program last year when, in a series of flights, it successfully demonstrated its ability to transition from vertical to forward flight.

NASA is investigating other rotorcraft concepts with future commercial or military potential. Important tools of this effort are two heavily-instrumented flying laboratories known as the Rotor Systems Research Aircraft (RSRA). The RSRA can accommodate a variety of different rotor systems, obviating the expense of building a separate test vehicle for each new system. With the addition of a 45-foot wing and two turbofan engines, it can also investigate the potential of the compound helicopter (lower photo), a hybrid craft which offers higher cruise speeds while retaining the helicopter's vertical lift characteristics. The RSRA has been flown with and without wings and advanced flight testing is under way.

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Quiet Jet

The airplane shown above is an experimental craft designed to advance technology for future short range transports capable of operating from short runways at close-to-city airports with minimal noise impact on the surrounding community. Called the Quiet Short-haul Research Aircraft (QSRA), it is undergoing flight test at Ames Research Center. The principal aim of the test program is validation of a "propulsive lift" technique in which the exhaust from the plane's engines flows over the wing, then curves downward, following the contour of the specially-designed wing and flaps. The down-directed exhaust exerts an additional lifting force, giving the QSRA a lift capability three times that of a comparable jet transport in commercial service and making possible operation from very short runways. The high lift permits steeper climbout and approach angles, enabling pilots to avoid populated areas at the relatively low altitudes of normal takeoffs and landings, thereby lessening noise impact. In addition, the engines are mounted above the wing instead of conventionally below it, so the sound created by engine exhaust is blocked by the wing and diverted upward, away from the "eardrum zone" below. The engines are also soundproofed to muffle internal noise. This combination of noise reduction factors makes the QSRA the quietest jet of its size ever flown.

Pivoting Wing

A unique wing which can be pivoted from zero to 60 degrees while in flight is being tested on the small experimental jet plane pictured, which made its first flight in 1979. The manned miniplane is called the Ames/Dryden-1 (AD-1) for Ames Research Center, which conducted analytical and wind tunnel studies of the oblique wing concept, and Dryden Flight Research Center, which is conducting flight test operations. The ability to change the wing's angle provides efficiency at both low and high speeds. For takeoff, landing and low speed cruise, the wing is perpendicular to the fuselage; as the airplane flies faster, pivoting the wing to oblique angles decreases air drag, permitting greater speed or longer range for the same fuel expenditure. The AD-1 is intended only to demonstrate the pivoting wing concept and it is limited to speeds under 200 miles per hour.

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Airborne Systems Research

For the foreseeable future, aviation experts expect little if any increase in the number of major U.S. airports. Therefore, in view of rapidly growing air traffic, there is need for substantial improvement in the capacity of existing airports. Such improvement is the goal of an important coordinated research effort on the part of NASA, the Federal Aviation Administration (FAA), the airlines and the aircraft industry. NASA's activity, managed by Langley Research Center and known as the Terminal Configured Vehicle (TCV) program, seeks to develop technologies for advanced airborne systems and flight procedures to complement the improved ground-based navigation and landing aids being developed by FAA.

A key element of the program is the TCV research airplane pictured below, an internally-modified 737 jetliner. The airplane contains a variety of advanced electronic equipment, such as landing aids and cockpit displays, navigation and guidance systems and computerized automatic controls. It also has a second cockpit, located aft of the standard pilots' compartment. From the aft cockpit (upper photo), research pilots fly the airplane "blind," using their advanced systems and informational displays, while two pilots on the standard forward flight deck monitor safety aspects of the flight. TCV research focuses on the descent, approach and landing portions of a flight, where most air traffic control problems occur, particularly in adverse weather. In addition to air terminal capacity improvement, anticipated benefits include reductions in approach and landing accidents, weather restrictions, aircrew and ground controller workload, terminal area fuel expenditure and exposure of communities to aircraft noise.

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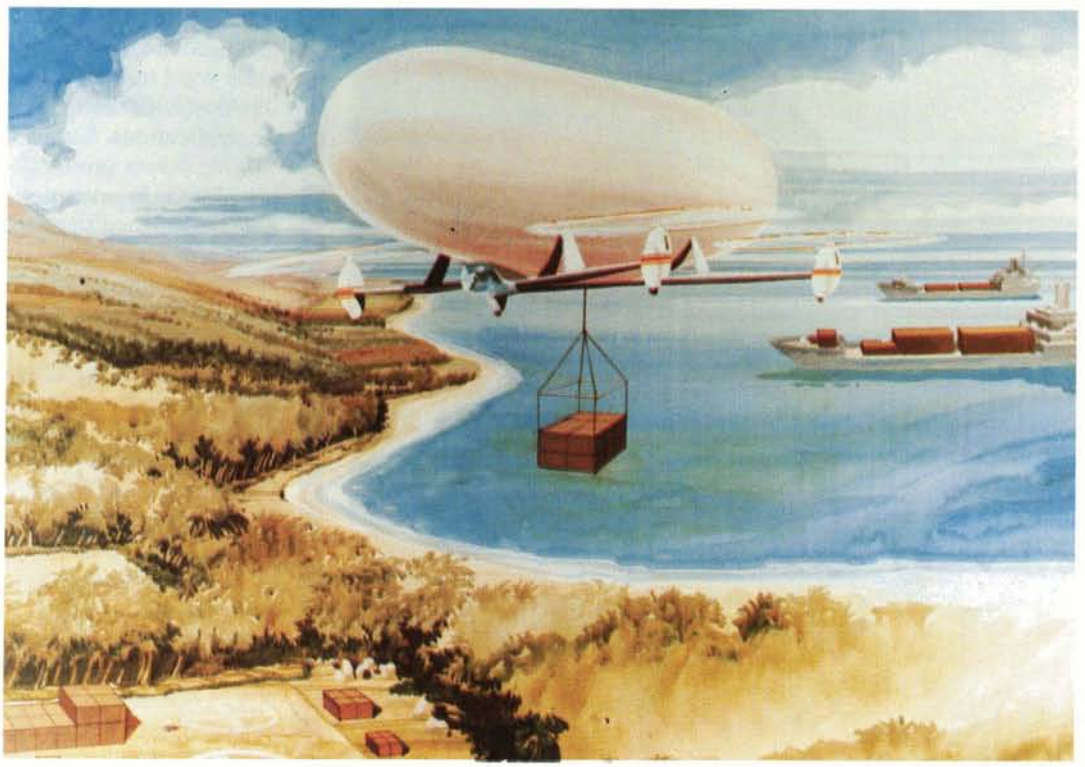
HiMAT

A new aeronautical flight research tool, first flown last July, is the unmanned HiMAT Remotely Piloted Research Vehicle (RPRV). HiMAT stands for Highly Maneuverable Aircraft Technology, a joint NASA/ Air Force program involving investigation of advanced technologies for future military fighters. Being tested at Dryden Flight Research Center, the HiMAT vehicle incorporates a number of new design features and construction advances. Because it is built in modular fashion, it can be modified to test new technologies as they come along—different wing shapes and engine nozzles, for example—with minimal modification time and expense. In its initial configuration, HiMAT's main wing and winglets are supplemented by a small "canard" wing for increased maneuverability; the plane has twice the turning capability of the most maneuverable fighter now in service. Air-launched from a B-52 carrier plane, HiMAT is controlled by a pilot in a ground-based cockpit. The NASA-developed RPRV concept allows testing of many new technologies at one time and eliminates the normal provisions for pilot occupancy and safety, thereby reducing vehicle cost.



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Airship Studies

There has been a revival of interest in lighter-than-air (LTA) craft in recent years and NASA is investigating the possibilities of applying modern technology to LTA ships. Studies show that airships are not competitive with commercial jetliners, but could offer advantages in certain applications. One such application is a hybrid airship, combining helicopter and LTA components, which could lift cargoes weighing as much as 1,000 tons over short distances (concept shown). Another possibility is a short-range feeder airship, operating from roof tops or heliports to provide connecting service to major airports. NASA is conducting a limited LTA technology development program which emphasizes research on the aerodynamic considerations of combining LTA hulls with large diameter helicopter-like rotors.

Technology for Energy

NASA is applying its technical expertise in the national quest for new ways of producing and conserving energy

The experimental 200,000-watt wind energy system pictured is one of several—of varying size and output—being developed by the Department of Energy and NASA. Intended for use in small communities, it was installed last year at Block Island, Rhode Island. During the windy winter months, it is expected to generate 50 percent of the power needed by the island's 500 permanent residents.

On a hill above the town of Boone, North Carolina, there is a structure resembling a gargantuan airplane propeller mounted atop a framework tower. A modern counterpart of the age-old windmill, it is a wind turbine generator which harnesses the power of the wind to produce two million watts of electricity, enough to serve the needs of several hundred homes.

Introduced to service last fall, the Boone generator is the newest and largest operational system in a Department of Energy/NASA program aimed at development of advanced technology, cost-competitive wind turbines as alternative power sources. Computer controlled, the system at Boone has a 200-foot diameter rotor which is automatically aligned with wind direction for maximum efficiency. Wind force spins the rotor, which in turn drives an electricity-generating turbine; the electricity thus produced is fed into the local power grid for public consumption.

NASA's Lewis Research Center manages the development of large-scale wind turbine generators and demonstrates their efficiency in realistic applications. Six machines of varying power production capability are already in operation and a new system designed to generate 2.5 million watts is being developed.

NASA's activity in wind energy is only one facet of a broader research and development effort in which the agency is applying its aerospace-acquired expertise in support of national energy goals. In most of its energy-related jobs, the agency serves as project manager and technical consultant, conducting assigned projects funded by the Department of Energy and other government agencies.

By virtue of extensive experience in developing aerospace technology, NASA contributes a number of special capabilities to energy research. Wind energy systems, for example, are based essentially on aerodynamic propeller and rotor technologies, areas in which years of aeronautical research has made the agency uniquely qualified to pursue advancements. Similarly, the agency has long been engaged in developing technology for solar cell arrays and fuel cell powerplants which supply electric power for spacecraft; these systems are now promising candidates for Earth applications. Know-how in space systems develop-

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ment and orbital operations may be brought to bear on a program of vast potential: the Satellite Power System, which would draw multi-megawatt energy directly from the Sun and beam it to Earth receivers. Generally, NASA's aerospace programs have produced a corps of highly-skilled personnel with expertise in an exceptionally broad range of scientific, technological and managerial disciplines; their collective talents can be employed to advantage in many fields of energy research and development.

In addition to the areas mentioned, the agency's varied energy program includes development of technology for improved solar heating and cooling equipment; solar thermal electric systems which use Sun heat to generate electricity; ways of increasing production in coal mining operations; processes for converting coal into clean gaseous or liquid fuels; advanced propulsion systems for autos, buses and other ground vehicles; more fuel-efficient industrial gas turbines; new and more effective methods of storing energy; and disposal in space of wastes from nuclear reactors.

Such employment of NASA's special talents represents a dividend to the nation on its investment in aerospace technology. And while helping to solve one of the world's most pressing problems, NASA is honing its own skills by venturing into new avenues of effort and thereby broadening its capability for future aviation and space research.

This is a bird's eye view of the world's largest wind turbine generator. Introduced to service last fall at Boone, North Carolina, it employs a 200-foot rotor to convert wind force into electrical energy. At optimum wind speeds of 25 miles per hour, the generator produces two million watts, enough to meet the electrical requirements of several hundred homes.

Solar Heating/Cooling

The building below is the Kaw Valley State Bank, Topeka, Kansas, which is both heated and cooled by the solar panels on the roof and associated heat storage, heat exchanging and ducting equipment. It is one of more than 100 residential and commercial demonstration facilities managed by NASA's Marshall Space Flight Center for the Department of Energy's National Solar Heating and Cooling Demonstration Project, aim of which is to stimulate interest in solar energy as an alternative to fossil fuels. The Marshall role is that of supervisor, technical consultant and data analyst for such demonstrations. Marshall installs sensors at each site to monitor the performance of solar equipment; the results are taped, relayed periodically to Marshall's Huntsville, Alabama headquarters, analyzed and evaluated, providing information applicable to future developments. Marshall has the additional responsibility of developing new technology for more advanced solar heating and cooling systems.

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Solar Air Conditioner

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With the assistance of a team of contractors, Marshall Space Flight Center has developed a highly efficient home air conditioner which is powered by heat from the Sun. The accompanying photos show a demonstration home (above) in Duffield, Virginia where the air conditioner (below) has been successfully tested. The solar panels on the roof of the home collect Sun energy to heat a fluid used to drive a small turbine. The turbine, in turn, drives a standard compressor like those in existing air conditioners; the unit has a cooling capacity of almost three tons, sufficient to cool the average U.S. home.

The system includes a specially designed auxiliary electric motor which powers the unit at night or on cloudy days when Sun heat is not available. The motor doubles as an electric generator, a feature which offers an interesting bonus: when there is more solar power available than is needed for air conditioning, the motor can produce electricity to be used elsewhere in the home or fed back to the local utility grid, reducing electricity costs and easing the utility's peak load generating requirements. Tests indicate that the system has promise for commercial availability at competitive prices by the mid-1980s.

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Energy Storage System

An important part of the national energy program is finding new and more efficient ways of storing energy. Solar energy and wind electric systems, for example, must store electricity for use at times when sunlight and wind force are not available. On a larger scale, utility companies need an economical, efficient means of "load leveling"—storing energy during low demand periods for use when demand peaks.

Among a number of energy storage concepts being investigated by NASA and the Department of Energy is a system called Redox which promises significant cost reduction, long-term reliability and minimal environmental impact. Redox is a fluid battery which its originators at Lewis Research Center believe can eventually be produced for one-third the cost of conventional lead batteries. A small-scale demonstration unit is shown at right.

In Redox as in conventional batteries, electrical energy is changed to chemical energy for storage and reconverted to electricity when needed. The difference is in the method of conversion. Redox employs a "stack" of flow cells (below) through which two reactant fluids are pumped. Within each flow cell, the fluids are kept separate by a special membrane. The fluids transfer electricity through the membrane as each fluid reacts with a separate electrode surface; the electrical energy thus produced is withdrawn from the system. For recharging the battery when the electrochemical energy of the fluids is depleted, the fluids are simply pumped through the stack again, but with electrical energy supplied by an outside source.

Operation of the pumps takes only one percent of the system's energy and 75 percent of the energy stored is returned on discharge. In addition to reduced cost, Redox advantages include long useful life, estimated at 20 to 30 years; ease in monitoring and correcting changes in output voltage and total storage capacity without interrupting system operation; and flexibility in sizing the stack and storage tanks for desired power output and time between recharge cycles.

Lewis Research Center has developed a 2,000-watt prototype which will be tested this year. A battery of this size could reduce storage costs and thereby speed wider adoption of solar electric and wind energy systems. Design flexibility offers the possibility of scaling up the system for the much higher energy storage requirements of electric power companies.

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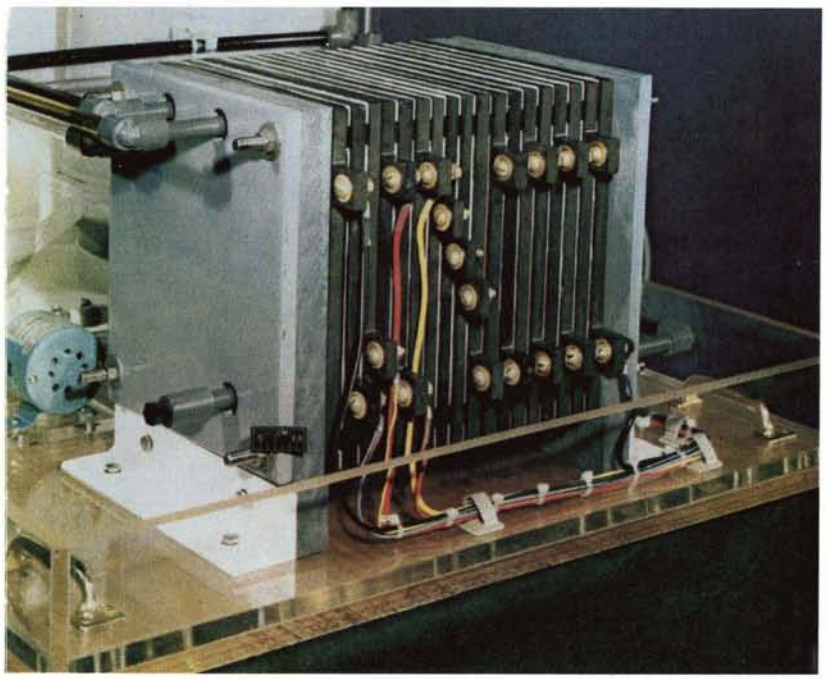

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Electricity from Sunlight

Solar cells, which supply power for most spacecraft, convert sunlight into electrical energy in a process called "photovoltaic conversion." In two decades of space operation, they have demonstrated exceptional reliability and are promising candidates for Earth applications if costs can be sufficiently reduced. Even today, photovoltaic systems are proving useful in a number of installations where conventional power supply is not available.

NASA has a two-part role in the Department of Energy's Photovoltaic Conversion Program. Jet Propulsion Laboratory manages a technology advancement program aimed at making solar cell power cost-competitive by the mid-1980s, with focus on new techniques for mass producing cells at lower unit cost. Lewis Research Center is working to stimulate a market for solar cells by designing and installing applications which demonstrate the advantages of this type of power generation.

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In one such demonstration, jointly sponsored by the Department of Energy, NASA, the U.S. Public Health Service and the Papago Indian tribe, the 95-person Papago village of Schuchuli, Arizona became the world's first solar electric community in 1978. Remotely located, Schuchuli never had electricity until Lewis installed the 3,500-watt solar cell array (above) which provides Sun-derived power for lighting homes and community buildings, water pumping, family refrigerators and a communal washing machine (below).

In another project, NASA is working with the U.S. Agency for International Development to explore the potential of photovoltaic technology in lesser developed countries.

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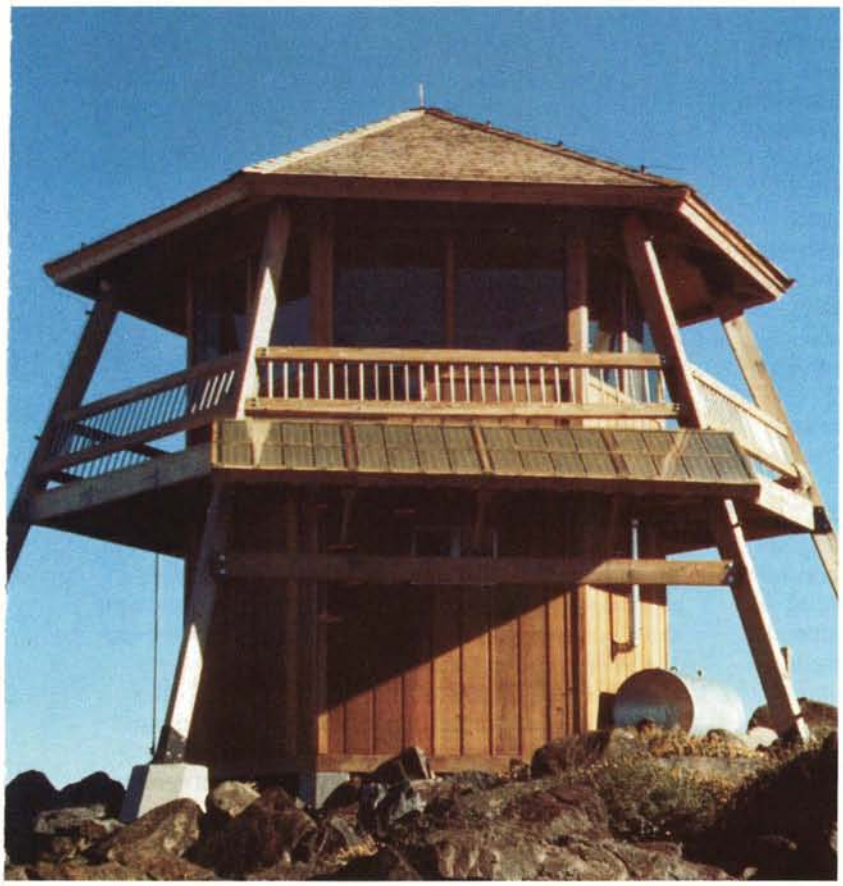

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The above photo shows a solar cell system in the West African village of Tangaye, Upper Volta which —like Schuchuli—had never experienced electricity prior to installation of this system. The solar cell array at right generates 1,800 watts to power a water pump (tank in center) and a grain mill (building at left). The system went into operational service last year.

At left is the first Sun-powered U.S. Forest Service firewatch tower, located on Antelope Peak in California's Lassen National Forest. At mid-level of the six-sided tower is an array of some 600 solar cells (below) which generates 300 watts to power the lookout post's lights, two-way radio, refrigerator, water pump and television set.

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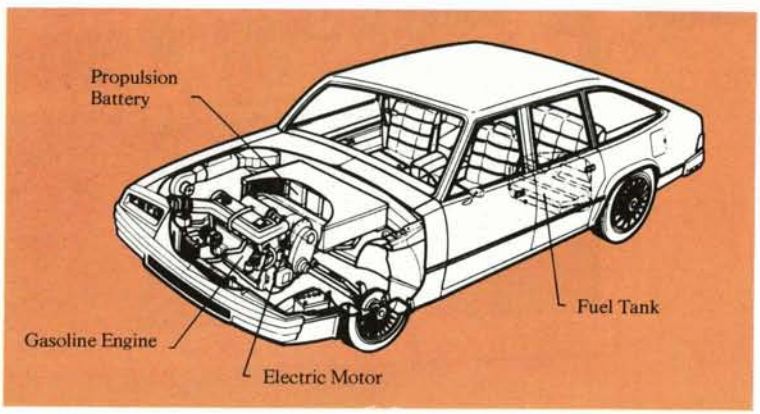
Advanced Ground Propulsion

The Greyhound bus pictured seems similar to its counterparts in intercity service but it is internally quite different. Instead of the customary Diesel engine, its propulsion unit is an advanced automotive gas turbine which offers high fuel efficiency, reduced emissions and lower noise levels. The bus is one of four operating on Washington-Boston routes in a two-year experiment to determine what fuel and maintenance savings may be realized by substitution of turbine engines. A major advantage of turbines is their ability to operate efficiently on virtually any type of flammable liquid. A key part of the experiment involves running the buses on methanol and ethanol, two forms of alcohol. Multi-fuel capability will become increasingly important as synthetic fuels become available, permitting reduced dependence on petroleum products.

Another major difference is indicated by the rear-end oval-shaped stacks shown at right. They are part of an exhaust/heat exchanger system necessitated by the fact that the turbine engine does not need the usual radiator, whose hot water is normally tapped for heating the coach. The heat exchanger, located in the outboard stack, transmits hot exhaust gases to a closed fluid system which heats the coach's interior to a precisely controlled 70 degrees. When internal heat is not required, the exhaust gases are expelled from the inboard stack.



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The Greyhound project is one of a number of experiments in the Department of Energy's Heat Engine Highway Vehicle System Program, in which NASA is playing a supporting role. Lewis Research Center, working with auto industry contractors, is managing a development program focused on the gas turbine and the Stirling-cycle propulsion system, another type of continuous combustion engine. Both types offer potential for multi-fuel capability, low emissions and improved fuel economy; a long-range goal is a 30-50 percent improvement in highway vehicle fuel economy by the early 1990s.

Two NASA centers—Lewis and Jet Propulsion Laboratory—are also engaged in research, development and demonstration activities in support of the Department of Energy's Electric and Hybrid Vehicle Systems Program, which is designed to advance technology in battery-powered vehicles to the point where they can compete with existing transportation modes. An example of work under way in this program is an experimental hybrid passenger car, shown in cutaway at left, which has two separate drive systems—one gasoline-powered and one battery-powered. A modified Chevrolet Malibu, the vehicle will use less fuel than conventional internal combustion automobiles and have far greater range and flexibility than all-electric cars.

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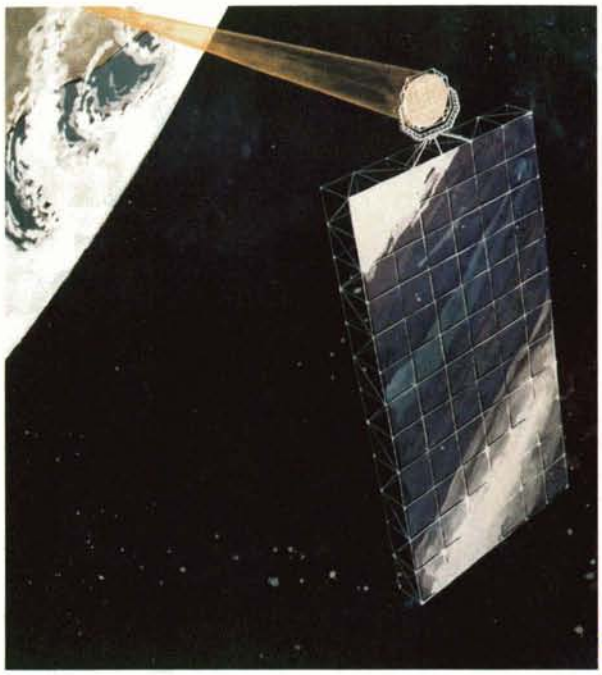
Satellite Power System

A concept of enormous potential in meeting future energy needs is the Satellite Power System, an orbiting power station (right) which would draw upon the abundant energy of the Sun to produce enough electricity for the needs of a large city. A number of such satellites could generate a significant portion of the nation's power requirement in the 21st century when, experts say, the world's petroleum reserves will be depleted.

Constructed in orbit from materials delivered by Space Transportation System vehicles, the individual satellite would be a large platform, several miles in length, containing a "farm" of solar cells capable of converting sunlight into electricity. The electricity thus produced would be beamed as microwaves to an Earth "rectenna" (below), then reconverted to electricity for consumer use. NASA and the Department of Energy are jointly investigating the technical, economic and environmental considerations of the concept. Study findings, expected this year, will determine the future direction of the program.



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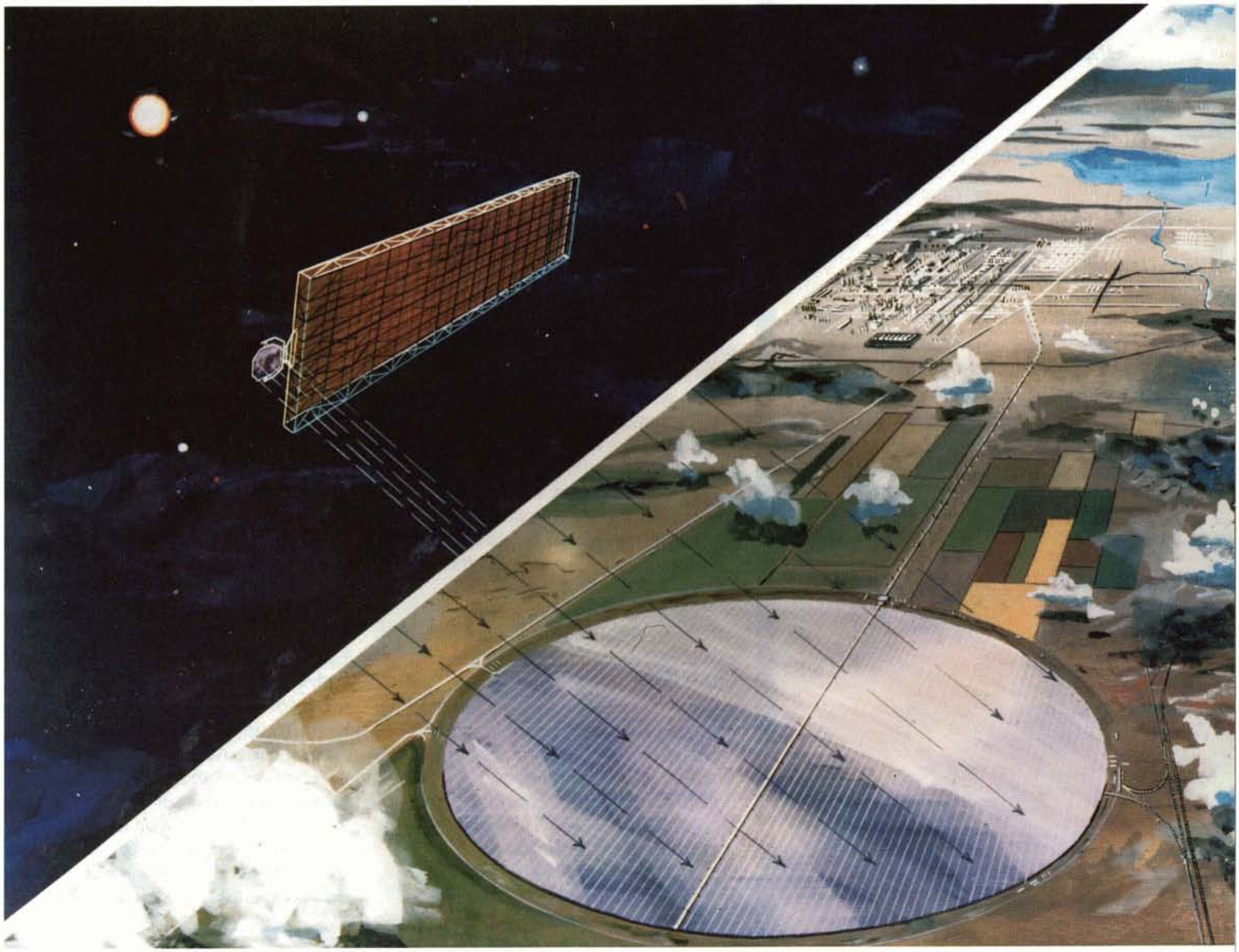

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Dividends from Technology Applied

A wealth of direct benefit to Earth's people is emerging from NASA's multifaceted applications program

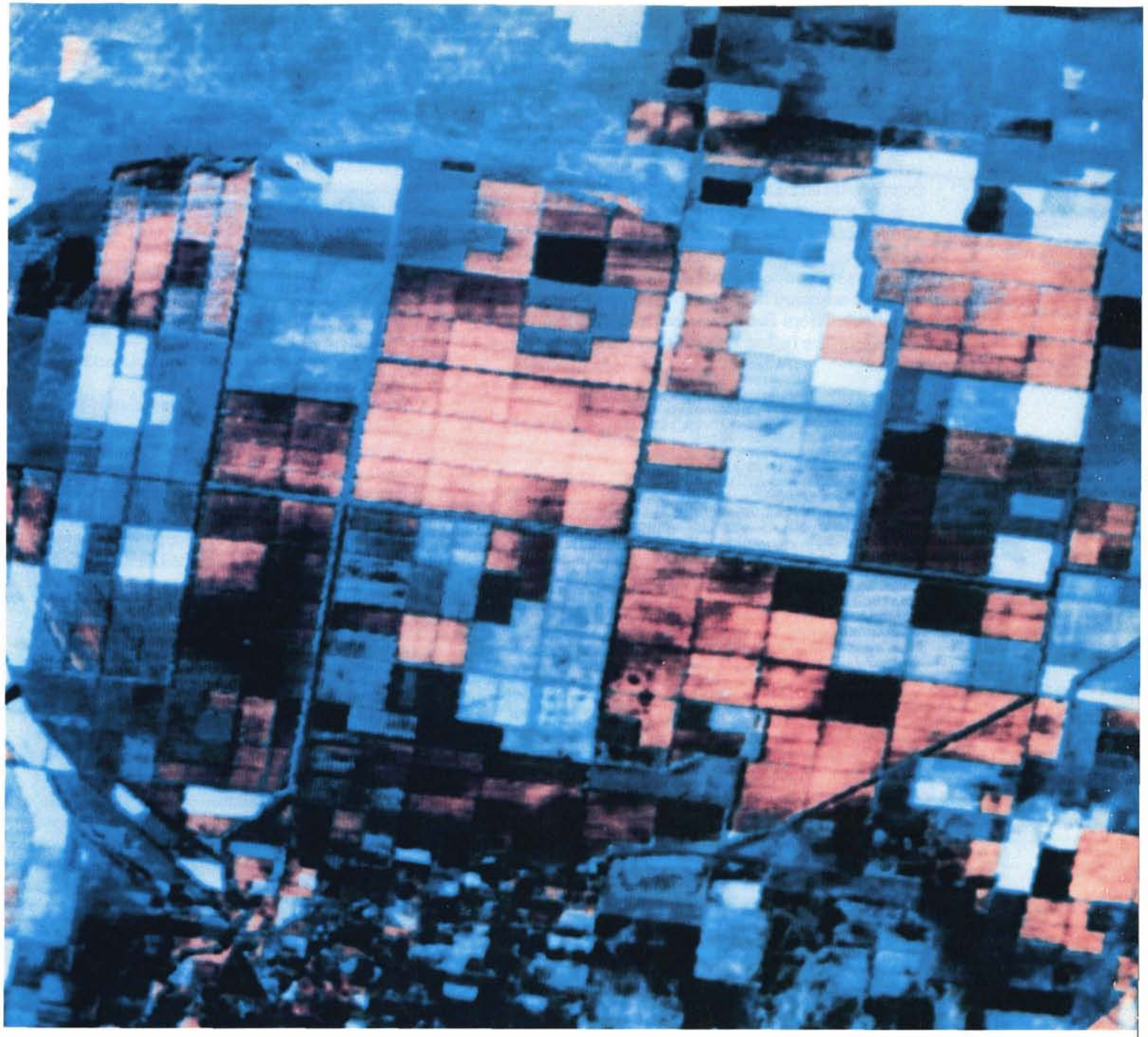
In 1978, Brazil's soybean crop turned out to be much smaller than expected, a factor which later caused a big jump in world soybean prices. But American growers had already disposed of most of their soybeans before they learned of the Brazilian shortfall. Had they been earlier aware of the situation, they could have received several hundred million dollars more for that year's soybean crop.

This is one of many examples which point up the need for a better system of reporting and forecasting international crop production. Accurate information on foreign commodity production is critical to U.S. Department of Agriculture decisions as to commodity price programs, export strategies and the level of grain reserves. A really effective global system would also benefit international agricultural trade by advising which nations would produce surplus crops and which might fall short of expectations. Advance information on crop yield would help agribusinessmen plan distribution of crops and serve a number of other farm management needs.

Remote sensing from orbiting satellites offers a basis for establishment of a global system for information about crops and other resources. Such a system is still some years down the road, but a major step toward it has been taken with initiation of a six-year research program known as AgRISTARS (Agriculture and Resource Inventories Through Aerospace Remote Sensing). AgRISTARS is a joint effort involving five U.S. agencies: the Departments of Agriculture, Commerce and Interior, the Agency for International Development, and NASA, whose Landsat resource-surveying satellites will provide a major portion of the informational input.

AgRISTARS' main thrust will be in agricultural inventory. The primary aims include development of an early warning system able to detect conditions affecting crop production—for example, drought, excessive rainfall, snowmelt rates, or infestation—and development of techniques for more accurate commodity production forecasts, both foreign and domestic. The participating agencies have identified five other areas of interest, including use of remotely-sensed data for classifying the many ways in which land is being used, estimating land productivity, inventorying renewable resources, assessing the effectiveness of conservation practices, and detecting pollution.

AgRISTARS research will focus on eight types of crops—wheat, barley, rice, corn, soybeans, sorghum, sunflowers and cotton—grown in seven countries: Argentina, Australia, Brazil, Canada, India, the Soviet Union and, of course, the United States. The crops will be continually scanned by NASA's Landsats, whose data will be combined with weather information from meteorological satellites operated by the National Oceanic and Atmospheric Administration, with observations from several thousand ground-based weather stations, and with comparison data on weather and crop yield in previous years. All of this and other information will be fed into computers, processed, analyzed



and validated to determine the extent to which satellite technology can contribute to an important public need.

NASA's participation in AgRISTARS is one example of a broad applications program wherein aerospace technology is being applied to generate direct public benefit. The principal focus of the program is development and demonstration of remote sensing techniques for a variety of practical purposes. NASA is also developing technology for other types of space systems—communications satellites, for example; the agency has embarked on a new communications technology program designed to allow more effective use of radio frequencies at the nearly-saturated geostationary orbit level, and to reduce costs of space communications services. The applications program also includes investigations aimed at future use of the weightless environment of space for unique methods of processing materials. Additionally, NASA conducts applications of a non-space nature where opportunities exist for improving public or private efficiency, services or productivity through development of systems, equipment or devices.

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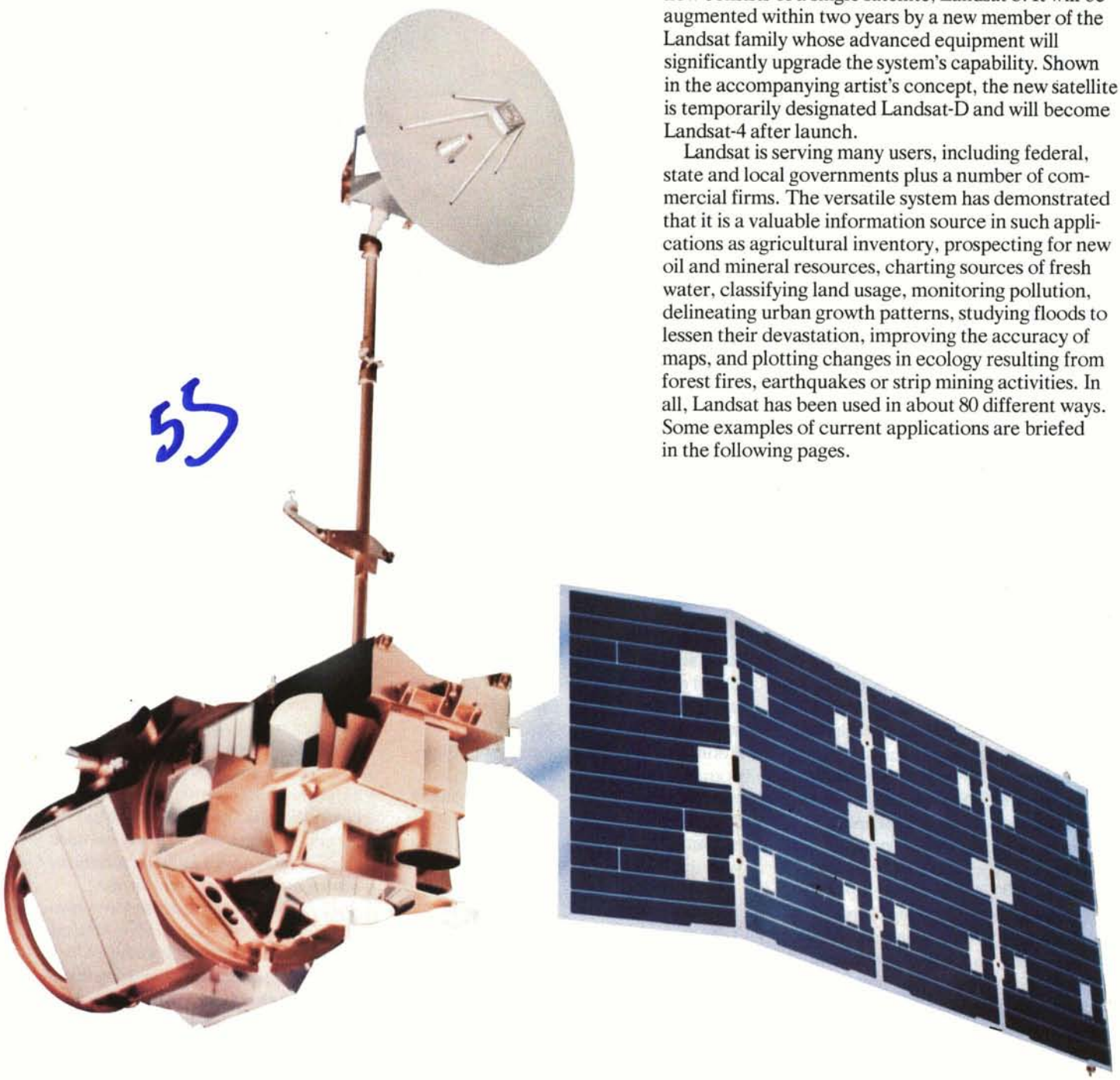
In a research program known as AgRISTARS, five U.S. agencies are assessing the potential of satellite remote sensing as part of a global Earth resources survey system. AgRISTARS' main thrust is in agricultural inventory. The illustration—a crop map of California's San Joaquin Valley—exemplifies the type of information that can be extracted from digital data supplied by NASA's Landsat satellites; fallow ground (blue) and various crops—cotton, wheat, safflower—show up in different colors, enabling analysts to determine the acreage under cultivation for a particular crop. Combined with weather reports, prior year comparisons and other information, Landsat data provides a basis for predicting crop yield.

Landsat

NASA's Landsat is a remote sensing satellite which acquires voluminous data about Earth surface features from orbital altitudes above 500 miles. Reporting continuously on the changing face of the planet, Landsat offers great potential for Earth benefit through more effective management of Earth's resources. The satellite's exceptional utility stems from the ability of sensitive on-board detectors to pick up energy emitted or reflected from Earth and thereby to distinguish among surface features. Data from Landsat can be interpreted to tell the difference, for example, between one type of vegetation and another, between densely-populated urban areas and lightly populated farmland, or between clear and polluted water. The satellite's data is computer processed at a number of ground-based facilities and translated into images and tapes from which informative resource maps can be prepared; the Master Data Processing Facility is at Goddard Space Flight Center and the Department of the Interior's Earth Resources Observation System Data Center, Sioux Falls, South Dakota handles storage and distribution.

With the early 1980 retirement of Landsat-2 after five years of service, the space segment of the system now consists of a single satellite, Landsat-3. It will be augmented within two years by a new member of the Landsat family whose advanced equipment will significantly upgrade the system's capability. Shown in the accompanying artist's concept, the new satellite is temporarily designated Landsat-D and will become Landsat-4 after launch.

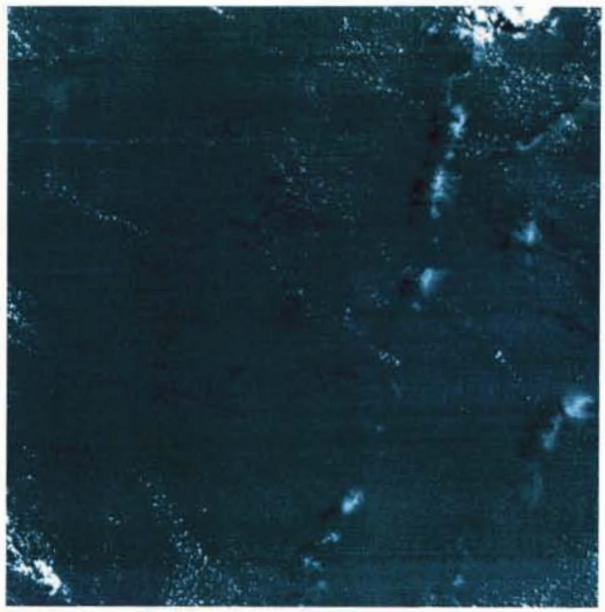
Landsat is serving many users, including federal, state and local governments plus a number of commercial firms. The versatile system has demonstrated that it is a valuable information source in such applications as agricultural inventory, prospecting for new oil and mineral resources, charting sources of fresh water, classifying land usage, monitoring pollution, delineating urban growth patterns, studying floods to lessen their devastation, improving the accuracy of maps, and plotting changes in ecology resulting from forest fires, earthquakes or strip mining activities. In all, Landsat has been used in about 80 different ways. Some examples of current applications are briefed in the following pages.



Oil Spill Monitoring

Last summer, history's worst oil spill occurred with the blowout of the Ixtoc I oil well in the Gulf of Mexico offshore of Mexico's Yucatan Peninsula. More than 100 million gallons of oil leaked from the well and drifted to the north and west, threatening beaches, wildlife and fishing industries in coastal Mexico and Texas. The U.S. Coast Guard sought to minimize economic and environmental loss by tracking the oil slick, predicting its movement and warning affected communities. To supplement localized observations from aircraft flying at relatively low altitudes, the Coast Guard asked NASA for Landsat views which, taken from orbital altitude, embrace far greater areas.

Examples of Landsat's contributions are shown in the accompanying illustrations. At right is a basic Landsat image in which the oil shows up as dark streaks (the white areas are clouds). The other illustration is a computer-enhanced color image of the same area, clearly showing the oil distribution in red with particularly heavy oil accumulations depicted in green. Repetitive time-coded and geographically coordinated images, together with aircraft, surface and ancillary environmental data, provided a basis for determining the status, location, projected movement and velocity of the oil slick. Until the well was capped, Goddard Space Flight Center relayed Landsat data to the Coast Guard, the U.S. Geological Survey and the Mexican government. The Department of the Interior's Earth Resources Observation System Data Center prepared Landsat image mosaics, covering large segments of the Gulf, which served as situation maps for the response team planning remedial actions.



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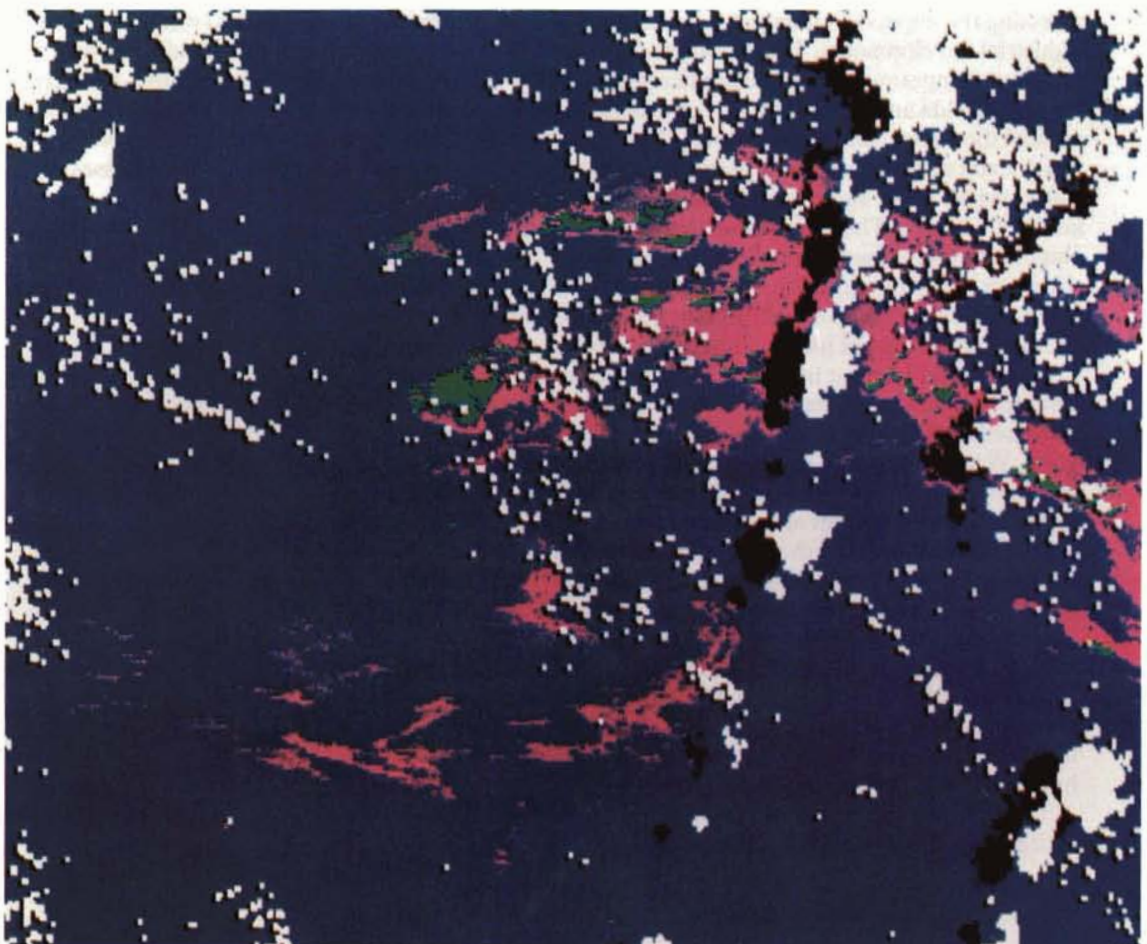

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Class Description	Acreages
Dense Pine	8,888
Scattered Pine with Native Grasses	306
Coastal Scrub	9,132
Brush and Shrubland	9,637
Native Grasses <35% Brush	16,781
Brush & Native Grasses/ Periodically Flooded	1,520
Sand/Inert Materials	3,238
Sand/Tidal Flats	3,202
Fresh Water Marsh	1,971
Water with Scattered Cypress	484
Water 1 Highest Spectral Reflectance	2,143
Water 2	2,868
Water 3	8,201
Water 4	11,541
Water 5 Lowest Spectral Reflectance	157,371
Total	237,283

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Florida Survey

In Florida, NASA is assisting state agencies in preparing Landsat inventories of land and water resources which provide an informational base for assessing the impacts of planned agricultural and industrial developments. The accompanying illustrations are computer-processed classification maps of several Florida areas. At right is a color-coded overview of the central and western parts of the state in which each color represents a particular feature—water, urban areas, agricultural land, forests, marshland and so forth. The other illustrations are Landsat classifications focused on particular locations within the overview area.

The illustration above and its color key provide an example of the type of information that can be extracted from Landsat imagery; this vegetation inventory is part of an impact assessment for a proposed superport at Port Saint Joe on the Gulf coast. Water is shown in several shades of blue; the shadings can be related to water differences, such as depth, levels of sediment and undersurface vegetation.

On the opposite page, the upper left image is a classification map of the Apalachicola Bay area, intended to help planners determine the impact of current and planned industrial developments in the area. At upper right is a view of land cover around Choctawhatchee Bay in western Florida, where Landsat data is being used—along with other information—to determine the extent to which urban development has caused water shortages in the Fort Walton area.

The bottom right image covers an area in northwestern Florida known as Sneads Quadrangle. This land use inventory is an aid to state officials studying where projected industrial developments might be located without interfering with the area's extensive farming activities and where water resources are adequate for both agricultural and industrial needs. Cropland shows up in yellow, pasture land in brown, water in shades of blue and the quadrangle's dense pine coverage in red; the other colors indicate various types of tree stands, native grasses and bare soil.

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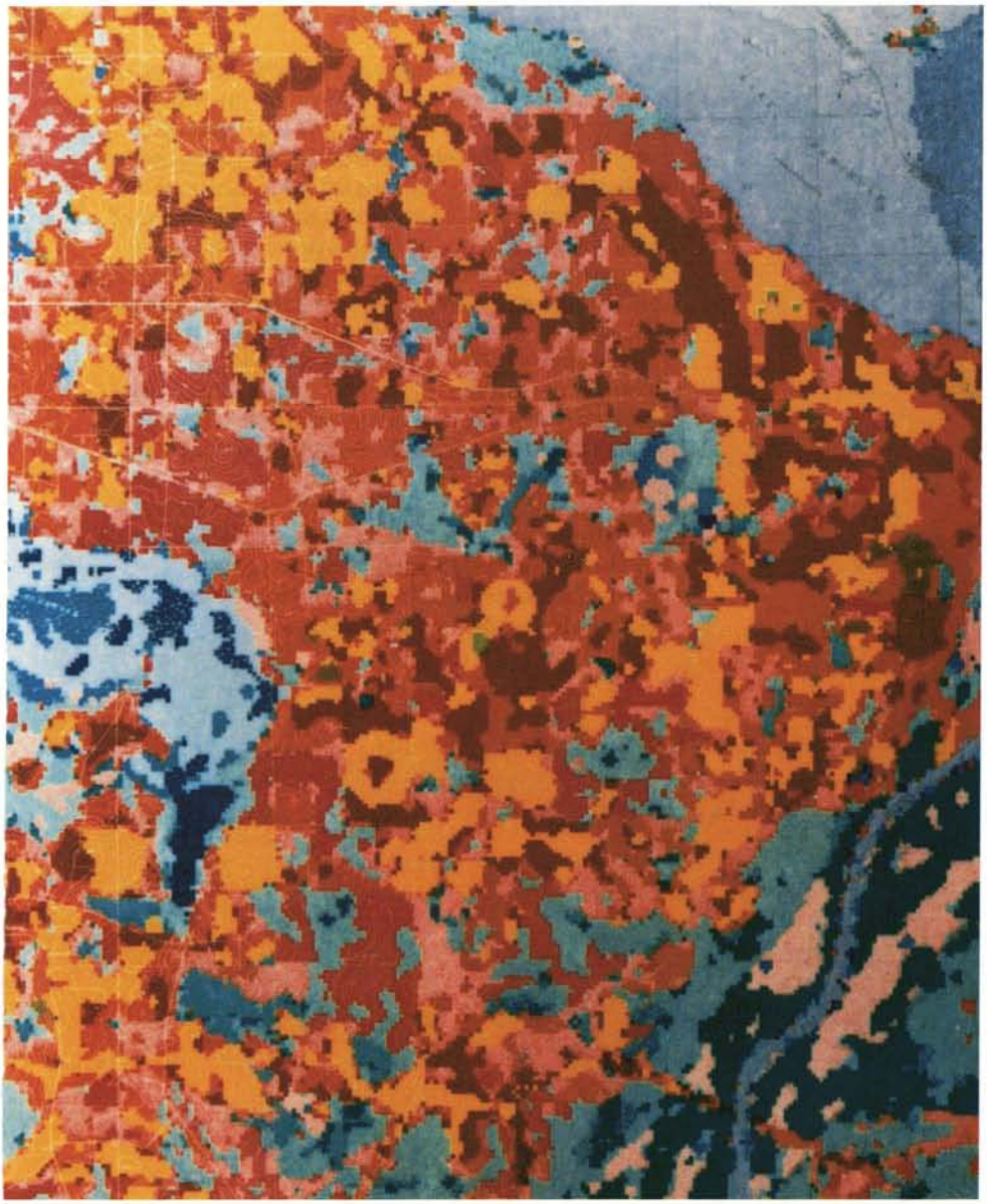

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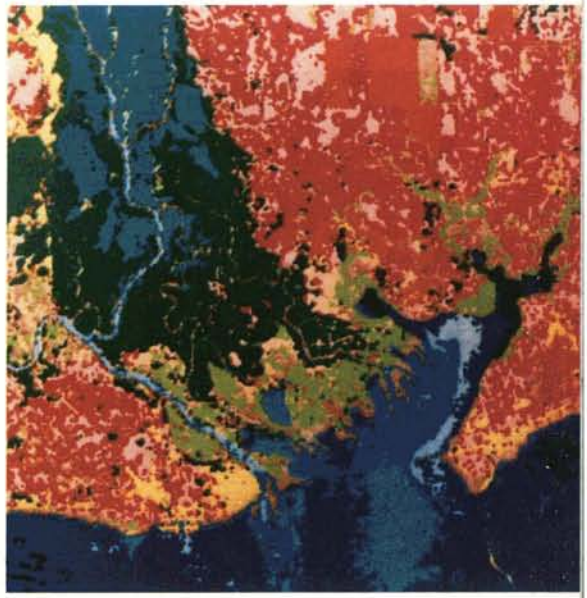

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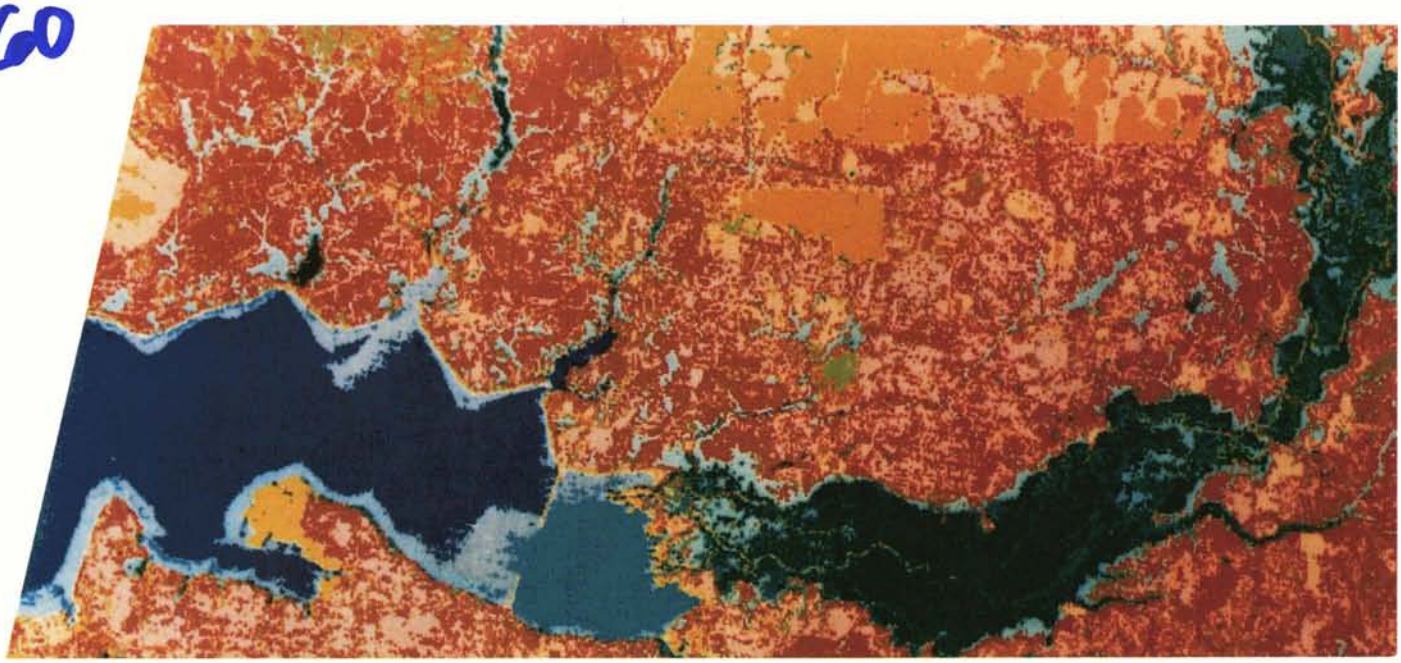

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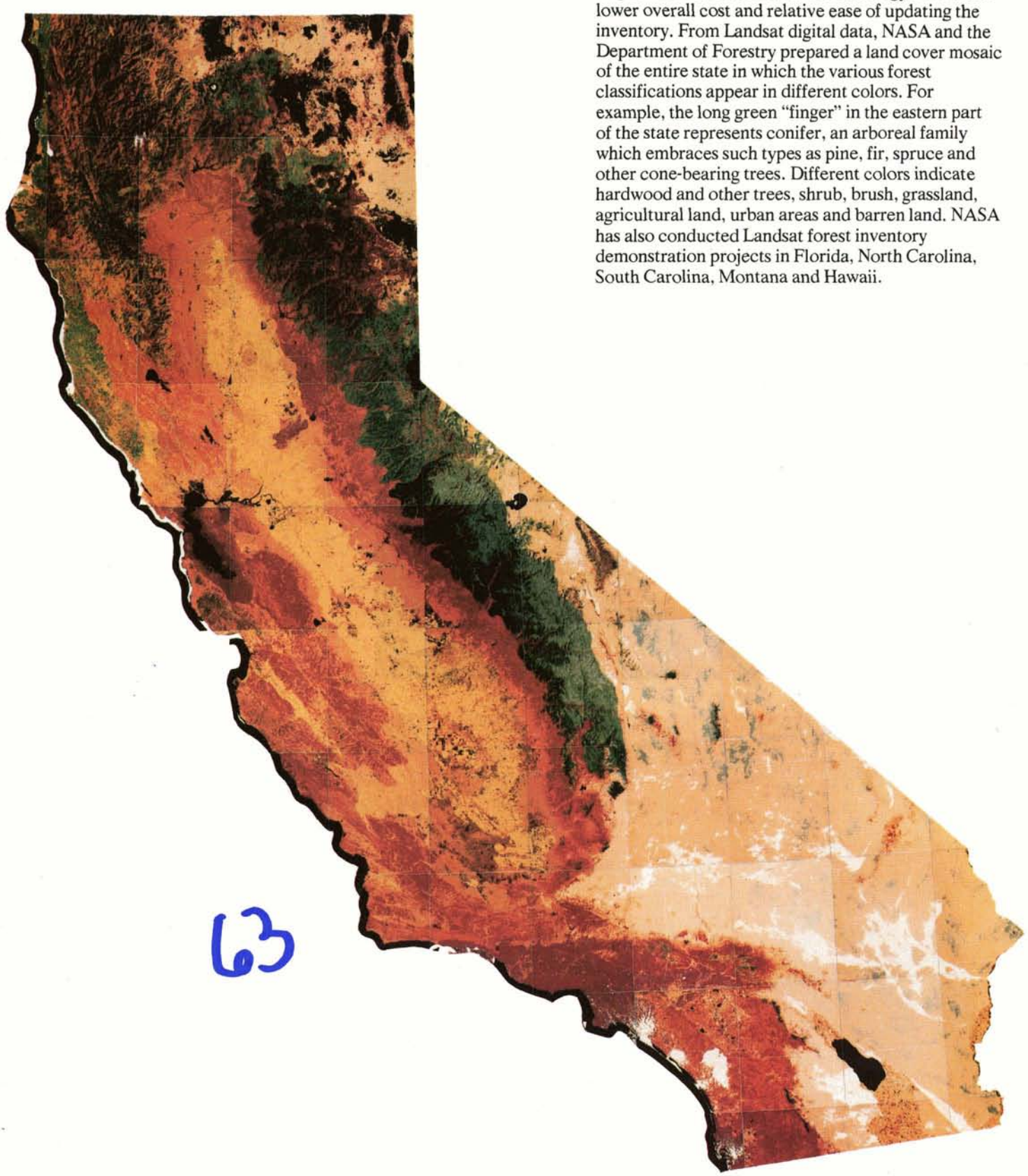
California Inventory

The California Department of Forestry was required by state law to inventory all California forest land by August 1, 1979 and to develop updated inventories every five years thereafter. After investigating several methods of obtaining the needed information, the Department selected Landsat technology because of lower overall cost and relative ease of updating the inventory. From Landsat digital data, NASA and the Department of Forestry prepared a land cover mosaic of the entire state in which the various forest classifications appear in different colors. For example, the long green "finger" in the eastern part of the state represents conifer, an arboreal family which embraces such types as pine, fir, spruce and other cone-bearing trees. Different colors indicate hardwood and other trees, shrub, brush, grassland, agricultural land, urban areas and barren land. NASA has also conducted Landsat forest inventory demonstration projects in Florida, North Carolina, South Carolina, Montana and Hawaii.



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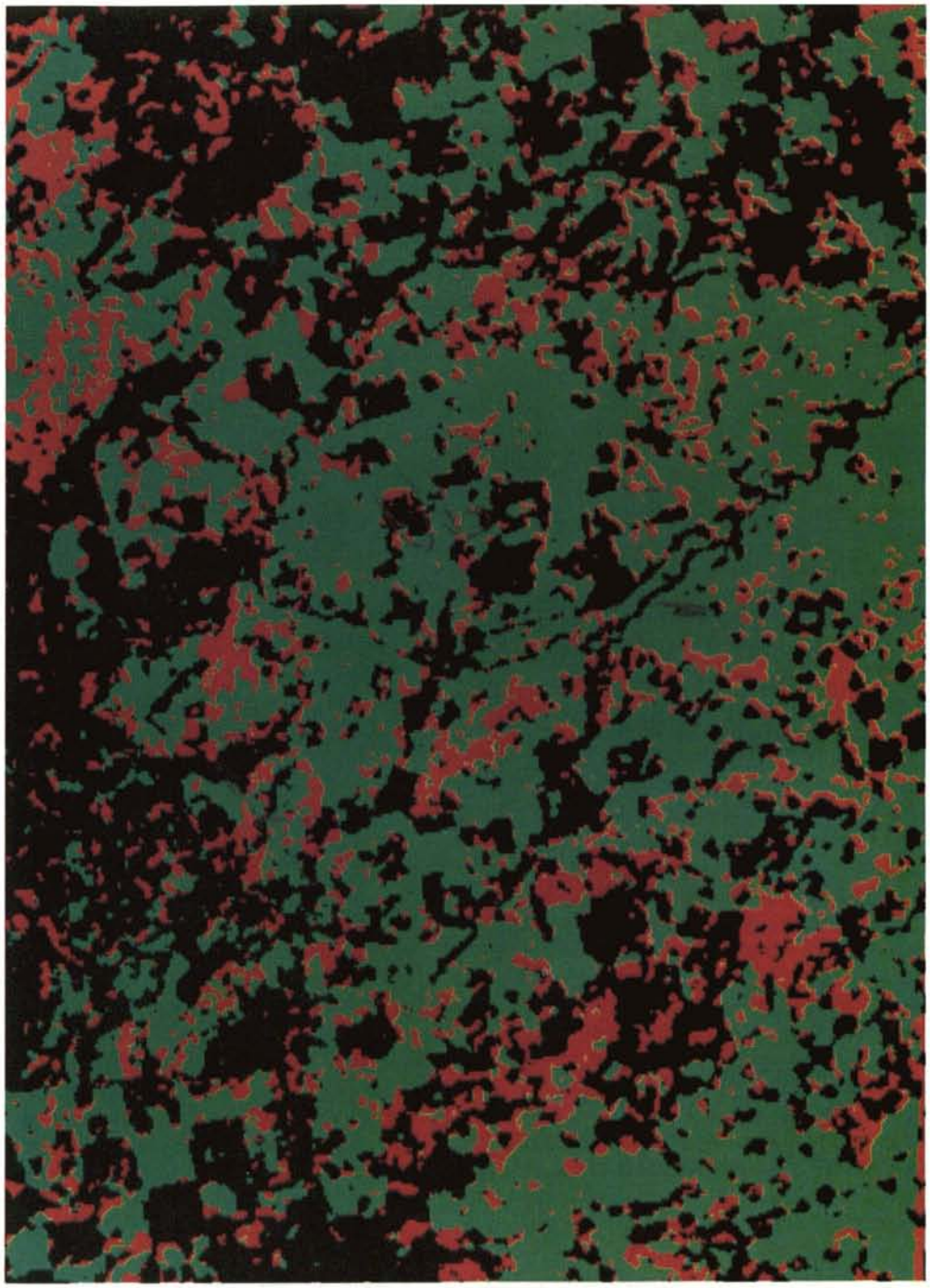

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Forest Survey

Under the auspices of the Pacific Northwest Regional Commission, the states of Washington, Oregon and Idaho have for several years made extensive use of Landsat data in studies of agriculture, range lands, forestry, water resources, noxious weed control, surface mining and coastal zone management. This work is exemplified by a project which demonstrated Landsat's ability to detect changes in forest conditions over a period of time. Focused on Oregon's Douglas County, the change detection experiment was a cooperative effort involving the Oregon State Forestry Department, the U.S. Geological Survey and Ames Research Center.

As the nation's leading timber producing county, Douglas County bases its economy on timber and related industries. Increasing foreign and domestic timber demand caused considerable drain on the county's forest resources and emphasized the requirement for accurate information on the forest reserve. The demonstration project, centered on a 220,000-acre test site in the eastern part of the county, sought to determine the amount and location of forest lands that underwent change—including timber clear-cutting operations—over a two-year span. Landsat images for each year were computer-processed and overlaid on a ground coordinate system to produce the accompanying change analysis. Non-forest lands are black and forest acreage which did not change during the survey period is shown in green; the red areas are those where change occurred. Measurements produced the information that some 35,000 acres experienced change, 88,000 acres remained forested and non-forest land accounted for 97,000 acres.

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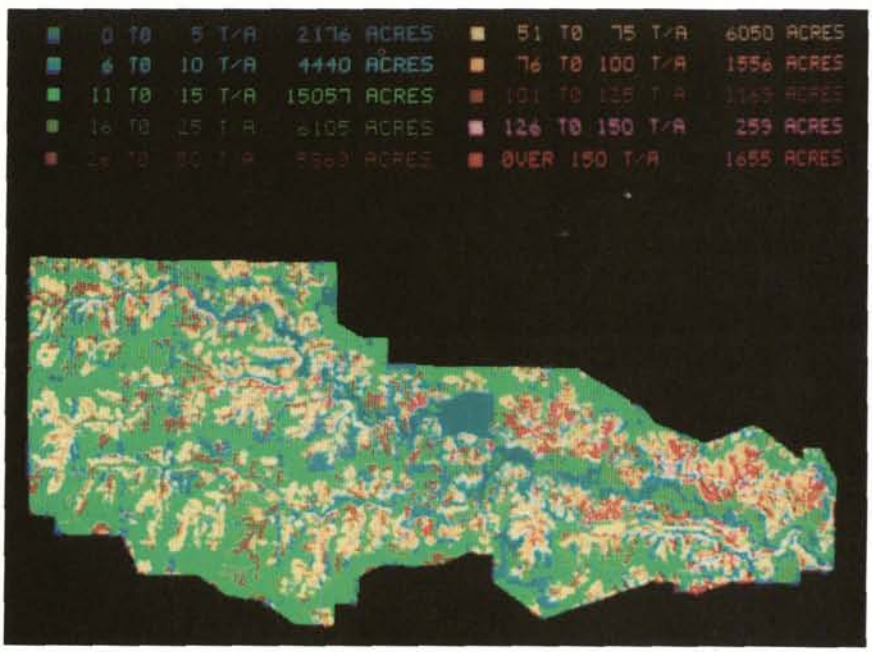
Erosion Potential

The State of Iowa and the Earth Resources Laboratory of NASA's National Space Technology Laboratories teamed in a demonstration of how remote sensing techniques can contribute to determination of land erosion potential, a matter of importance to one of the nation's major agricultural areas. The project addressed the increased soil erosion resulting from conversion of pasture land to row crops in unsuitable locations—for example, on high slope terrain with unstable soils.

Landsat-derived classification maps showed the various changes in land cover that had occurred from 1973 to 1978. For example, the upper illustration—a computer-analyzed image of Iowa's Madison County—shows 1978 land cover, predominantly row crops (red) and pasture/cover crops (yellow); the white areas indicate new row crops planted since the baseline year 1973. Multiple analyses like this, combined with digitized soil maps and terrain data, enabled calculation of expected soil erosion and identification of potential problem areas, thus providing a focus for field inspection. The "bottom line" is illustrated in the lower image; the color key indicates the degree of erosion potential, ranging from least likely (blue) to most likely (red). The success of this and related projects influenced Iowa's decision to purchase its own system for continuing Landsat applications work.



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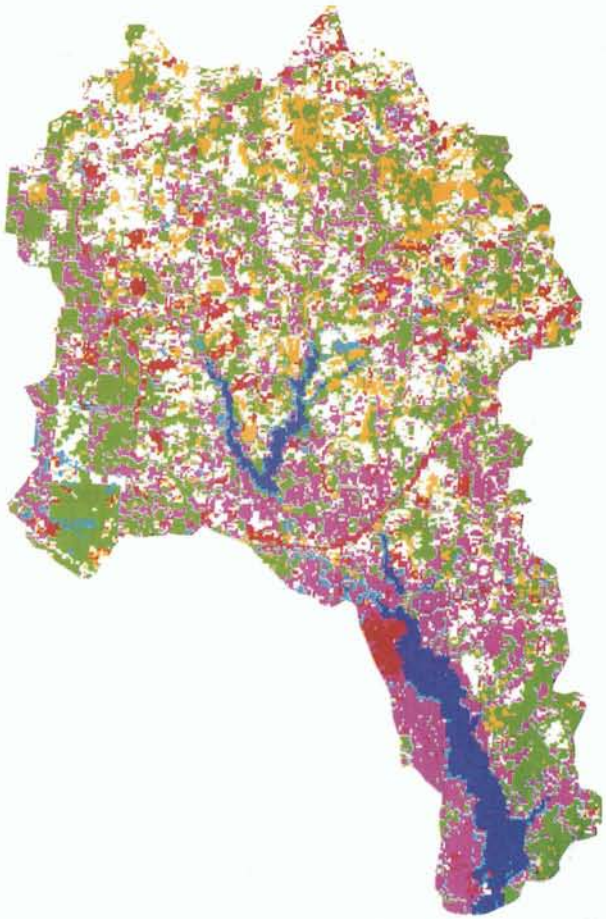
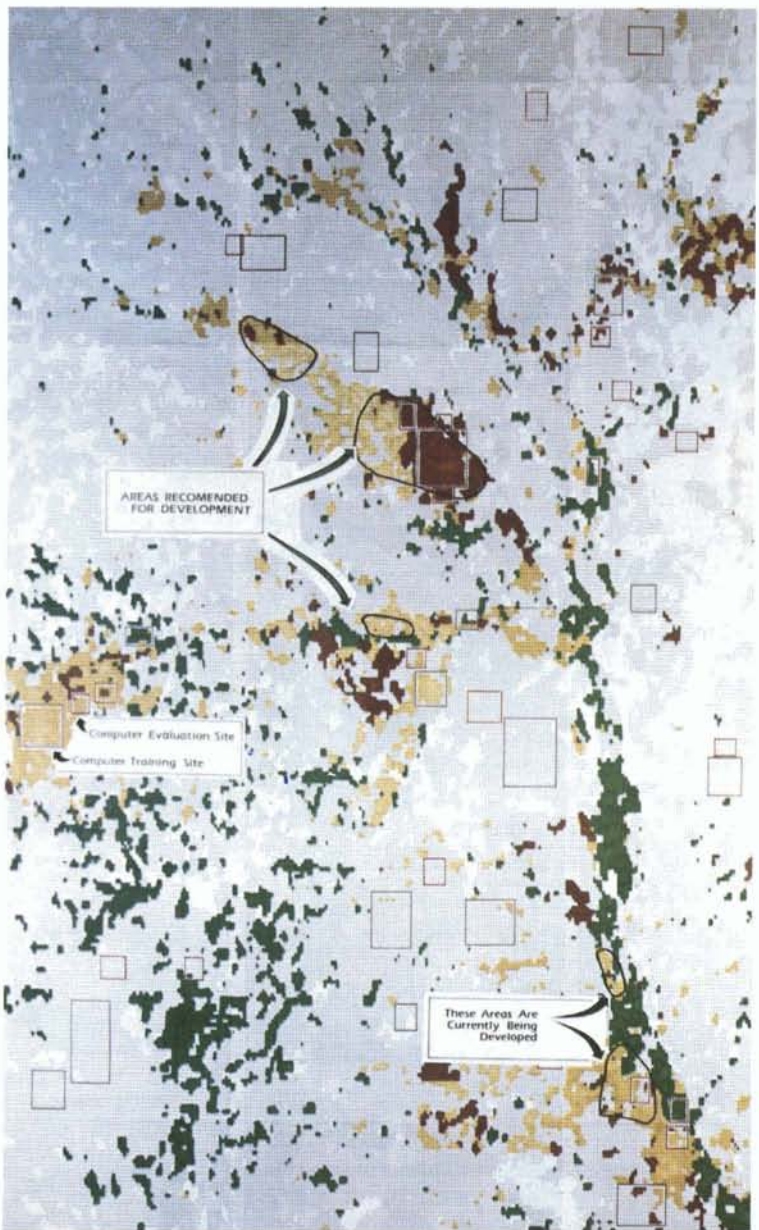
Water Pollution Control

New Jersey's Division of State and Regional Planning is using Landsat data to map and inventory the state's land cover as a basis for general planning and environmental control activities. The Landsat-derived classification map shown, prepared by the New Jersey Department of Community Affairs for the state's Department of Environmental Protection, was used as an aid to development of a water quality plan required by federal regulations. The map covers the Navesink watershed in the northeastern part of the state. Red indicates high density urban areas and purple is medium/low density urban land; blue and aqua are water and wetlands; yellow is cropland, green is forest and white represents vacant, pasture or barren land. The land cover classification served as input to a predictive model for determining the water pollution effect generated by such sources as agricultural and urban activities.





Land Suitability

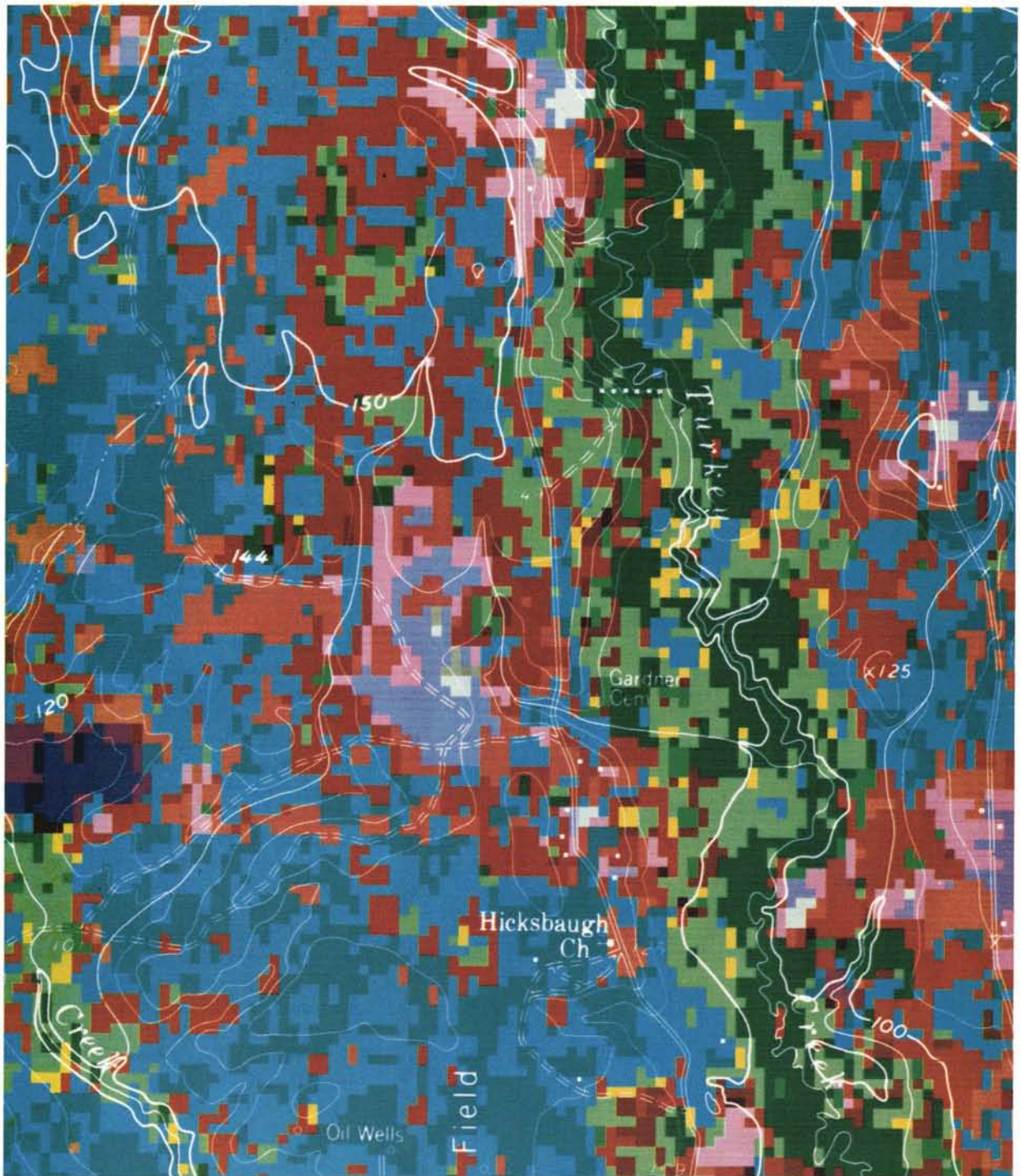
In Arizona, Landsat data backed by surface survey contributed to increased agricultural output by the San Carlos Indians. The tribe was farming some 900 acres of its largely barren million-acre reservation. Faced with a high unemployment rate, the tribal council sought to create new jobs and generate more income by boosting crop production. A problem was the fact that the tribe did not know just how much productive land was available and where it was. Survey assistance was provided by the University of Arizona applications group, one of a number of university units which, under NASA grants, undertake to solve problems which seem susceptible to solution by use of remote sensing techniques.

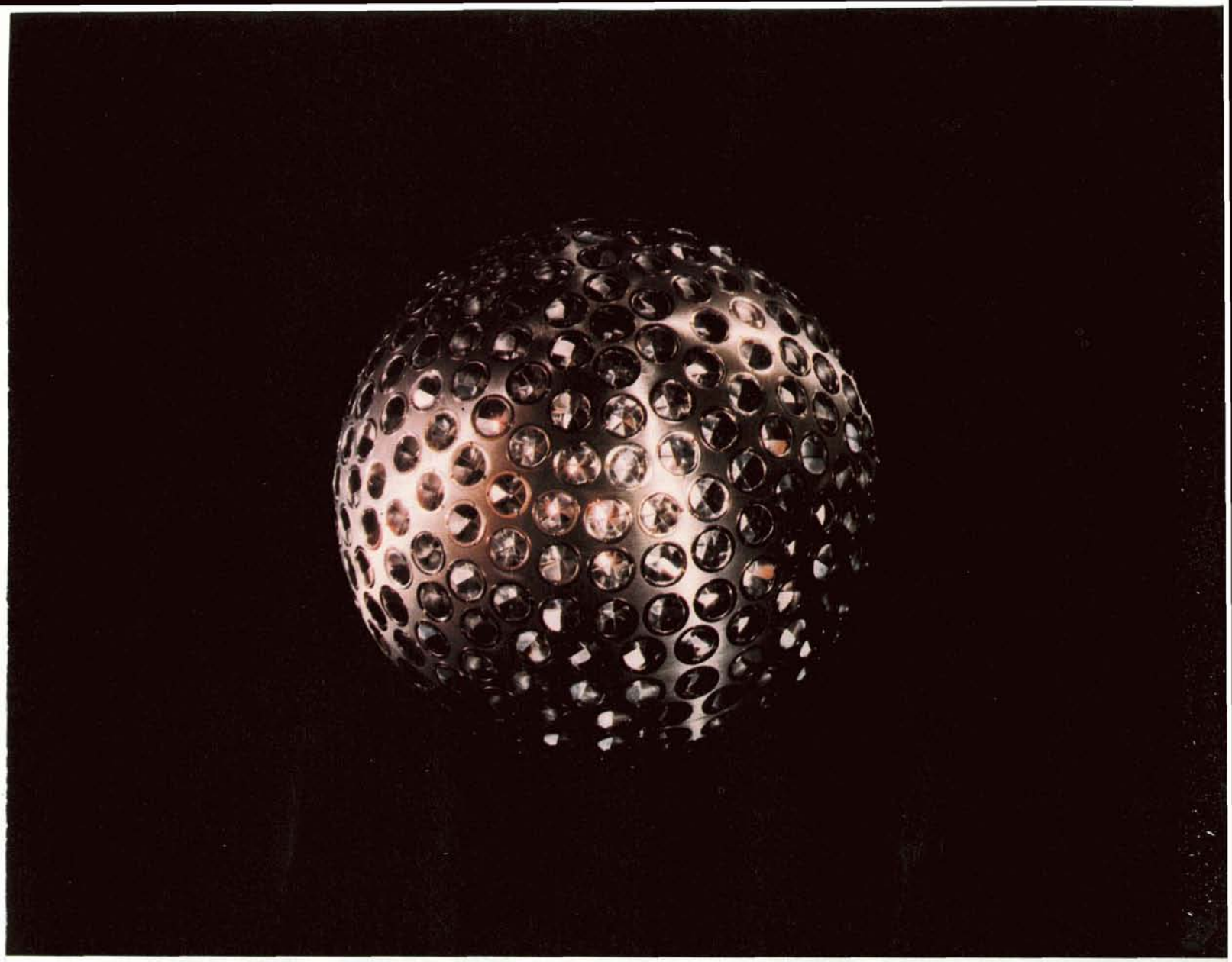
The group first prepared a Landsat classification map showing a number of areas of the reservation potentially suitable for agriculture. By follow-up visits to candidate sites thus identified, and assessment of soil, water availability and other considerations, the university team delineated the locations most suitable for development, the circled areas in the accompanying map. In this illustration, buff and brown shadings indicate land generally suitable for agriculture, green identifies flood hazard zones and the uncolored areas represent non-arable land. The San Carlos Indians started cultivation of the additional land designated most suitable, 70 percent more than was initially used for crop production.

Vegetation Analysis

Proper management of national parks requires comprehensive information on the types and distribution of vegetation, updated periodically to assess the effects of natural and man-induced changes. The Denver Service Center of the National Park Service, in cooperation with the Earth Resources Laboratory of NASA's National Space Technology Laboratories, is using Landsat data to develop a cost-effective system that will supply the requisite information. A test case involves analysis of the diverse vegetation and other land cover in the Big Thicket National Preserve of southeast Texas. Landsat data is providing inventories difficult to obtain by conventional ground methods because of access problems and the widely-scattered location of Big Thicket's 12 separate units.

The color-coded classification below, covering a part of one of the units, illustrates the type of information Landsat can supply to park managers. The black areas represent hardwood forest, the light blues are pine, and red is mixed pine and hardwood; the other colors indicate water, swamp forest, natural and planted grasses, and such inert features as concrete, sand and plowed fields. The vegetation classification is useful, for example, in developing fire management strategy or in identifying sites with potential for infestation by southern pine beetle; it also provides input for wildlife management. Land cover classification, when combined with other information, serves a variety of planning purposes, such as locating sites for roads, trails and campgrounds.





Earth Crustal Study

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The Laser Geodynamics Satellite (Lageos) pictured and a global network of ground-based laser satellite tracking systems are being used as part of a long-term program involving study of the strain building up in the Earth's crust. Lageos is part of NASA's Crustal Dynamics Program, managed by Goddard Space Flight Center, the objective of which is to improve understanding of Earth's dynamic behavior. That, in turn, should lead to better understanding of what causes earthquakes. The program is also expected to contribute new knowledge as to how Earth's mineral deposits were emplaced, an aid to mineral exploration.

Earth's crust is believed to contain about a dozen large and almost rigid "tectonic plates" which are constantly in motion and continually grinding against each other. Theory holds that an earthquake occurs when crustal rocks near the plate boundaries become locked together and are strained beyond their breaking point. By precisely measuring the barely perceptible movements of Earth's crust—inches or fractions of an inch annually—it is possible to analyze conditions under which pent-up strain may be released and cause earthquakes. Lageos was specifically designed to allow extremely precise measurements by serving as a space reference point for ground lasers. The laser system flashes a narrow column of light pulses to the satellite, which reflects the light back to its source. Measurement of the laser beam's roundtrip transmission time permits scientists to pinpoint the location of the tracking system to within two inches. Repeated measurements over the course of time are made to determine changes in baseline length—hence crustal motion.

Another method of measuring crustal motion—called Very Long Baseline Interferometry—uses changes in arrival times of radio signals from distant stars (quasars) as they are recorded at specially-equipped tracking and astronomy facilities. As in laser tracking, this technique allows determination of baseline length, changes in length, and finally crustal motion. Since accuracies of exceptional order are required, it is important to calibrate periodically the results obtained by the two totally different methods.

Stratospheric Investigation

In recent years, there has been growing concern for the environmental quality of the stratosphere, which begins at an altitude of about eight miles. Ozone in the stratosphere protects Earth and its people from much of the Sun's ultraviolet radiation. The stratosphere's aerosol concentration—a layer of tiny solid particles or liquid droplets—also serves as a sunlight filter and, like ozone, plays an important role in the radiation balance of Earth's environment. NASA and other organizations are conducting a number of scientific investigations—in laboratories, balloons, aircraft and satellites—to determine whether man's industrial and technological activities adversely influence the stratosphere, and to determine how the stratosphere reacts to such natural particle injections as those caused by volcanic eruptions.

A major information contributor to these investigations is NASA's Stratospheric Aerosol and Gas Experiment (SAGE) spacecraft shown. Launched early last year, SAGE has an instrument—called a photometer—which "looks" at stratospheric gases and particles against the bright solar background and measures atmospheric concentrations of ozone and aerosols. SAGE was fortuitously launched just prior to the violent eruption of the Caribbean volcano La Soufrière, which provided a scientifically valuable opportunity to measure the abrupt change in aerosol concentrations caused by the eruption and to map the global spread of the volcanic "veil." Tracking such aerosol dispersions is not only important to radiation balance studies but it also gives insight as to how atmospheric pollutants might be transported globally. The SAGE experiment is managed by Goddard Space Flight Center; Langley Research Center has responsibility for instrumentation.

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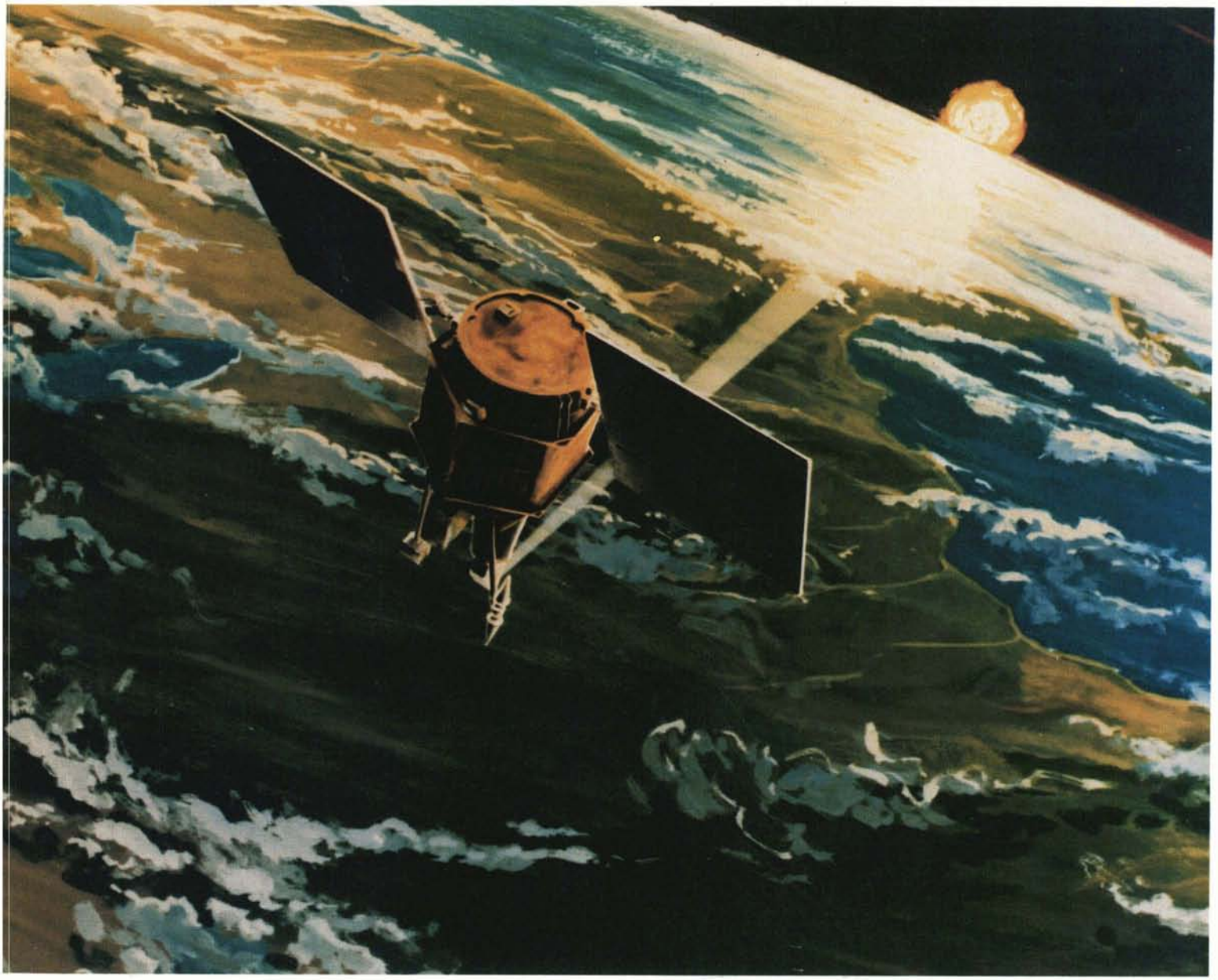

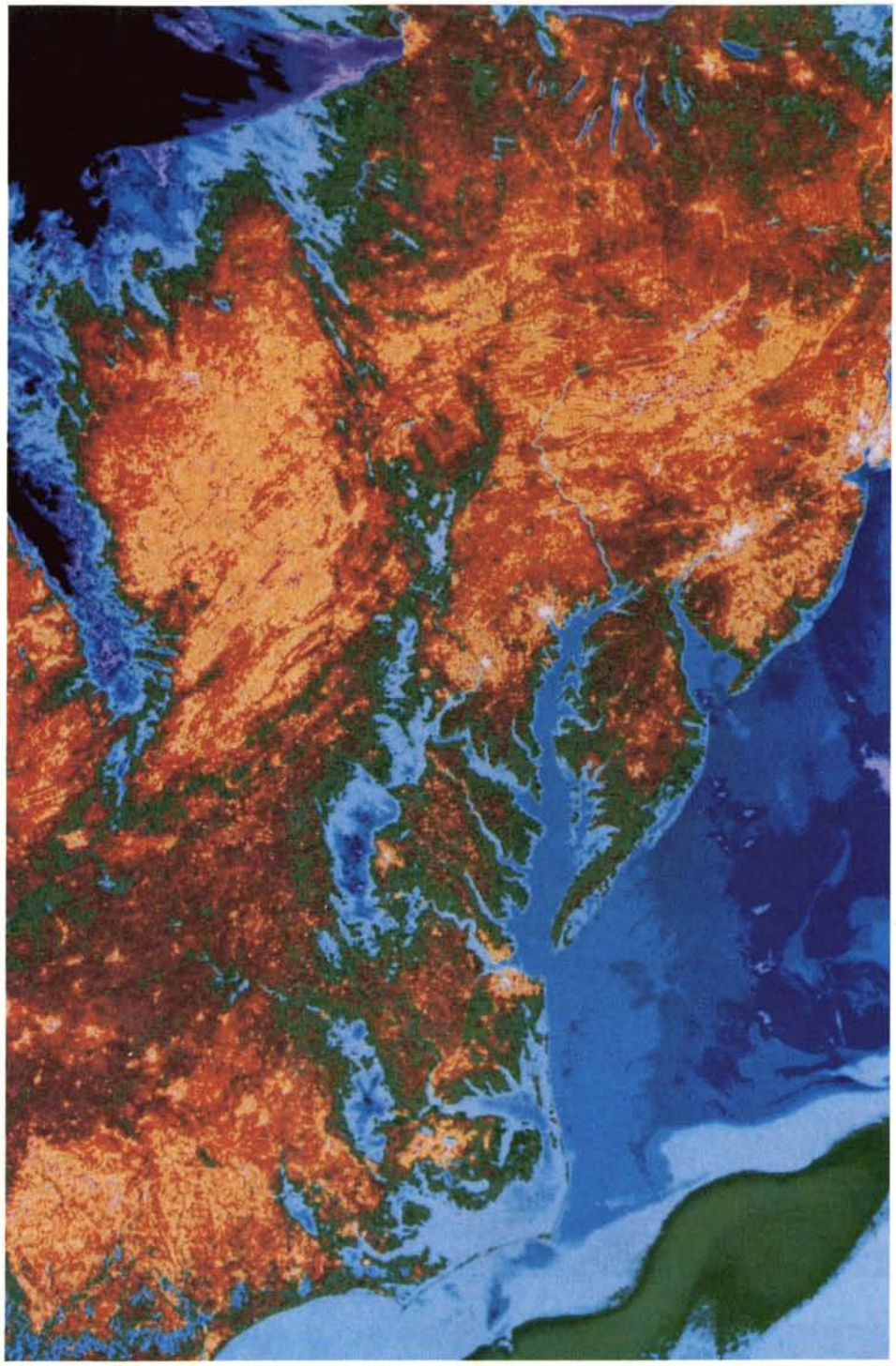

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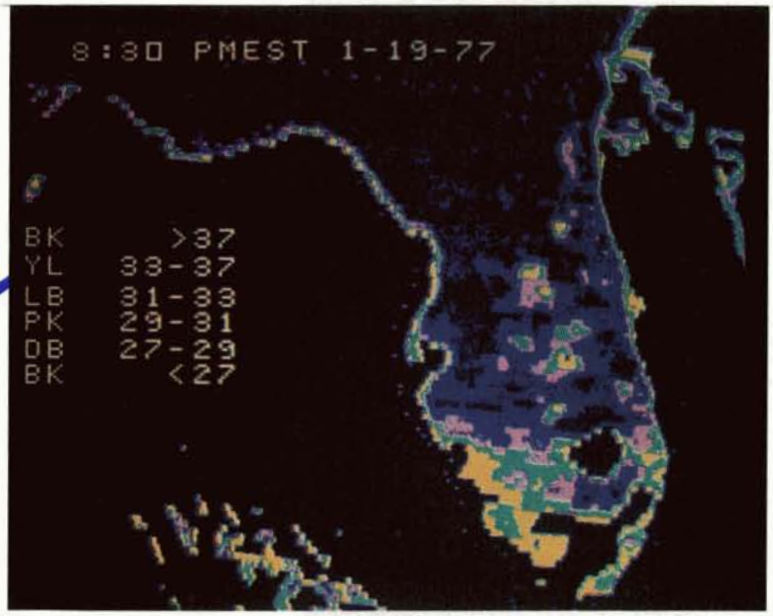
Heat Mapping

The Heat Capacity Mapping Mission (HCMM) spacecraft shown is equipped with sensors to measure variations in Earth surface temperatures. HCMM's data provides a basis for development of color-coded temperature maps which serve a variety of purposes. For example, heat analysis allows discrimination among various types of rocks, a possible aid to locating mineral resources; day-night temperature variations in soil indicate moisture content and help in predicting crop yield; observations of temperature changes in vegetation enable differentiation between healthy and "stressed", or diseased, plants; measurement of snow field temperatures assists scientists in calculating the time and rate of snowmelt for water runoff predictions. HCMM's information also permits study of "heat islands"—concentrations of heat rising from large cities—to learn the extent to which local weather is affected by the higher temperatures associated with metropolitan areas, and to determine whether such temperatures cause long-lasting changes in regional climate.

The accompanying illustration is a color-coded heat map which shows the type of information HCMM makes available to analysts. The map covers a large area of eastern North America from North Carolina into Canada. The colors represent heat values, with purple and blue the coldest, gray and white the hottest; the other colors indicate various intermediate temperatures. The HCMM satellite was designed and integrated by Goddard Space Flight Center, which also handles data processing.



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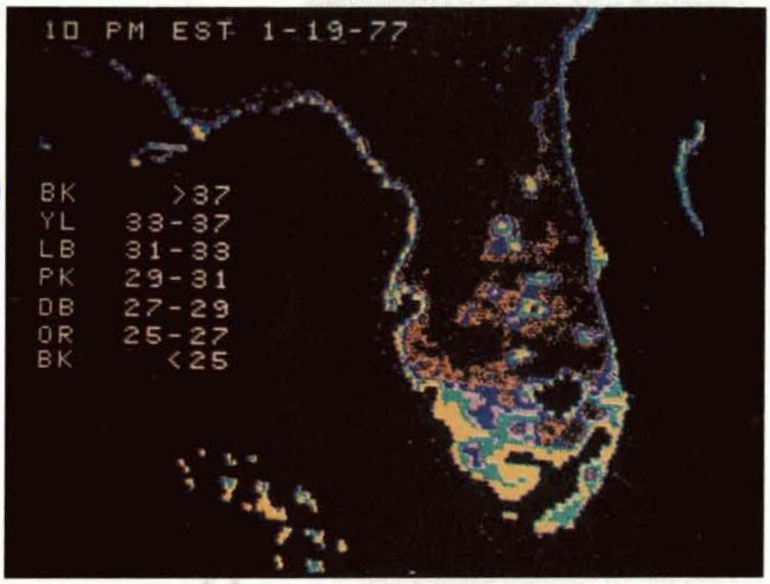

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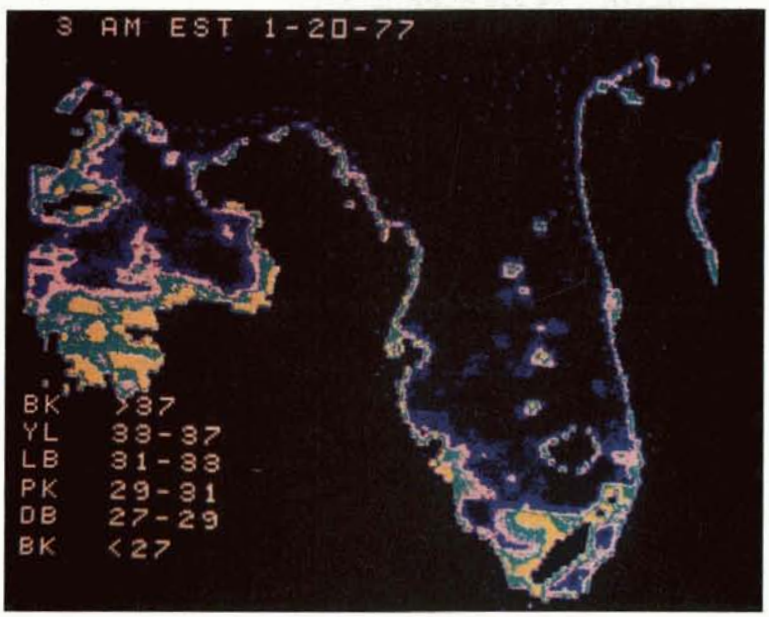

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Freeze Prediction

A satellite-based temperature forecasting system offering economic decision aid to crop growers is being demonstrated in Florida in a joint program involving Kennedy Space Center, the University of Florida and the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA). The "eye" of the system is NOAA's Geostationary Orbiting Environmental Satellite, which sends to Earth every 30 minutes infrared pictures revealing detailed temperatures over the entire state of Florida. A NASA-operated computerized image analyzer converts satellite digital data into color-coded, geographically-mapped temperature displays such as those pictured, a sequence which covers a six and a half hour nighttime period. Comparison of the maps and their color keys shows how temperatures, generally above freezing at 8:30 p.m., dropped sharply to sub-freezing levels overnight. The system provides an accurate means of observing freeze conditions and, in low-wind situations, for predicting exactly when and where freezing will occur and how long it will last.

Such information is vital to agricultural interests, particularly citrus growers, whose entire crop can be ruined by a sustained freeze. When freezing is indicated, growers use grove heaters, wind machines and other measures to prevent crop damage; in the Florida citrus industry alone, the expense of using all protective means can run as high as $6 million for a single night's operation. And, in case of longer-than-expected freezing, early ignition of grove heaters would not solve the problem, since the trees would die when the heaters ran out of fuel. Precise information on freeze timing and duration is essential for effective protection. The NASA-National Weather Service-University of Florida system is demonstrating the requisite accuracy and it is still being improved. Further successful demonstrations around the nation could eventually result in area-specific freeze forecasting systems of great benefit to local producers of cold-sensitive crops.

II

Technology Twice Used

NASA's mainline programs, such as those described in the previous section, produce a steady flow of technology which is being reapplied to create new products and processes. These spinoffs range over a wide spectrum of public needs and conveniences, collectively generating social and economic benefits of significant order.

Spinoff developments highlighted in this section are based on information provided by secondary users of aerospace technology, individuals and manufacturers who acknowledge that aerospace technology contributed wholly or in part to development of the product or process. Publication herein does not therefore constitute NASA endorsement of the product or process nor confirmation of manufacturer's performance claims related to particular spinoff developments described.

Echo's Legacy

Space-spurred expansion of metallized products manufacture exemplifies the breadth and economic value of aerospace spinoff

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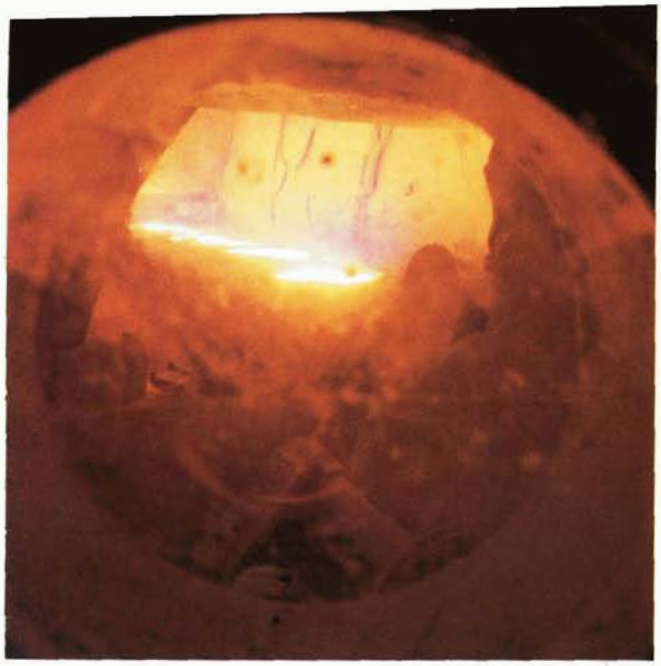
Launched 20 years ago, Echo 1 was NASA's first experiment in satellite communications. The satellite was simply a very large balloon, its diameter roughly equivalent to the height of a 10-story building, which served as a space relay station for reflecting communications signals from one point on Earth to another.

In developing Echo 1, NASA needed a special material for the balloon's skin. For "bouncing" signals, the material had to be highly reflective. It also had to be lightweight and exceptionally thin so that it could be folded into a beach ball-size canister for delivery to orbit, where the balloon would automatically inflate. The material selected was mylar polyester coated with a reflective layer of tiny aluminum particles so fine that Echo's skin had a thickness about half that of the cellophane on a cigarette package.

Metallization—the process of coating plastics or other materials with a superfine mist of vacuum-vaporized metal to create a foil-like effect—was not an exotic space-age development. In fact, it originated in the 19th century, but the technology and its applications developed slowly. By the late 1950s, when Echo was in design status, there was little that could be called a metallization industry; metallized plastics were being produced commercially, largely for decorative purposes, but the market was slim and production was of very limited order.

Echo 1 became the catalyst that transformed a small-scale operation into a flourishing industry. Echo requirements triggered extensive research and development of metallization techniques for the special considerations of space use. This led to further space applications, mostly for thermal radiation insulation; metallized film was used on virtually every U.S. spacecraft from early satellites of Echo's vintage through the manned Apollo and Skylab programs. The impetus thus provided spurred new Earth applications and resulted in development of a broad, still-growing line of commercial metallized products.

The original Echo contractor was acquired by another company, which in turn was sold to the current inheritor of the NASA-sponsored technology—Metallized Products Division of King-Seeley Thermos Company (KST), Winchester, Massachusetts. KST has significantly improved the technology of vacuum metallizing plastic films and expanded the process to include a number of metals other than aluminum, among them gold, silver, copper and zinc; the range of applications for industrial and consumer use has similarly expanded. KST markets some products itself, in other cases supplies metallized rolled sheet materials for use in products manufactured by other firms. The total product line embraces scores of items from insulated outdoor garments to packaging materials for frozen foods, from wall coverings to aircraft covers, bedwarmers to window shades, labels to candy wrappings, reflective blankets to photographic reflectors. Examples of the products are shown on the next two pages and in the Home and Recreation chapter, page 124.



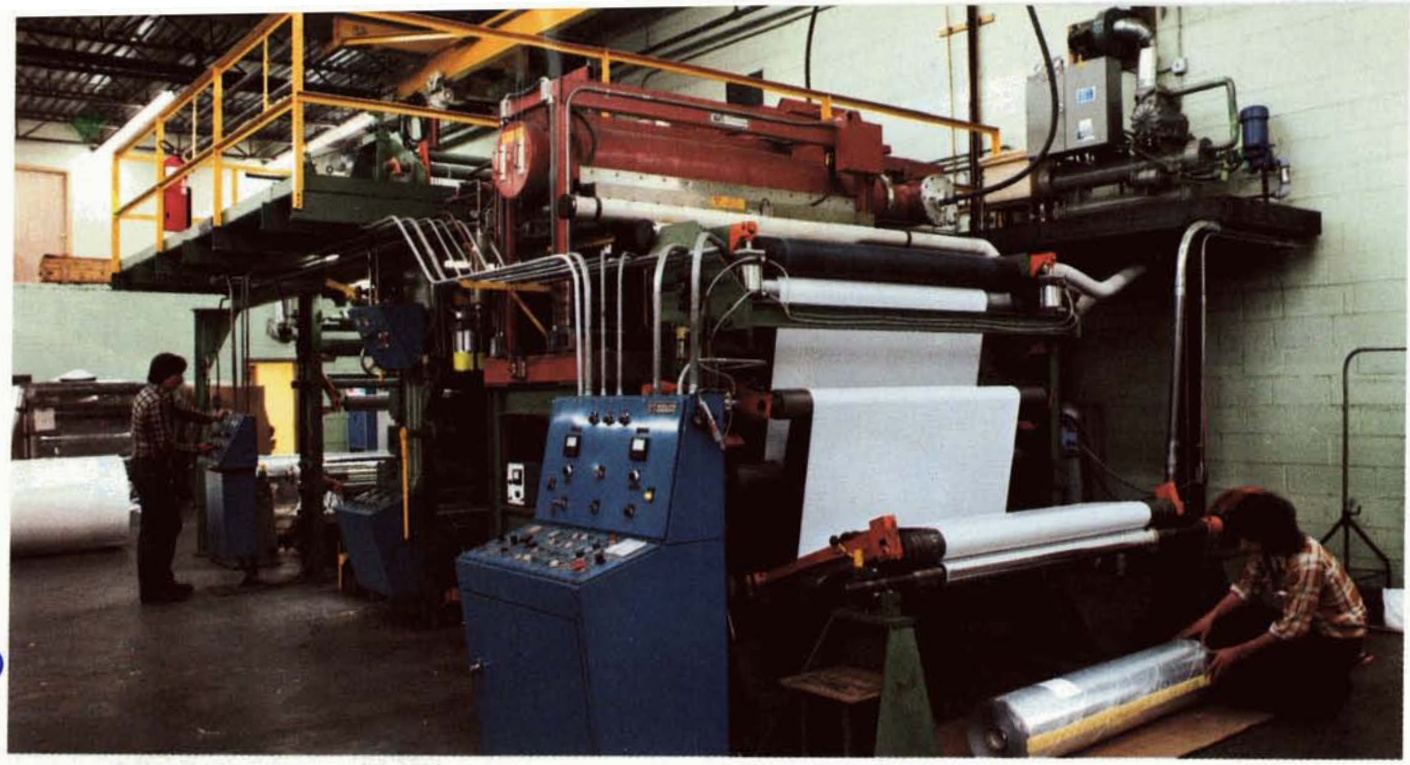
The photo sequence illustrates the process whereby multipurpose metallized plastic film is manufactured by the Metallized Products Division of King-Seeley Thermos Company. At far left, a technician is preparing aluminum for a vacuum metallizing run. The view through the port of the vacuum chamber (above) shows the aluminum being vaporized at temperatures of more than 2,000 degrees Fahrenheit. As the aluminum vapor rises, it is deposited evenly on rapidly-moving plastic film. At right, an employee inspects the finished product; in the background is the vacuum metallizing chamber.

The metallization story is an excellent example of the aerospace spinoff process. This instance involves a technology that existed before the NASA application, but space use prompted far greater commercial applicability. There are many similar examples, where adaptation of an existing technology to an aerospace requirement resulted in expanded markets for the technology, to the benefit of the U.S. economy. More often, spinoffs stem from technology specifically developed for aerospace purposes and later adapted to Earth needs and conveniences.

Metallization is a case wherein a single technology found multiple new applications. At times the reverse is true: multiple aerospace technologies are sometimes employed in development and manufacture of a single secondary application. The instrument of technology transfer may be an entrepreneur who recognizes the potential of technology available for transfer and invests in its further development; it may be an aerospace contractor seeking product line diversification; or it may be an individual aerospace worker who moves to another industry, bringing with him aerospace-acquired skills and know-how applicable to non-aerospace use. NASA also serves as a transfer catalyst, by means of a number of mechanisms which are detailed in Section III of this volume.

Finally, the metallization example underlines the economic potential of aerospace spinoff. Many of the individual items within the broad metallized product line are sold in volumes reaching multimillions of dollars annually. Technology transfers of that scope occur frequently. In other instances, spinoffs offer only moderate economic gain but provide public benefit in other ways, ranging from simple conveniences to significant developments in medical and industrial technology.

For the past 18 years, under its Technology Utilization Program, NASA has been actively engaged in promoting the secondary application of aerospace technology. The results have been impressive; thousands of aerospace-spurred or aerospace-originated innovations have found their way into everyday use. They are contributing to lifestyle improvement, helping solve major problems of public concern, and supporting the national economy by increasing industrial efficiency, stimulating productivity and creating new jobs. In the aggregate, they represent a substantial return on the aerospace investment.



This sophisticated King-Seeley equipment is employed in a new electron beam processing technique for curing—instantly drying—solid coatings; the coatings are exposed to streams of electrons and cured in five-thousandths of a second. The machine also laminates sheets of material for greater strength and quick-cures the laminating adhesive.

Among the most widely used of the many products made from metallized film is the high-reflectivity Thermos® Blanket, which keeps heat in or blocks heat out, depending on the use. For example, as a stadium blanket (above) it retains 80 percent of the wearer's body heat. For camping (above right), it serves as an insulated packaging material, picnic spread, tent floor or heat-reflecting canopy for protecting food and beverage. The multipurpose blanket is marketed by King-Seeley's Thermos Division, Norwich, Connecticut.

® Thermos is a registered trademark of King-Seeley Thermos Company.

In addition to marketing its own products, King-Seeley supplies a wide range of metallized material for products of other companies. An example is Astrolon® II, a multilayer derivative of astronaut space suit material which has exceptional heat reflection and heat retention characteristics. One of many applications of Astrolon II is the "Spacecoat," marketed by Spacecoat Garments, Ltd., London, England. Shown above, the lightweight Spacecoat is useful for home energy savers who are turning down their thermostats; it is a personal insulator whose reflective layer of vaporized aluminum slows loss of body heat by radiation. The Spacecoat is finding wide acceptance among elderly people living in minimally-heated quarters, as protection against respiratory and circulatory illnesses induced by lowered body temperature.

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® Astrolon is a registered trademark of King-Seeley Thermos Company.

A special application of Astrolon II is its use in clothing worn by members of the 1979-82 British Transglobe Expedition, which is attempting the first polar circumnavigation of the world by land, sea and ice. Designed by Spacecoat Garments, Ltd., the lightweight, bulk-free suits pictured will provide protection from extreme cold as the expedition crosses the South and North Poles.

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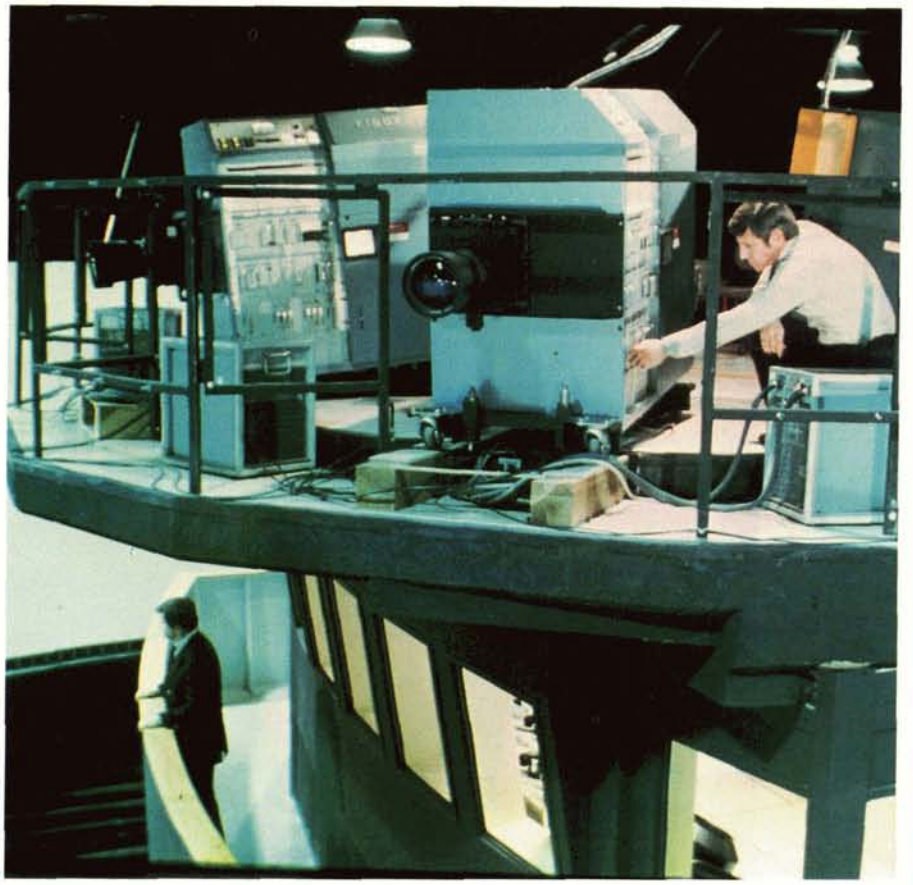
Simulators for Safer Shipping

Aerospace-derived research and training aids for reducing maritime accidents highlight spinoffs in the field of transportation



Through the windows of the CAORF bridge, deck officers see a simulated harbor exactly as it would appear on a real approach. Computer-directed equipment (shown above the bridge) projects a visual image on a panoramic screen, and for extra realism harbor sounds are also duplicated.

Each year one ship out of every five afloat collides with another vessel, or rams a dock, or runs aground. Such accidents cost multimillions annually, but the monetary loss is the lesser part of the problem. Of greater concern is the incalculable cost in human lives, injuries sustained and environmental damage.

The marine safety problem is compounded by the fact that merchant ships are getting bigger and faster, therefore harder to handle. Additionally, maritime traffic density is increasing. When a supersize ship with inherently difficult handling qualities approaches a crowded, marginal harbor designed for the smaller ships of an earlier era, there is high potential for accident.

The situation, says the U.S. Maritime Administration (MarAd) of the Department of Commerce, is one of "increasing seriousness." MarAd is doing something about it. In addition to its general work to improve merchant shipping safety and productivity, MarAd has established a special program to reduce the number of ship accidents by learning more about how they are caused—and aerospace technology is playing a part in the effort.

Located on the grounds of the U.S. Merchant Marine Academy, Kings Point, New York, MarAd's National Maritime Research Center is seeking answers to the problem through operation of a highly sophisticated ship maneuvering simulator. Called CAORF—an acronym for Computer Aided Operations Research Facility—the simulator was designed and built by the Sperry Division of Sperry Corporation, Great Neck, New York. CAORF incorporates technology developed in a wide variety of aerospace simulation and technical training programs for the military services and NASA. Management and operational services for CAORF are provided by Grumman Data Systems Corporation, a subsidiary of Grumman Corporation, Bethpage, New York. Grumman built the Apollo Lunar Module for NASA, and the company has applied some of the expertise acquired in that program to its CAORF work.

CAORF can be set up to duplicate the exact handling qualities of any vessel, under various conditions of wind, tide and current; currently, a dozen different ships can be "plugged in." Bridge instrumentation is typical of modern shipboard equipment, in-

What appears to be a ship's wheelhouse is actually the bridge of a highly realistic simulator operated by the U.S. Maritime Administration in a research program aimed at reducing ship accidents. Based in part on aerospace simulation technology, the simulator is called CAORF for Computer Aided Operations Research Facility. 85

cluding radar, internal and external communications, and new collision avoidance systems. The make-believe ship—called "Ownship"—is manned on test runs by experienced masters, pilots and deck officers drawn from the merchant fleet.

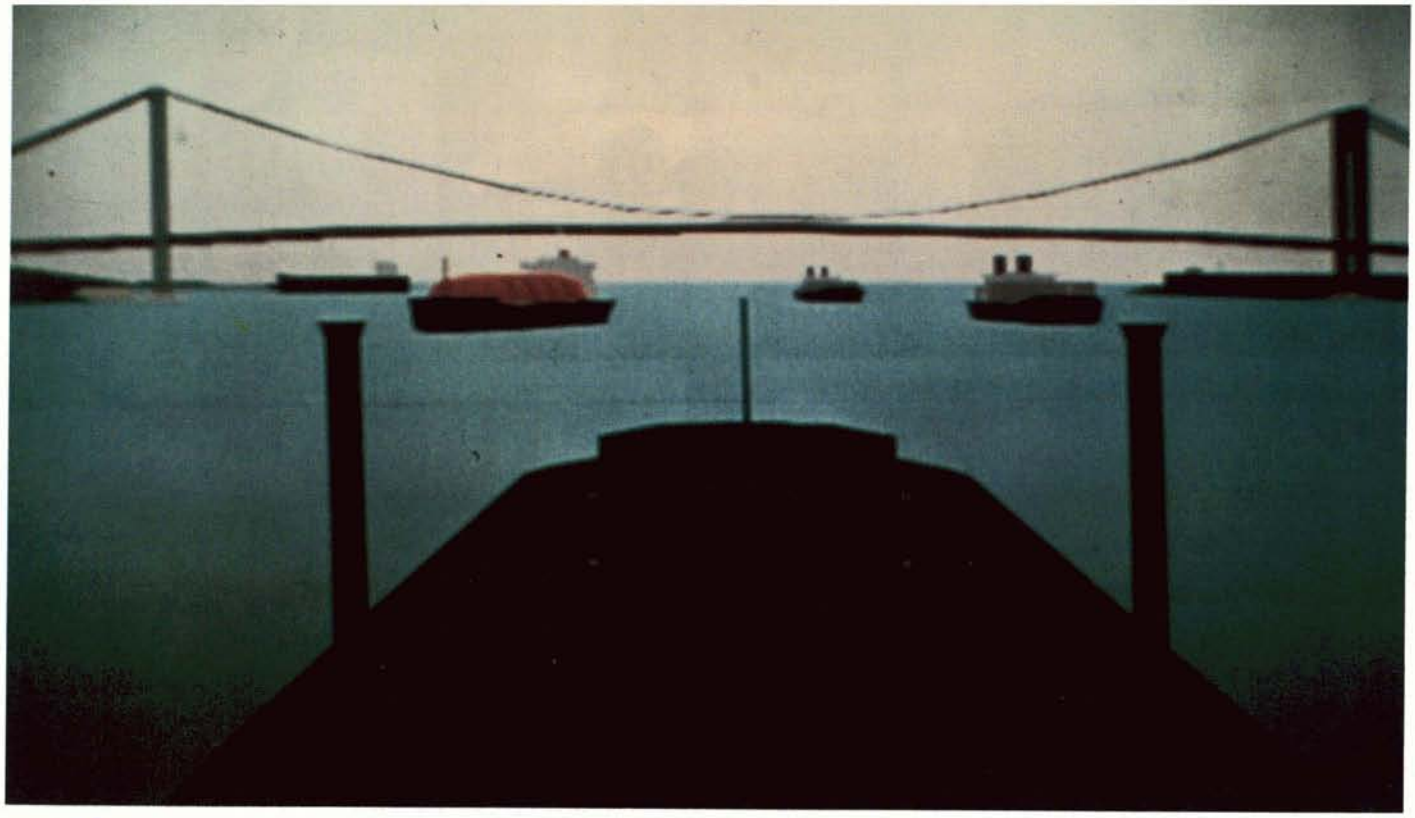
Simulation focuses on harbors and restricted waterways within or just beyond sight of land, where sea lanes merge, traffic increases and human performance is most critical. Computerized equipment can simulate the sights and sounds of any harbor approach—in daytime, nighttime, fog or haze—as viewed through the bridge windows. Portrayed in full color on a 125-foot panoramic screen are other ships, shorelines, navigational aids, docking areas, bridges, buildings—everything the bridge crew would see if they were actually approaching the harbor simulated. Six moving ships can be shown simultaneously and the scene changes in response to the movements of "Ownship." In addition, the radar screen can project up to 40 ships that are simulated to be over the horizon and out of sight.

MarAd's research emphasizes the human element. CAORF includes a Human Factors Monitoring Station where a skilled psychologist assesses, via closed circuit TV, the behavior of watch officers in terms of work load, decision-making and reaction to hazard. A controller can induce ship malfunctions or precipitate collision danger to measure human performance in an emergency. MarAd explains the aim of this part of the research:

"Human error has been labeled the cause of 80 percent of maritime accidents. Yet it may well be that the fault lies somewhere else—with the need for operational procedures more in keeping with the real world, perhaps, or better equipment and information displays, or more efficient bridge designs."

From repetitive operation of the simulated ships, MarAd is building a valuable data base for improving marine safety. In addition to provisions for better human performance, the data can be applied to developing better vessel controllability in shallow waters, modifying restricted waterways for safer navigation, and determining harbor and terminal design criteria for large ships.

Sperry employed the same technology in development of another simulator, different in that it is designed for training bridge crews where CAORF is used for research purposes. Known as the Sperry Shiphandling Simulator, the system was built for Marine Safety International, Inc. (MSI), located at New York's LaGuardia Airport. MSI uses it to provide deck officer training for a number of ship-operating companies. The Shiphandling Simulator's exceptional realism, similar to that of CAORF, gives bridge crews hands-on experience under severe operating conditions without the risks associated with maneuvering real ships in critical situations.



This is a view from the wheelhouse as a simulated tanker—"Ownship"—approaches New York's Verrazano Bridge. The scene changes in response to movements of Ownship. Realism is further heightened by the fact that the other ships in the image also move, at the same relative speed as they would in a real-life situation. Analysis of ship collisions—and how they may be prevented—is a major part of the CAORF research program.

At CAORF's Human Factors Station, a psychologist monitors, via closed circuit television, the performance of the bridge crew and their reactions to simulated emergencies. Human error is considered the cause of most marine accidents, but the Maritime Administration is studying the extent to which other factors—such as operational procedures, information displays or bridge designs—may contribute.

CAORF exercises are managed from a console in the facility's control center. The research coordinator directs the simulated vessels involved in the test scenario, sometimes inducing malfunctions or precipitating collision courses as part of the experiment.

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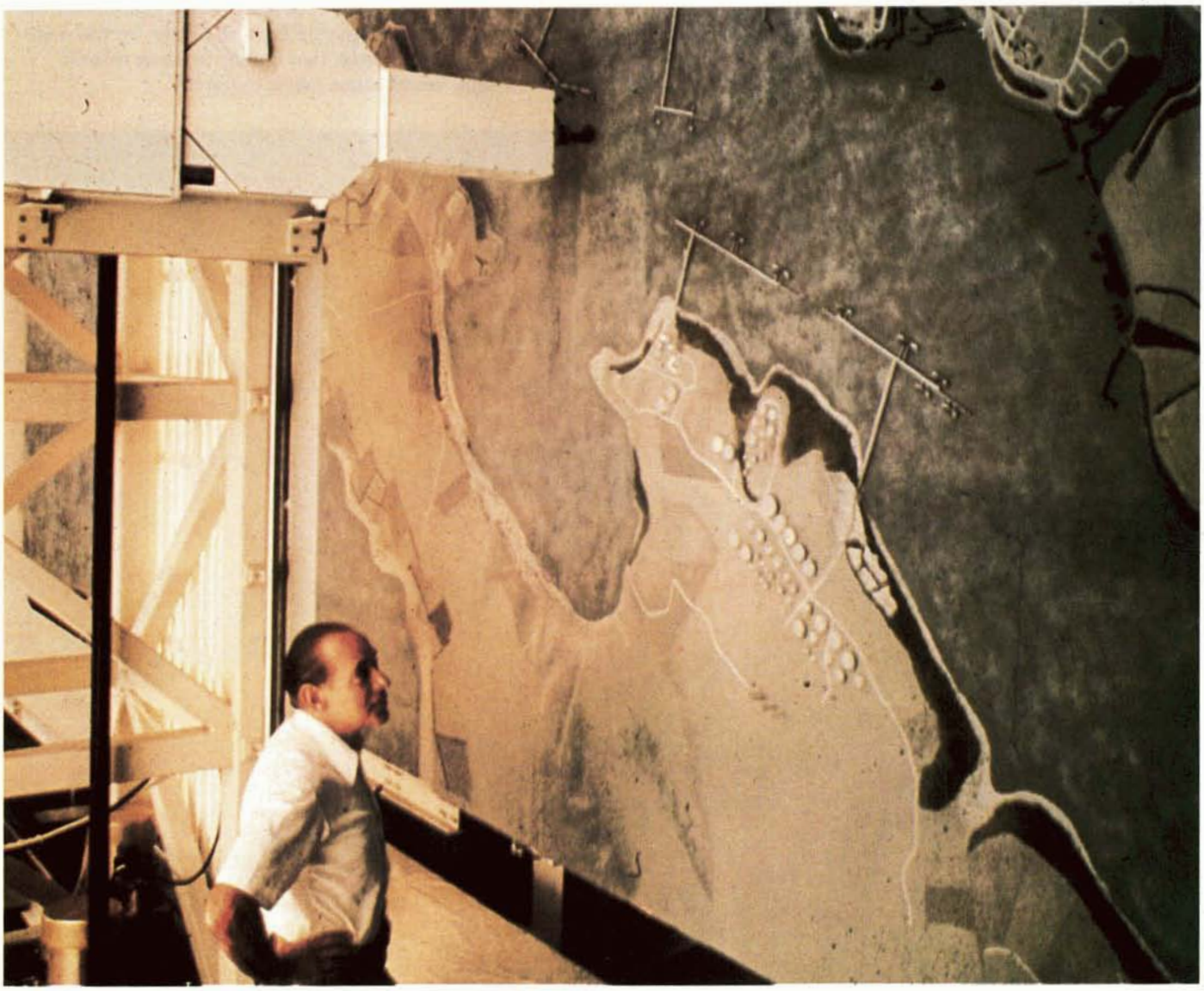
A companion system to CAORF is the Sperry Shiphandling Simulator, similar in operation and capability but designed for training where CAORF is used as a research tool. Located at New York's LaGuardia Airport, the Shiphandling Simulator is operated by Marine Safety International, Inc., a commercial firm which trains deck officers for shipping companies.

At Marine Safety International, a simulation engineer studies a model board of the harbor at Milford Haven, Wales. Scale models like this, painstakingly constructed to duplicate every detail of the real harbor, provide the basis for computerized projection of a life-size image on a screen forward of the Shiphandling Simulator's bridge.



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Longhorn Business Jets

The airplane shown is the new Learjet Longhorn 55, a twin-turbofan, 13-place widebody business jet which—along with visually identical companion models Longhorn 54 and 56—will make its service debut this year. Manufactured by Gates Learjet Corporation, Wichita, Kansas, the Longhorn 54/55/56 models feature "winglets," nearly-vertical extensions of the wing (shown in closeup below). Developed in NASA's Aircraft Energy Efficiency program, the winglet is an aerodynamic innovation designed to reduce fuel consumption and generally improve airplane performance. Gates Learjet was the first manufacturer to use the winglet design in production-type jets, initially on the Longhorn 28/29 models introduced to service in 1979. Several other plane builders are taking advantage of the NASA technology.

Winglets are lifting surfaces designed to operate in the "vortex," or air whirlpool, which occurs at an airplane's wingtip. This complex flow of air around the wingtip creates drag which retards the plane's progress. The winglet reduces the strength of the vortex and thereby substantially reduces drag. Additionally, the winglet generates its own lift, producing forward thrust in the manner of a boat's sail. The combination of reduced drag and additional thrust adds up to significant improvement in fuel efficiency.

Winglets are particularly effective on the Learjet Longhorns, which are capable of flying at altitudes up to 51,000 feet, unusual for civil aircraft. At such altitudes, where the air is thinner, the drag reduction afforded by the winglets is more pronounced, thus fuel savings are greater. Winglets, together with an advanced design basic wing, give the Longhorns longer range than predecessor Learjets for the same speed and payload; alternatively, for the same range and payload, they can fly at lower takeoff weight because less fuel is required.

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Reborn Sabreliner

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The airplane pictured, known as the Raisbeck Mark Five Sabreliner 60A, is a modernized, higher performance version of the Sabreliner business jet originally designed more than 20 years ago. Aeronautical research has advanced tremendously since the Sabreliner's debut, so the airplane suffered competitively with newer business jets. The Sabreliner manufacturer—Rockwell International, El Segundo, California—decided to update the design to incorporate the latest technology, thereby insuring continuing production of a competitive new airplane and protecting Sabreliner owners' investments by allowing them to convert to the updated configuration.

Rockwell entered into an agreement with The Raisbeck Group, Seattle, Washington, a research/engineering/manufacturing firm which specializes in applying modern technology to earlier-built business and commercial jet aircraft. In the process of redesigning the Sabreliner, The Raisbeck Group employed NASA technology.

Redesign of the airplane involved extensive changes in aerodynamics, structure and on-board systems. Key to the Mark Five design is a new wing, which has greater fuel capacity, increased span and improved airfoils to reduce fuel consumption. Ames Research Center cooperated with The Raisbeck Group in designing the wing, assisting in applying the Ames-developed technique known as CFD—for Computational Fluid Dynamics—a computerized method of simulating and analyzing the three-dimensional flow of air over an airfoil. By programming wing design data into a computer, Raisbeck engineers were able to determine the wing's reaction to various conditions of flight and refine the design until optimum results were obtained. Use of CFD saved Raisbeck an estimated 4-1/2 months of flight testing and associated costs.

The Mark Five design that emerged offers, among a number of improvements, about 25 percent longer range along with higher cruise speed and reduced takeoff/landing distance requirement. The Raisbeck Group is converting existing Sabreliners to Mark Five configuration at its facilities on Boeing Field, Seattle, Washington; Sabreliner owners can get the Mark Five for less than one-fourth the cost of an equivalent-performance new airplane. Raisbeck also sells Mark Five system components to Rockwell's Sabreliner Division, St. Louis, Missouri; these components form the aerodynamic and structural basis for the latter company's new fanjet Sabreliner Model 65.

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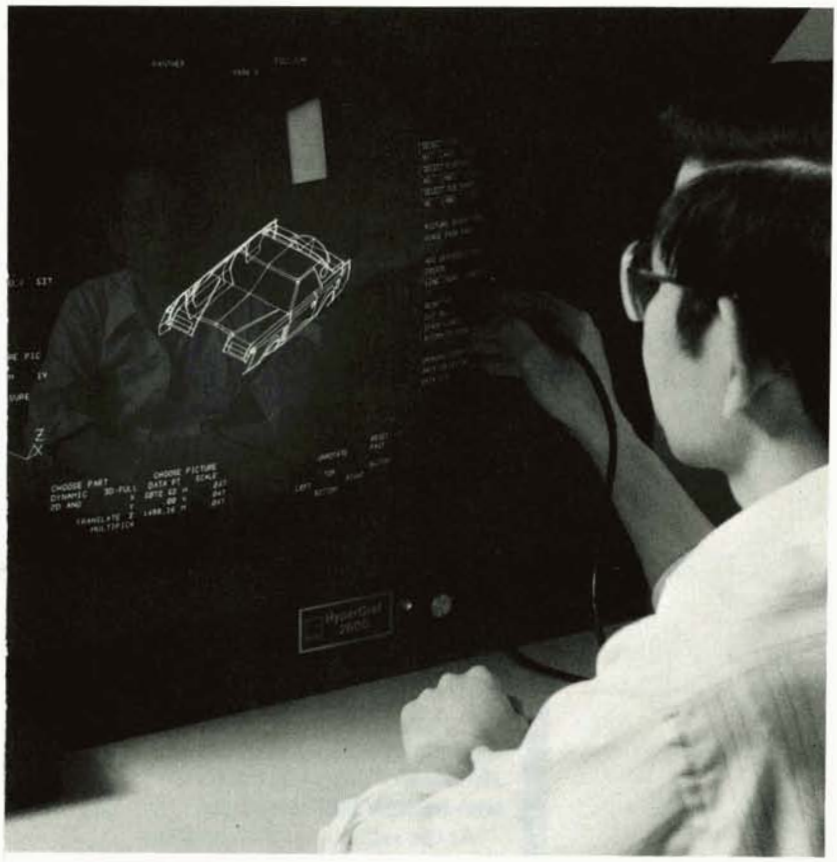
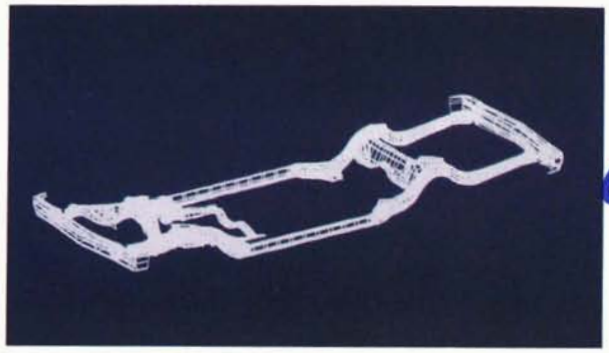
Streamlined Livestock Trailer

Shown in full view and front-end closeup is a Bull Nose® livestock trailer, one of a line of highway transport vehicles manufactured by American Trailers, Incorporated, Oklahoma City, Oklahoma. The slant-side front end is a streamlining feature based on a NASA research program which investigated the aerodynamic characteristics of trailer/tractor combinations and suggested ways of reducing air resistance. Application of the NASA technology to the Bull Nose design resulted in a 10 percent reduction in air drag, which translates into annual fuel savings of several hundred dollars. American Trailers reports an increase in sales due to the streamlining innovation. The company is also offering an optional reduced drag design on its line of refrigerated vans.

® Bull Nose is a registered trademark of American Trailers, Incorporated





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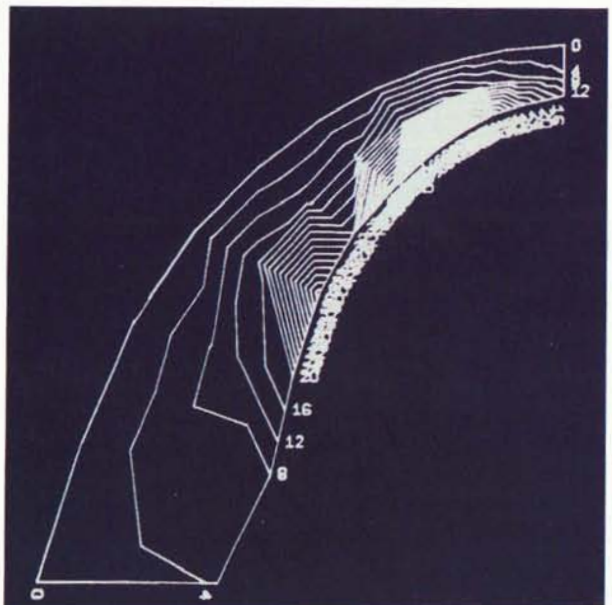
Automotive Engineering Software

In recent years, automotive equipment manufacturers have greatly increased their use of computer techniques in designing, engineering and manufacturing autos, trucks and other vehicles. Ford Motor Company, for example, completed in 1979 a multimillion dollar facility at Dearborn, Michigan, which houses under one roof all of Ford's rapidly expanding engineering computer activities. Ford's North American Automotive Operations has taken advantage of computer programs supplied by NASA's Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC maintains a large library of programs developed by NASA and other technology-generating government agencies. They are made available to industry at a fraction of their original cost, saving industry the time and expense of developing entirely new programs.

Ford has made particular use of the NASTRAN® (NASA Structural Analysis) program, which electronically analyzes a computerized design and predicts its reaction to many different conditions of stress and strain. For example, Ford used NASTRAN to analyze the combined torsional, bending and axial loading conditions of a new automobile (above left); as a result of the analytical solutions, fewer prototypes had to be built and tested, with resultant reduction of development time and cost. Company engineers have used NASTRAN for such other jobs as auto frame buckling and stress analysis (computer representation top right); defining high stress points and vibrational characteristics of sheet metal components in passenger car and truck bodies; and static analyses of various suspension components.

Ford's Turbine Engineering Department has made use of other COSMIC programs in analyzing designs of metal and ceramic turbines intended for automotive applications. Example: engineers applied a COSMIC Fortran program to analysis of a cast aluminum turbine (above). A computer representation of the stress on a turbine blade is shown below.

® COSMIC and NASTRAN are registered trademarks of the National Aeronautics and Space Administration.



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Space Coatings for Industry

A line of lubricants and protective coatings derived from space technology heads a sampling of spinoff products and processes contributing to industrial efficiency and productivity

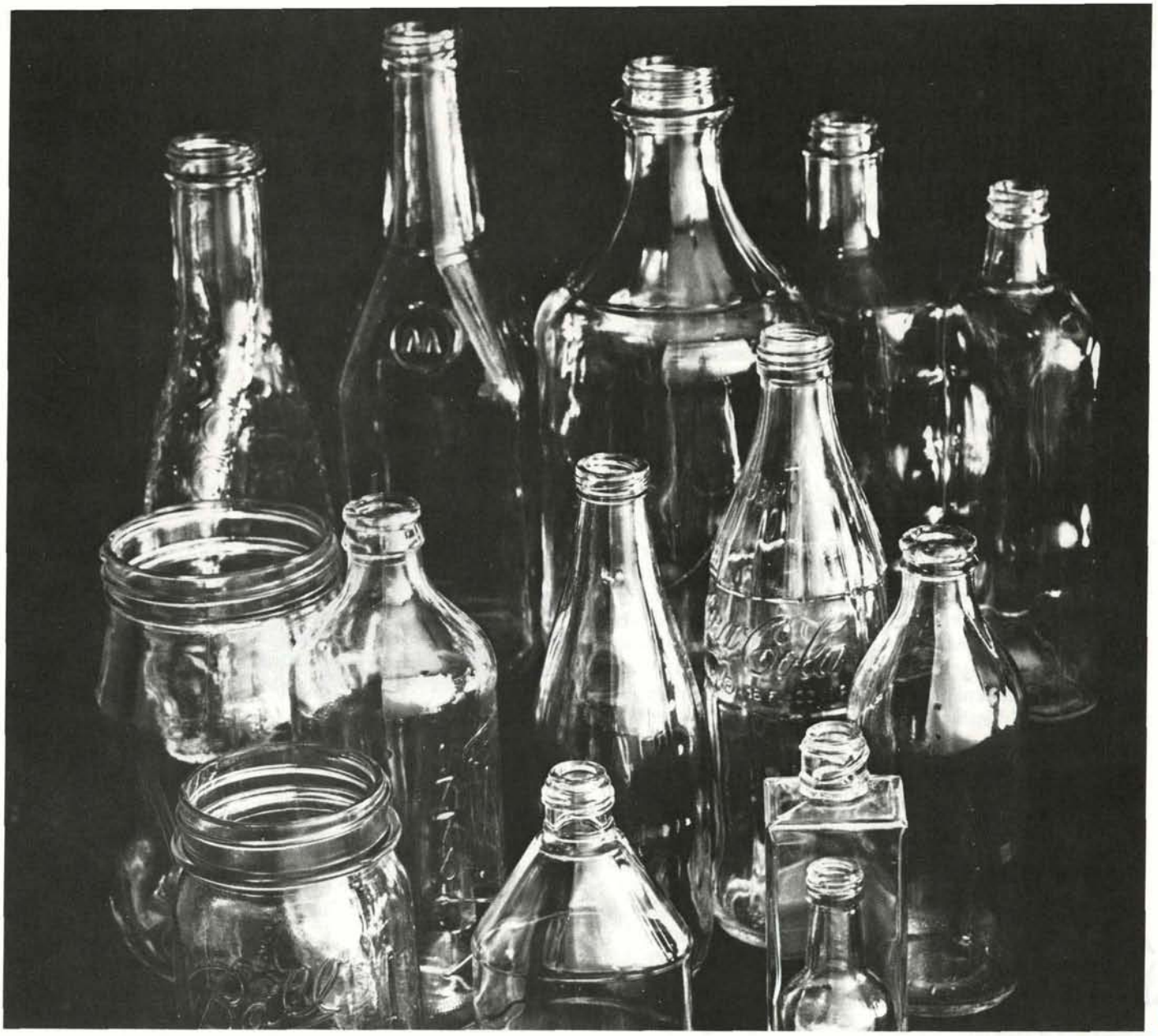
A spinoff coating helps control "outgassing"—material burnoff—in solar collection systems, thereby preventing loss of heat-collecting efficiency. The coating is used on the Sunpump Solar Energy System shown, which is produced by Entropy Ltd., Boulder, Colorado.

In the early 1960s, when space flight was in its infancy, NASA experienced a problem in developing a Sun-study spacecraft known as the Orbiting Solar Observatory (OSO). NASA's contractor for OSO—Ball Aerospace Systems Division, Boulder, Colorado—found that conventional lubricating materials, developed for Earth conditions, were unsuitable for use on satellite moving parts and instruments that would be exposed to the vacuum of space for months and even years.

So, to meet OSO requirements, Ball Aerospace first had to develop entirely new space lubrication technologies. From extensive company research on the requisite properties of spacecraft materials, there emerged a new family of dry lubricants specifically designed for long life in space, together with processes for applying them to spacecraft components in microscopically thin coatings. The lubricants worked successfully on seven OSO flights over the span of a decade and attracted the attention of other contractors, who became Ball customers.

At the same time, the company found that the lubricating properties needed for long service life in orbit offered advantages in many non-aerospace applications and began to explore those avenues. Over the years, the company acquired further space coating experience as builder of 10 satellites and participant in a number of other space programs. This work, along with parallel company research and development toward commercial applications, established Ball as a leader in the field of lubricants and protective coatings for both aerospace and non-aerospace use. The company has developed several hundred variations of the original OSO technology, generally designed to improve the quality and useful life of a wide range of products, or to improve the efficiency of the industrial processes by which such products are manufactured.

An example involves an old problem in glass container manufacturing. Hot glass sometimes sticks as it forms in the metal mold; to prevent that, a "release coating" must be applied to the mold. In the common procedure, an operator reaches into the high speed equipment periodically to swab coating material onto the hot mold, a method that subjects the operator to hazard; additionally, the swabbing material



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Applied to metal molds used in manufacture of glass containers such as those pictured, a coating derived from space technology reduces adhesion between the molds and hot glass, contributing to improved process efficiency and fewer container rejects.

generally used generates copious fumes, which must be limited for health reasons.

In a variation of the space-derived technology, Ball Aerospace developed a bonded release coating to ease the problem. Marketed under the trade name HIPAK™, the coating is sprayed onto the molds and heat-cured before the molds are used. The HIPAK coating reduces adhesion between glass and molds, thereby reducing the number of hand-swabbing operations required. It offers increased operator safety, fewer container rejects and less exposure to fumes for those working near the machinery.

Another example stems from Ball's work on the Apollo Telescope Mount for NASA's Skylab program, for which the company developed special coating materials to prevent "outgassing"—chemical breakdown of materials which causes contamination of adjacent surfaces. Ball Aerospace is applying this technology to solar energy collection systems. Some materials outgas rapidly at the high temperatures in solar collectors; outgassing can contaminate the transparent covers of the collectors and reduce the system's ability to capture and transfer solar heat. By proper selection of coating materials—along with cleaning procedures, design, handling and storage techniques—outgassing can be controlled to help maintain maximum solar collector efficiency.

Other examples of Ball materials technology applied in non-aerospace usage include a spray-on preservative coating for protecting the sound fidelity of phonograph records; a coating for motion picture film designed to reduce film breakage; a lubricant used by meat processing companies to solve machinery breakdown problems experienced in "cold room" conditions; and a method of treating electric motor and generator brushes which sharply reduces brush wear rates.

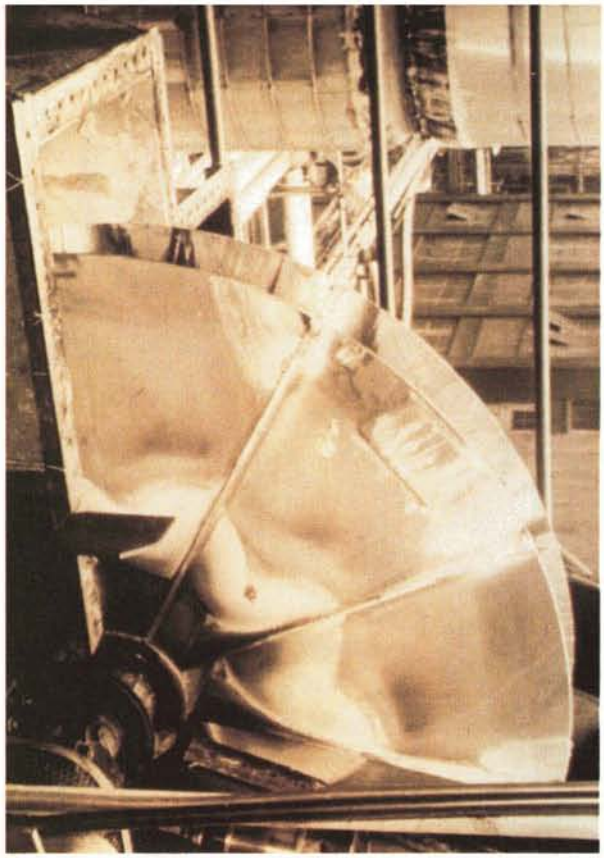
™HIPAK is a trademark of Ball Corporation.

Equipment Failure Analysis

The NASA-developed computer program NASTRAN® (NASA Structural Analysis) is widely used in industry as an aid in designing new systems. Available to industry through NASA's Computer Software Management and Information Center (COSMIC)®, located at the University of Georgia, NASTRAN electronically analyzes a design and predicts how it will stand up under various stresses and strains. One company—Tennessee Eastman Company, Kingsport, Tennessee—is employing NASTRAN in somewhat different fashion; as a failure analysis tool for production equipment used to turn out the company's line of fibers, chemicals and plastics.

Tennessee Eastman—part of the Eastman Chemicals Division of Eastman Kodak Company—uses NASTRAN to minimize lost production by pinpointing the causes of equipment failures and preventing recurrences. An example of the program's utility involves the large centrifugal fan shown at right, which developed cracks. Analysis showed that damage was occurring during start-ups and shutdowns, information that prompted redesign of the fan. Identification of the trouble brought a recommendation that the fan be allowed to run continuously, permitting uninterrupted production until the new fan could be built.

In another application, NASTRAN was used to predict difficulties that might be encountered in adding a planned 50-foot extension to a 100-foot stack (below). Analysis showed that the extension would generate unacceptable loads on the foundation and cause troublesome stack vibrations during high velocity winds. NASTRAN's investigation thus prevented installation of a potentially dangerous



structure whose failure could have caused significant production losses. Tennessee Eastman has made extensive use of NASTRAN, both as a failure analysis tool and as an aid to redesigning production hardware. The company reports that NASTRAN analyses have eliminated many initial and repeated failures, providing substantial reduction in maintenance costs and lost production.

®NASTRAN and COSMIC are registered trademarks of the National Aeronautics and Space Administration.

Automatic Design System

In electronics, an integrated circuit is one wherein the separate functions of several components—transistors, for example—are performed within a single small piece of semiconducting material. A modern advance is the large-scale integrated (LSI) circuit, or array, which performs several thousand functions within a semiconducting chip typically smaller than a fingernail. Because of heavy demand for LSI arrays used in sophisticated aerospace electronic systems, NASA initiated a research project—conducted by Marshall Space Flight Center—to reduce the lengthy time and

the high cost involved in designing complex LSIs. Under contract to Marshall, RCA Corporation, Camden, New Jersey developed an automatic design technique whereby a computerized system stores standard circuit cells, retrieves them from its memory on request, then positions and interconnects them to form an LSI array.

RCA has applied the results of the NASA-sponsored research in producing LSIs for its own product line—communications equipment, for example—and for use in products manufactured by other companies, such as the automobile engine analyzer pictured; developed by Chrysler Corporation's Huntsville, Alabama, Division, the analyzer employs an LSI array to diagnose and solve problems for as many as 60 engine functions in less than four minutes. RCA's computerized system enables design in one to three months of LSIs which once required six to 12 months, and there has been an attendant reduction in design costs.

Safe Handling Practices

The woman pictured below, an employee of Compugraphic Corporation, Wilmington, Massachusetts, is assembling a printed circuit board to be incorporated in phototypesetting equipment manufactured by the company. The black wrist band she is wearing is not an ornament; made of Velostat® conductive material, it creates a static-free environment at the work bench which reduces the chance of damage to the microelectronic chips on the circuit board. NASA technology contributed to this and other product-enhancing measures instituted by Compugraphic.

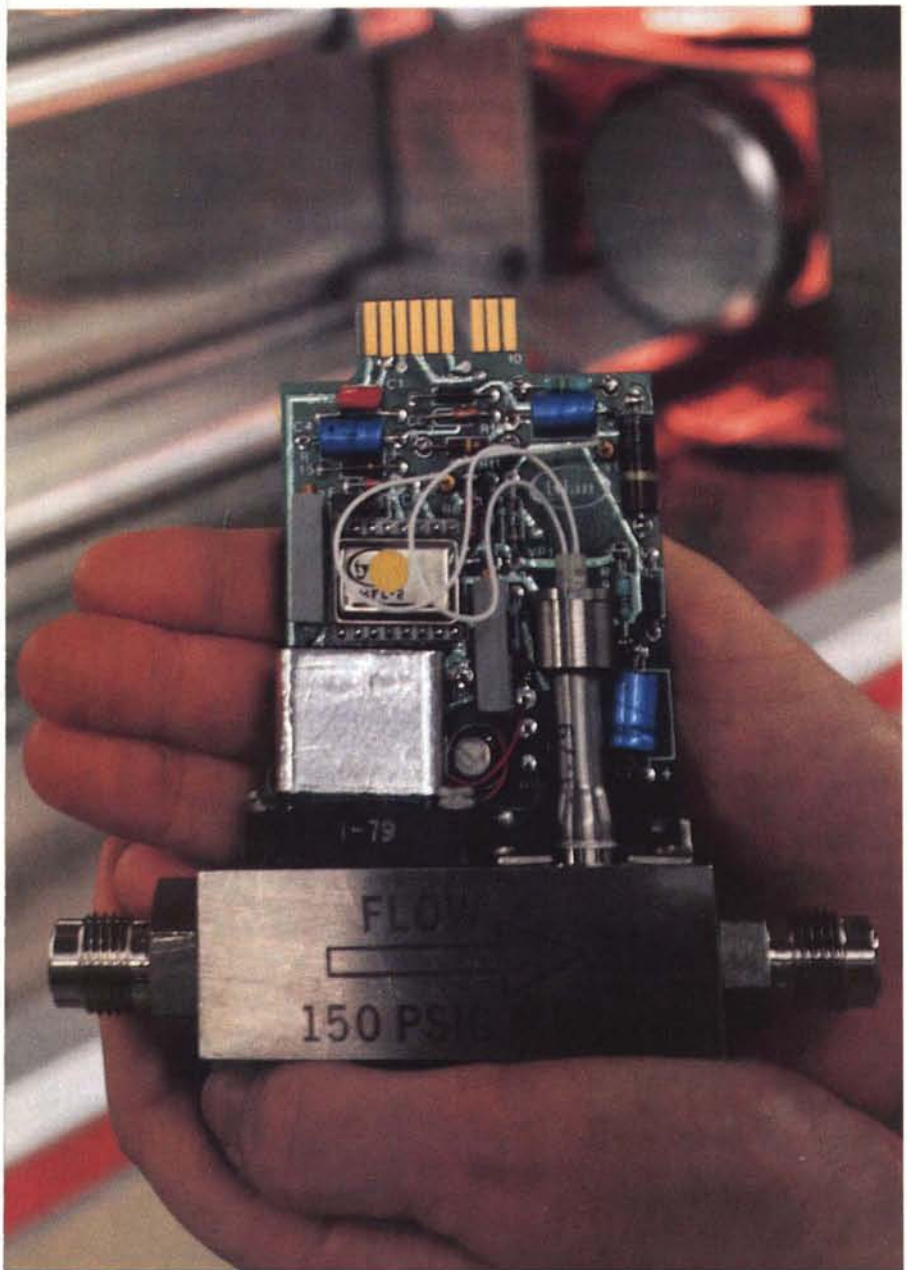
In 1977, Compugraphic was experiencing an unacceptable failure rate on microelectronic chips. Company engineers suspected that static electricity was causing the trouble because some electronic components are highly susceptible to damage by electrostatic charge. From a NASA Tech Brief, Compugraphic learned that Rockwell International, under contract to Johnson Space Center, had prepared a comprehensive report on safe handling practices for electronic components. On request, NASA provided the company a technical support package detailing some 50 safe handling procedures affecting workers, work areas, equipment and packaging materials. Compugraphic engineers made a survey of how the company's handling of microelectronic chips compared with NASA-recommended practices. Where poor practices were discovered, re-education of employees and other corrective measures were undertaken. Through use of the NASA technology, Compugraphic achieved a significant reduction of chip losses.

® Velostat is a registered trademark of 3M Company.

Gas Flow Controller

A critical item of equipment on Apollo spacecraft was a device used to measure the flow of oxygen in the spacecraft's life support system. Extremely accurate flow measurement was necessary to detect cabin leakage, to make sure that the oxygen supply was not consumed too rapidly, and to help the astronauts breathe normally. The measuring device, called the Mass Flowmeter, was developed by Tylan Corporation, Torrance, California.

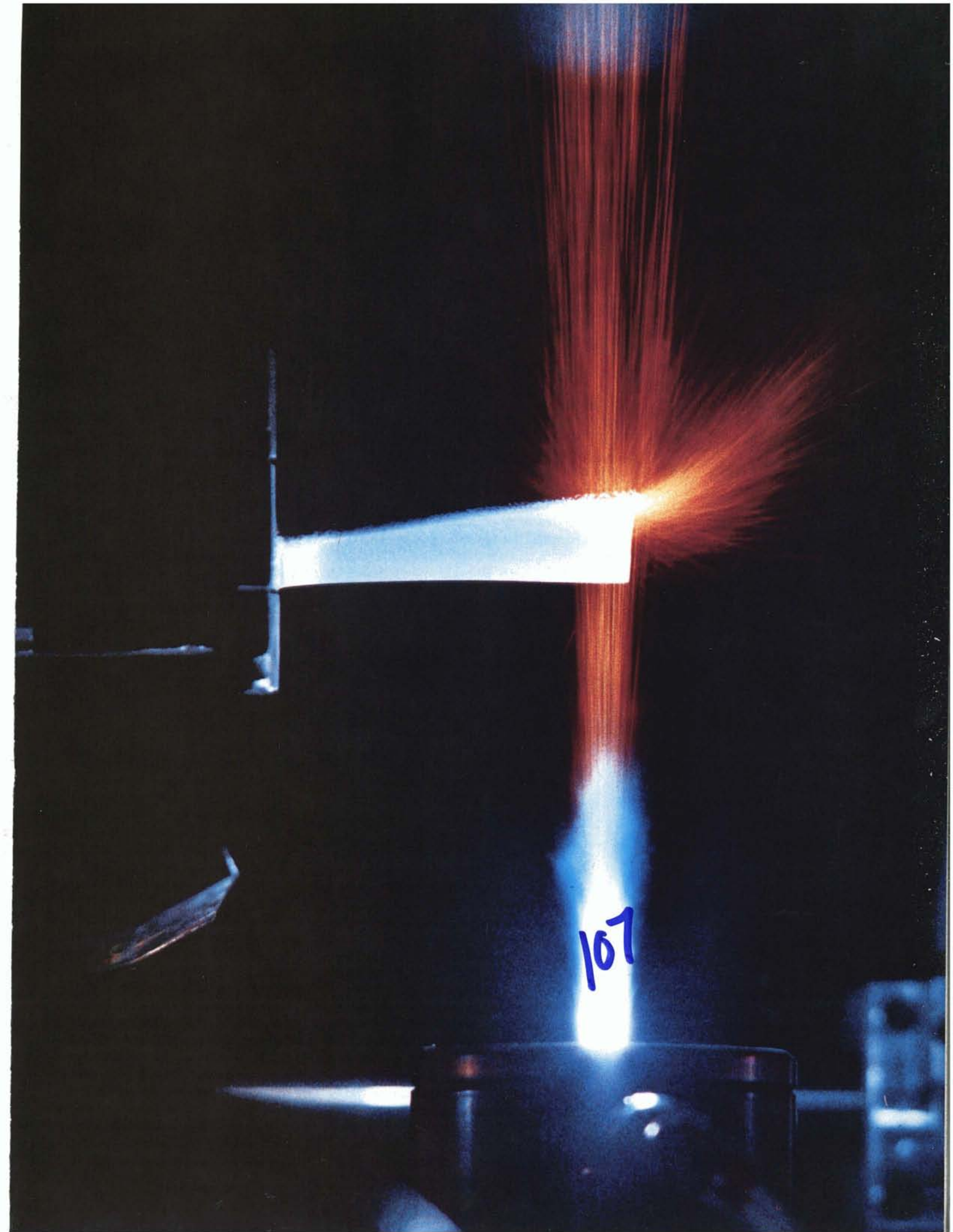
The technology developed for the Apollo flowmeter provided a basis for a commercial product now widely used in the semiconductor industry, the Tylan Mass Flow Controller pictured below. Its major application is accurate control of reactive gases—such as hydrogen, phosphine and silane—as they are diffused at extremely high temperatures into silicon wafers. The wafers are ultimately cut up into integrated circuits, or "chips," for electronic products. The precise process control afforded by the Mass Flow Controller makes it possible to produce circuit chips of greater performance at lower cost.



Plasma Spray System

NASA's Lewis Research Center is conducting research on "thermal barrier" coatings designed to improve aircraft turbine engine efficiency and reduce fuel consumption. These coatings, applied to turbine blades, combustors and other engine parts, act as insulators to protect the parts from corrosion in the extremely hot environment. The protection thus afforded allows increasing the operating temperature of an engine by several hundred degrees, a means of increasing overall engine efficiency. The technology also has applicability to utility and industrial gas turbines, and a Lewis contractor—TRW Inc.'s Materials Technology, Cleveland, Ohio—has invented an important system for applying the coatings to either aircraft or non-aerospace turbines.

In the photo at right, the computer-aided, fully-automatic TRW system is spraying a very hot plasma onto a turbine blade. Composed of gas into which metallic and ceramic powders have been injected, the plasma forms a two-layer coating which insulates the blade. A critical part of the operation is controlling the thickness of the deposit, which is measured in thousandths of an inch. This is accomplished by an optical detector which illuminates spots at various locations on the blade and determines thicknesses by measuring the light reflections. The optical sensor monitors the spraying process until the precise coating thickness and thickness profile are attained, then the computer halts the spraying. NASA has granted TRW a waiver of title to the invention, allowing the company to market it commercially.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Space Technology for Palate Surgery

Representative of spinoff innovations in the field of health and medicine is a new aid for treatment of children born with head and facial defects

In South Miami, Florida, Dr. Samuel Berkowitz is conducting research in an inconspicuous but important area of medicine. An orthodontist who also has a degree in anatomy, Dr. Berkowitz is exploring ways to improve care and treatment of infants born with abnormalities of the head and face, most commonly the condition known as cleft palate. He is aided by a new research tool: a NASA-designed instrument called the "optical profilometer," a device based on technology originally developed for the camera system of NASA's Mars-viewing Viking spacecraft.

Dr. Berkowitz is Associate Clinical Professor of Pediatrics and Director of the Cranio-Facial Anomalies Program of Mailman Center for Child Development, part of the University of Miami School of Medicine; the university—along with Mead Johnson & Company, Evansville, Indiana—supports his research.

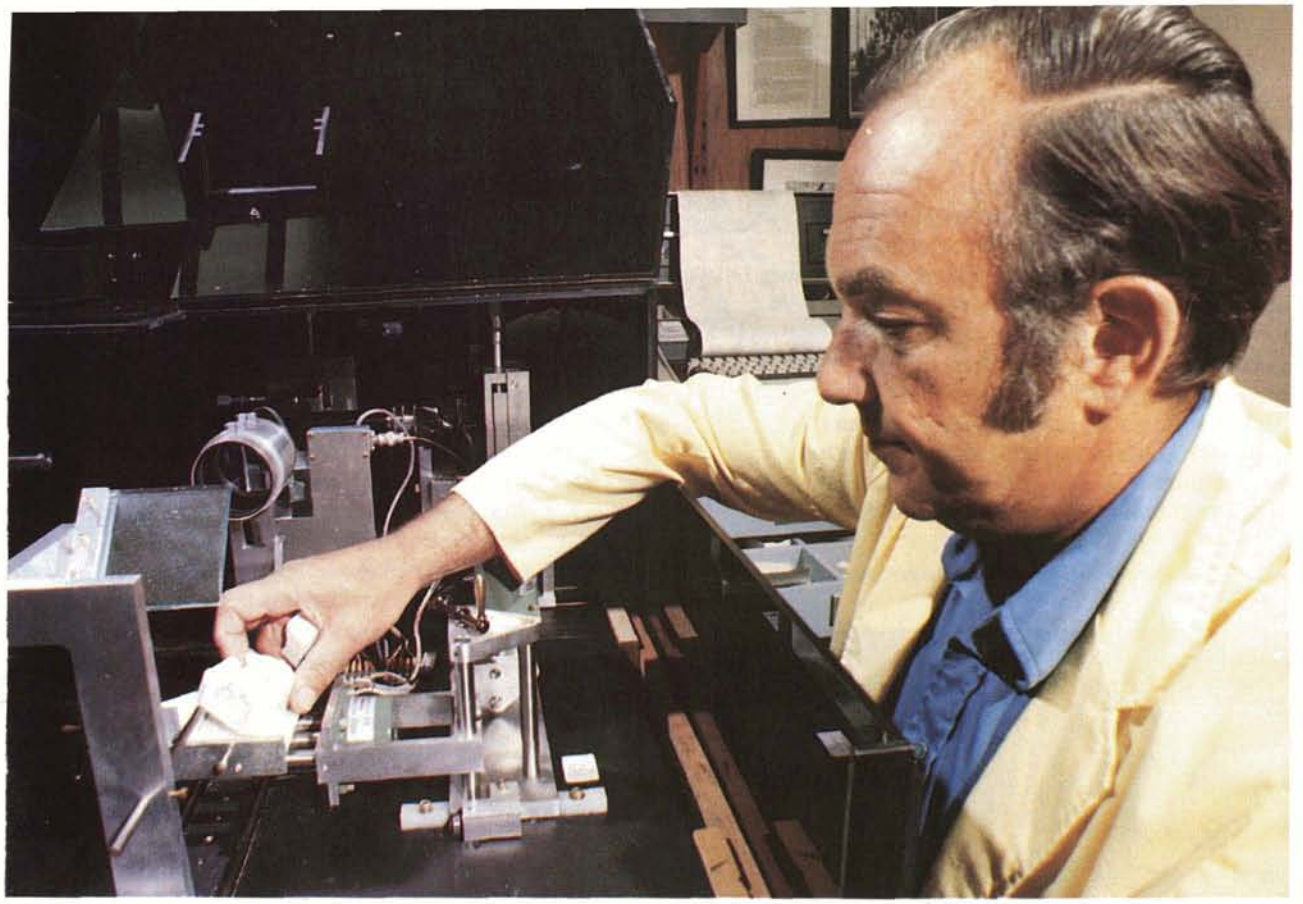
Dr. Berkowitz has worked on more than a thousand cases involving defects of the head and face, especially cleft palate, which is characterized by a fissure in the roof of the mouth. This defect causes facial deformity which may impair a child's psychological and social development and can also affect speech, sight and hearing. Treatment involves reconstruction of the palate by a series of surgical operations, starting shortly after birth and continuing over a lengthy period.

In planning surgery, cranio-facial specialists make repeated casts of the palate, initially during the patient's newborn period, later at various stages of treatment. Each cast is measured visually and photographically. By comparing successive casts, the surgical team notes the changes which have resulted both from surgery and from the patient's normal growth. Thus, cast analyses are, in effect, progress reports which provide information for determining the next surgical steps.

However, measuring the casts by conventional methods and comparing the irregular contours with previous casts is a difficult task whose efficacy depends to considerable degree on subjective judgments by surgeons. Dr. Berkowitz sought a more precise, objective, mathematical system of measurement. At the suggestion of a University of Miami colleague, he queried the NASA Biomedical Application Team at Research Triangle Institute (RTI), North Carolina, whose job it is to seek solutions to medical problems by adapting appropriate NASA technology to the need.

RTI conducted a technology search and found a possible answer in the optical profilometer developed by Langley Research Center to obtain three-dimensional photos of Mars, showing the height or depth of a planetary feature as well as its length and width. The three-dimensional capability was exactly what was needed for precise palate cast measurement, but further development was required to convert the profilometer to a medical research tool. With guidance from Dr. Berkowitz and three University of Miami assistants, Langley Research Center undertook the modification.

As a palate analysis aid, the optical profilometer electronically "reads" the contours of the cast, obtaining exact measurements by detecting minute differences in the intensity of a light



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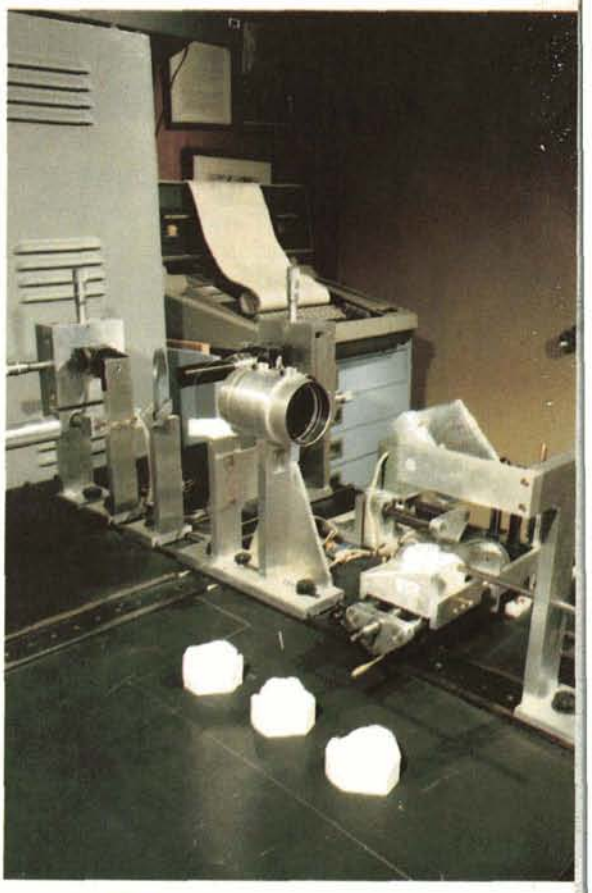
Dr. Samuel Berkowitz, a cranio-facial specialist at the University of Miami School of Medicine, is using a spinoff device called the "optical profilometer" as an aid to surgical treatment of cleft palate.

beam reflected off the cast. The information thus acquired is computer processed and delivered to the surgical team as a printed readout which amounts to a mathematical, three-dimensional "relief map" of the palate cast.

Dr. Berkowitz feels that the electronic profiling method of measuring casts will eventually replace the subjective observations now being made by surgeons. In addition to providing more accurate measurements, the optical profilometer has potential for significantly reducing the costs of analyzing palate casts. Perhaps more importantly, it permits cranio-facial specialists to maintain computerized records of procedures and results for reference in future work.

Taking advantage of this capability of the electronic system, Dr. Berkowitz has started to build a data bank detailing the surgical histories of a great many successfully treated cleft palate cases. As a first step, he is using the profilometer to plot his own large library of casts, representing more than 18 years of data gathering. Ten cranio-facial centers in the U.S. and abroad have agreed to contribute their data to the project.

Dr. Berkowitz believes that quantitative analysis made possible by the data bank will prove invaluable in improving treatment of cleft palate. Study of prior, successful corrections will enable a surgeon to plan a full course of treatment starting at the newborn period, matching surgical procedures to the changing form and size of the cleft palate.



The optical profilometer shown provides more accurate measurements of cleft palate casts than has heretofore been possible, enabling better planning of corrective surgery. In this photo, the lens-like instrument (center) is electronically scanning a palate cast, precisely measuring its irregular contours by detecting minute differences in the intensity of a light beam reflected off the cast. The readings are computer processed and delivered to the surgeon by the teleprinter in the background.

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Programmable Pacemaker

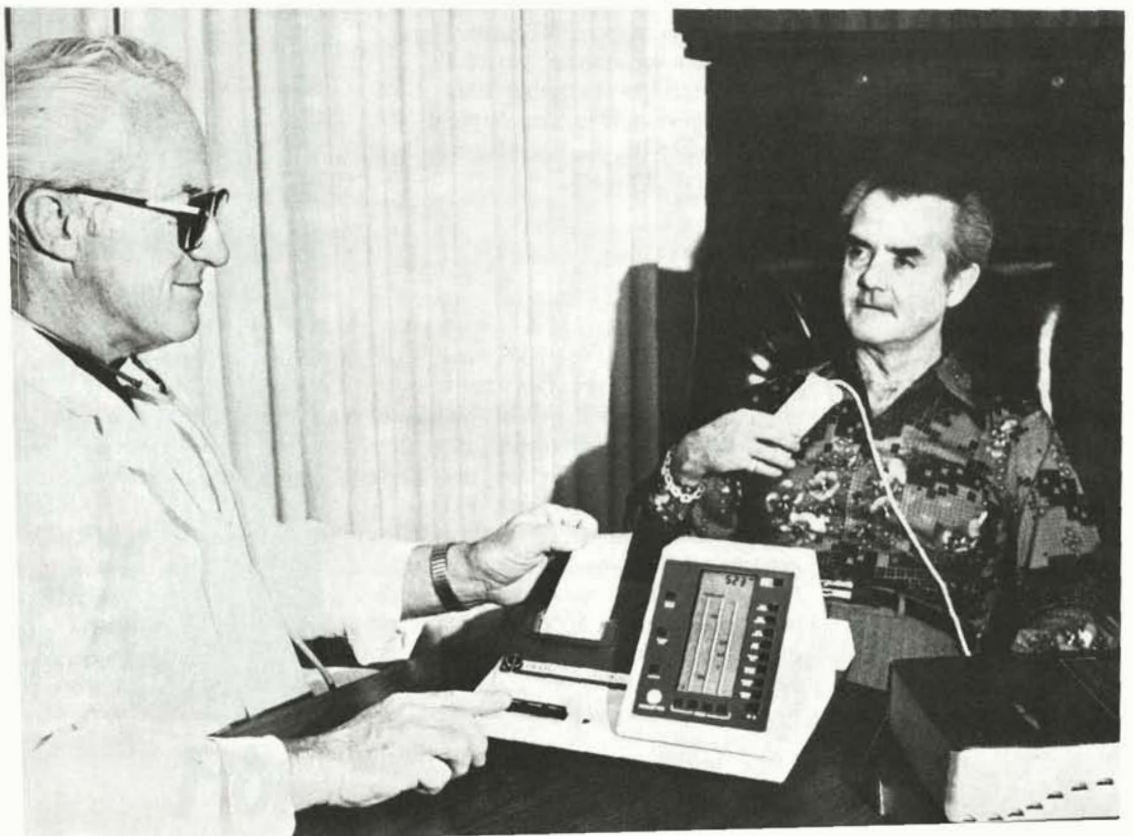
Pacesetter Systems, Inc., Sylmar, California, manufacturer of heart pacemakers, introduced in 1979 an advanced cardiac pacing system which allows a physician to reprogram a patient's implanted pacer without surgery. Called Programalith®, the system has two-way communications capability, an important innovation in heart-assist devices. It incorporates a number of technologies based on those employed by NASA to send coded instructions or queries to unmanned satellites and to receive information from satellites.

The Programalith system, shown below, consists of the implantable pacemaker together with a physician's console containing the programmer and a data printer. Below, the physician is communicating with the patient's pacemaker by means of wireless telemetry signals transmitted through the communicating head held over the patient's chest.

Where earlier pacemakers deliver a fixed type of stimulus once implanted, the Programalith system enables surgery-free "fine-tuning" of the device to best suit the patient's needs, which may change over time with changes in physical condition. The system permits the physician to re-set as many as six different parameters—heart stimulating functions—of the pacemaker. He can, for example, send a message instructing the pacemaker to alter the heartbeat rate; he will get a return signal confirming that the rate has been changed as instructed. When reprogramming is completed, the system prints out a copy of the new settings for the patient's record.

As an aid to determining the effectiveness of the pacemaker itself, the two-way communications capability allows the physician to interrogate the device as to the status of its interaction with the heart. The pacemaker can be asked, for example, for information on the electrical resistance of the wires connected to the heart; the response tells the physician how effectively the heart is being paced and also warns of possible wire breaks or short circuits. Similarly, the physician can elicit information as to how much life remains in the pacemaker's lithium battery. One other safeguard is use of space technology known as pulse code modulation, which assures dependability because the pacemaker will accept only properly coded instructions and will not respond to false signals generated by electrical noise or other interference.

® Programalith is a registered trademark of Pacesetter Systems, Inc.



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Implantable Heart Aid

The latest of many spinoffs from miniaturized space circuitry is a tiny patient heart-assist device, implanted like the pacemaker, that could annually prevent thousands of deaths caused by the erratic heart action known as ventricular fibrillation. The fibrillating heart loses its ability to pump blood, a condition which causes death or permanent brain damage in a matter of minutes if not immediately corrected. The new device—called the AID™ implantable automatic pulse generator—monitors the heart continuously, recognizes the onset of ventricular fibrillation, and then delivers a corrective electrical shock. The AID pulse generator is, in effect, a miniaturized version of the defibrillator used by emergency squads and hospitals to restore rhythmic heartbeat after fibrillation, but it has the unique advantage of being permanently available to the patient at risk. Once implanted, it needs no specially trained personnel nor additional equipment. Shown above, the AID system consists of a micro-computer, a power source and two electrodes which sense heart activity.

After years of development and more than two years of animal and laboratory testing, the AID pulse generator is being clinically tested at Johns Hopkins University Hospital, Baltimore, Maryland. It was developed by Medrad Incorporated and Intec Systems, Inc., both of Pittsburgh, Pennsylvania, in conjunction with Drs. M. Mirowski and M. Mower of Sinai Hospital and Johns Hopkins University School of Medicine, both of Baltimore. With NASA funding, Johns Hopkins' Applied Physics Laboratory—an organization with extensive experience in applying space technology to design of implantable devices—conducted an independent evaluation to assure that the pulse generator was ready for trials in selected patients who have high risk of experiencing ventricular fibrillation.

Applied Physics Laboratory developed an associated system. Shown below, it includes an external recorder to be worn by AID patients and a physician's console to display the data stored by the recorder. This system provides a record of fibrillation occurrence and the ensuing defribillation, information important to the physician in prescribing further treatment.

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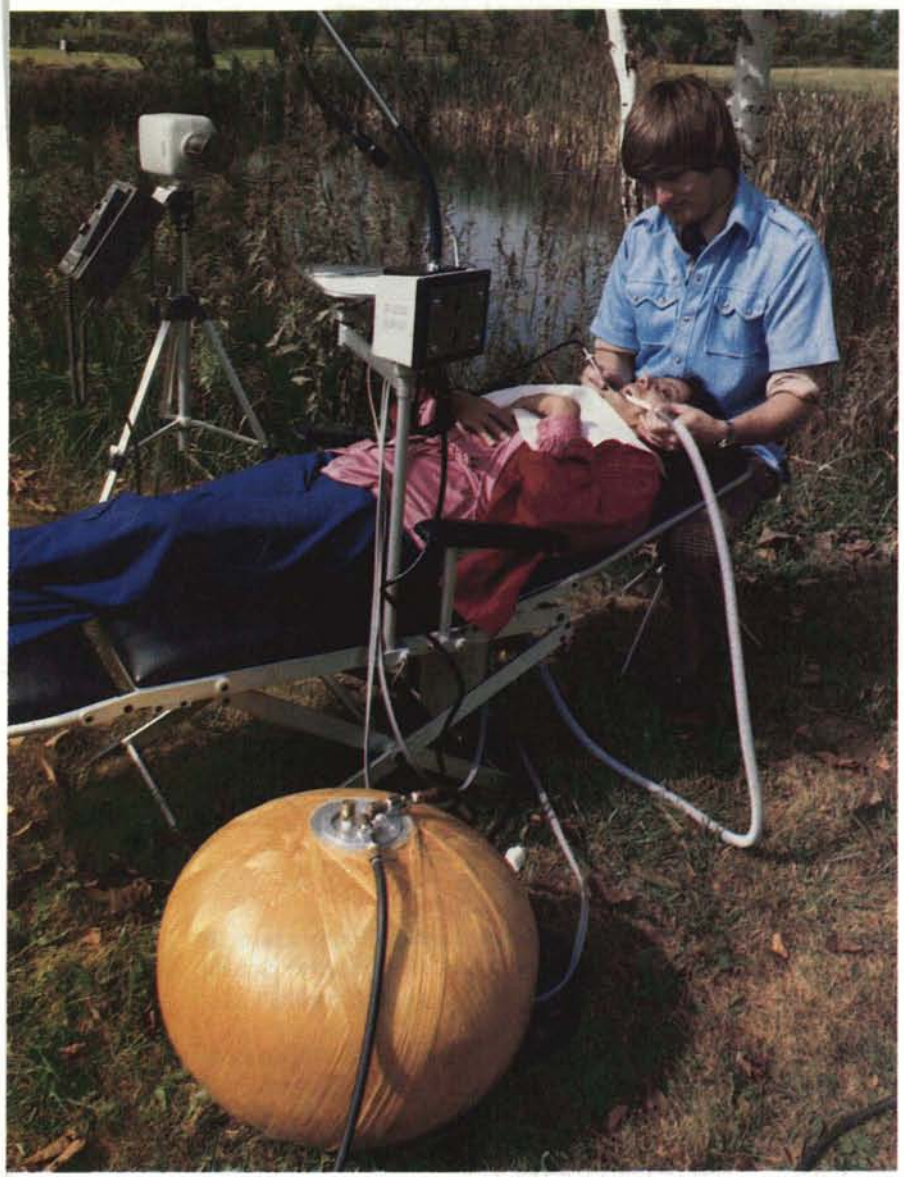
™ AID is a trademark of Medrad Incorporated.



Portable Dental System

At left, Dr. Robert Mallien of Marquette Medical Dental Team, Inc., Milwaukee, Wisconsin demonstrates his portable system for providing dental care to isolated communities. The system includes a patient's chair and dentist's stool, an x-ray machine and a power unit, all of which fold into compact packages. The large yellow "pumpkin" in the foreground is a collapsible compressed air tank, developed by Dr. Mallien in association with D&H Composites, Inc., New Berlin, Wisconsin and NASA's Biomedical Application Team (BAT) at the University of Wisconsin. The portable system has been used successfully in South America, where Dr. Mallien visits out-of-the-way communities with his backpackable system, and in American nursing homes; it is being evaluated for field dentistry by U.S. armed forces.

Using specifications drawn by Dr. Mallien, the Wisconsin BAT sought to apply NASA composite materials technology to development of the compressed air container. The BAT put Dr. Mallien in touch with D&H Composites, which specializes in filament-walled composite materials. The collapsible tank that emerged from the cooperative effort holds up to 38 liters of air yet weighs less than five pounds. Below, Dr. Mallien shows how it can be collapsed like a deflated balloon for easy transportability.

The tank design employs principles originally developed under NASA contract to meet a need for collapsible stow-away spacecraft tanks. The outer skin is made of aramid fibers, once used by NASA as reinforcing materials in filament-wound pressure vessels, such as rocket propellant tanks. The fibers are woven in flexible resin and wound around an inflated bladder which serves as the inner tube. The toughness and abrasion resistance of the composite fibers protects against punctures and insures leak-free operation. The tank is now commercially available from D&H Composites.

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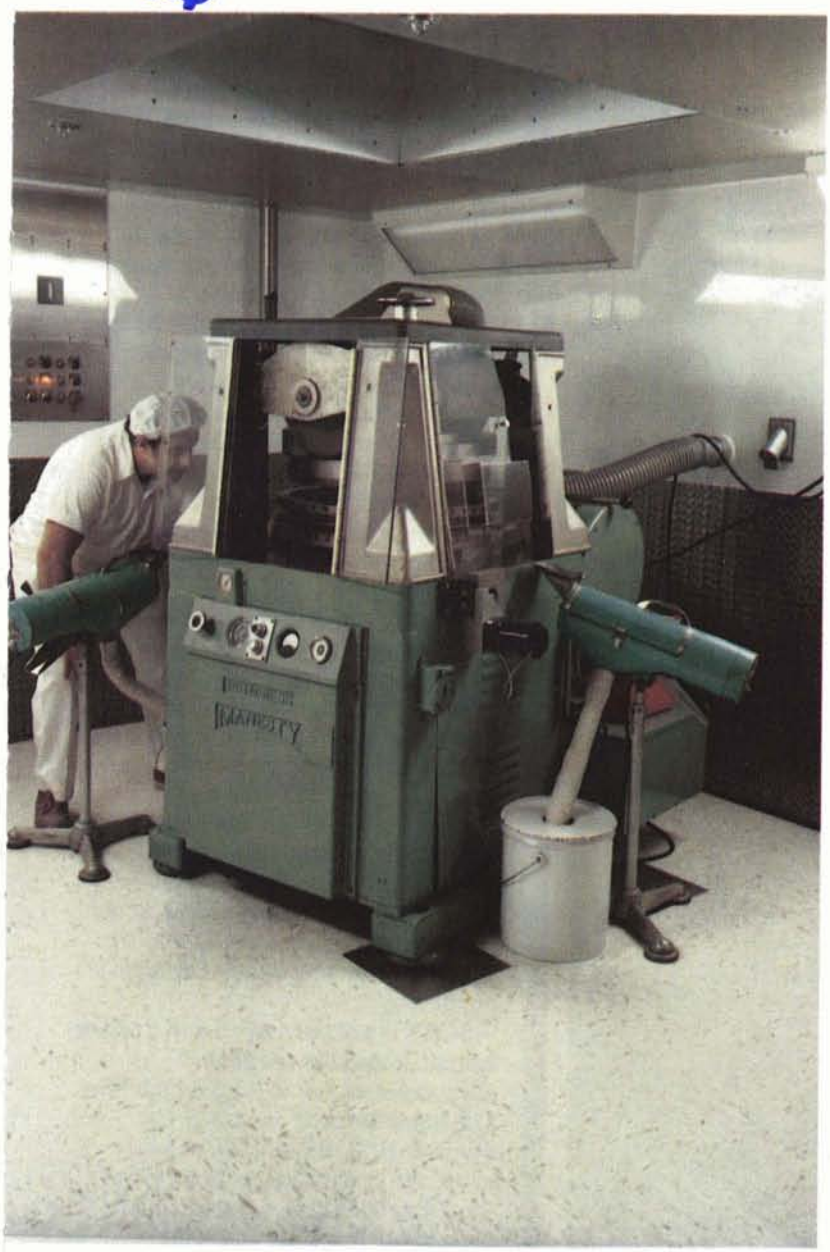
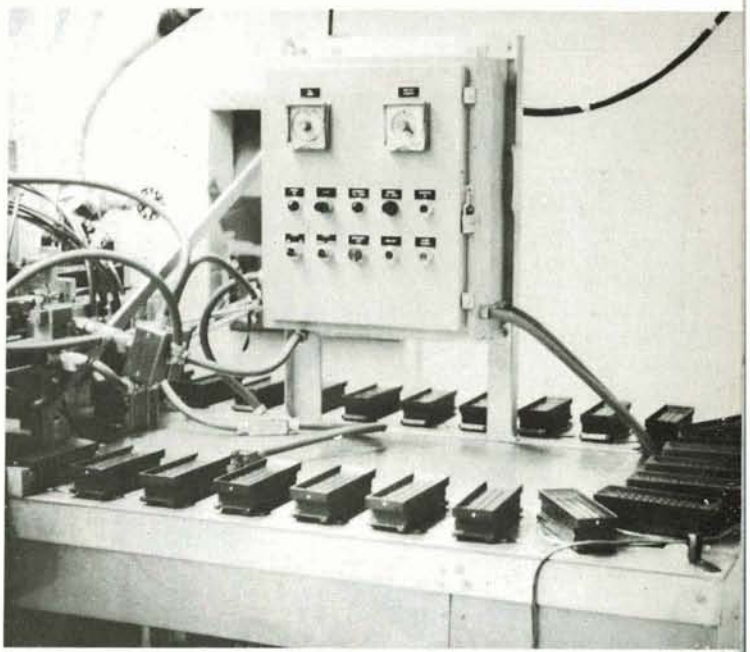
Protective Coatings

The machine pictured below is used in the pharmaceutical industry for high-speed pressing of pills and capsules. At right is an automatic system for molding glycerine suppositories. These machines are typical of many types of drug production and packaging equipment whose metal parts are treated with space spinoff coatings that promote general machine efficiency and contribute to compliance with stringent federal sanitation codes for pharmaceutical manufacture. Collectively known as "synergistic" coatings, these dry lubricants are bonded to a variety of metals to form an extremely hard, slippery surface with long-lasting self-lubrication. Essentially, they combine the best characteristics of other surface treatment materials and processes to produce an entirely new material superior to the metallic base to which they are applied.

The coatings offer multiple advantages: they cannot chip, peel or be rubbed off; they protect machine parts from corrosion and wear longer, lowering maintenance costs; and they reduce undesired heat caused by power-robbing friction. Synergistic coatings are especially useful in the drug industry because they do not react with or contaminate the substances being processed, they are easily cleaned, they prevent production interruptions and the hard, non-porous surface they create blocks formation of bacteria pockets.

Synergistic coatings resulted from the unique treatment requirements of new, lightweight metals—titanium and magnesium for instance—used in spacecraft construction for greater strength at reduced weight. Under NASA contract, General Magnaplate Corporation, Linden, New Jersey, developed a quality control program and handbook for Apollo spacecraft hardware. During this work, the company reported that conventional lubrication processes would not suffice for the relatively soft new metals, because the lubricants would boil away in the vacuum of space, leaving the surfaces unprotected. General Magnaplate subsequently developed processes for bonding various dry lubricants to space metals; not susceptible to boiloff, the lubricants prevented wear and abrasion and offered additional advantages in easier fabrication of spacecraft parts. They were applied to many components of such spacecraft as Apollo, Skylab, the Viking Mars Landers and the Space Shuttle.





Although the General Magnaplate family of coatings has special applicability in pharmaceutical manufacture, commercial use is much broader. The coatings are used on machinery employed in manufacture of several hundred household products, on food processing machinery, computers, turbines, pumps, valves and a great variety of other equipment. General Magnaplate's lengthy list of customers includes many of the nation's leading industrial firms and coating sales run into millions of dollars annually.

Silent Sentry

Representative of technology transfers in the field of public safety is a personal security system for summoning aid in emergencies

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Located in Watsonville, California, Independence Square is a hundred-unit apartment complex designed specifically to house physically handicapped and elderly tenants. Built and operated by the local Independence Square Housing Corporation, the complex has a number of architectural and functional provisions intended to improve the quality of life and promote self-sufficiency among its aged and handicapped clientele. One such feature is a NASA-developed personal security system that enables a resident to summon instant help in case of medical emergency or threatened violence.

Produced commercially by Sentry Products Inc., Santa Clara, California, the system is called SCAN, for Silent Communications Alarm Network. Its principal elements are a pen-shaped signaling device—"silent" because its ultrasonic alert signal is inaudible to the human ear—and a system of receivers interconnected with a constantly-monitored master console. At Independence Square and similar installations, it works this way:

The SCAN pen, which weighs only two ounces, is worn on a necklace or attached by a clip to the user's clothing. The person in trouble simply presses a clasp, releasing a hammer inside the pen which strikes an aluminum bar. The impact causes the bar to resonate like a tuning fork and emit the ultrasonic signal, which is detected by the nearest of many small receivers mounted in apartments, corridors, stairwells, elevators and carports.

The receiver converts the silent tone to electrical energy and triggers two simultaneous actions. The electric current lights a bulb on the receiver, acknowledging receipt of the call for help. At the same time, the alert is transmitted to the master console, setting off an audio alarm and activating a console light that indicates the location of the emergency. The console attendant initiates help action and also extinguishes the light at the victim's location, a signal that help is on the way.

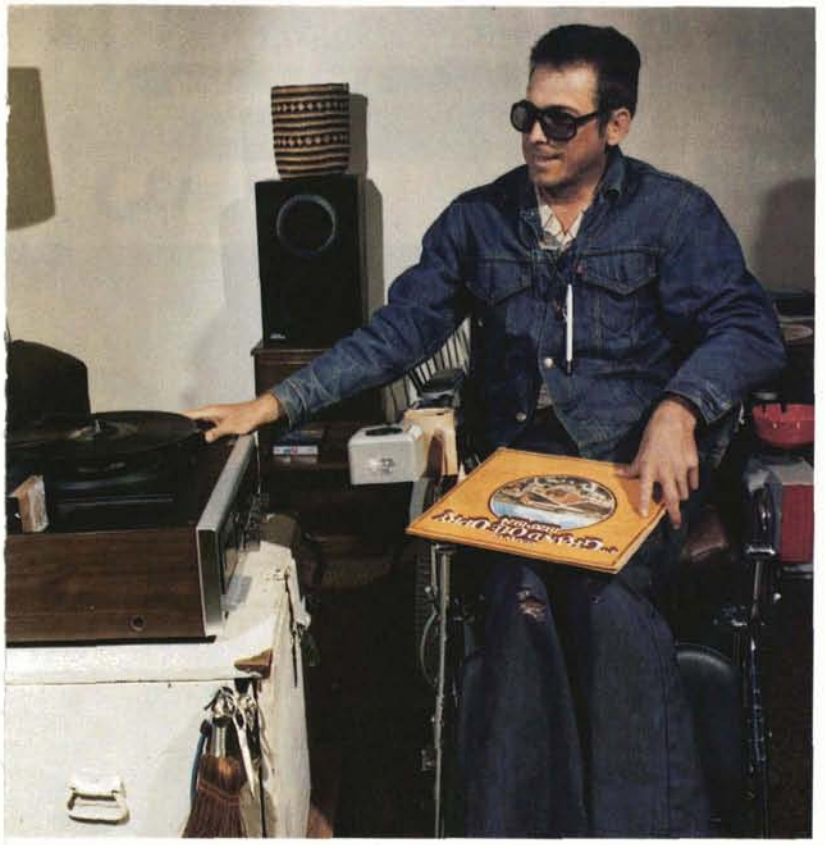
SCAN is not only an effective alarm system, it also has ancillary advantages. In use at housing facilities like Independence Square, it has psychological value: it offers peace of mind, the comforting assurance that, should an emergency arise, a simple press of the pen clasp will bring

assistance. In other applications—schools, for example—it acts as a deterrent to disruptive behavior.

It was an outbreak of violence in a school—John Kennedy High School, Sacramento, California—that triggered SCAN's development. Struggling to restore order, the school principal sought NASA's assistance in developing an alarm system. Since school violence was widespread in the U.S., NASA undertook the development as part of its Technology Utilization Program, one facet of which involves application of aerospace technology to solution of public sector problems.

In developing SCAN, NASA applied its electronics expertise in design of the receivers/master console segment of the system, but decided against electronics for the signaling pen in the interests of durability and maintenance; the pen has no batteries to replace nor electronic parts which might fail from the frequent jolts expected in a device constantly worn by the user. NASA combined ultrasonic transmission and space telemetry technologies to produce the simple, reliable and very durable pen that has only one moving part.

The first pilot test of the SCAN system was conducted in the Sacramento high school where the idea originated. A second experimental system was installed at Green Fair Towers, an apartment complex for the elderly in the same city. In both installations, SCAN demonstrated high reliability in the alarm function and a capability for almost zero maintenance. NASA subsequently licensed Sentry Products to manufacture and market the system, which is now in use in more than 40 major installations—apartments, schools, juvenile homes, correctional institutions, courthouses, hospitals, industrial facilities and public buildings.



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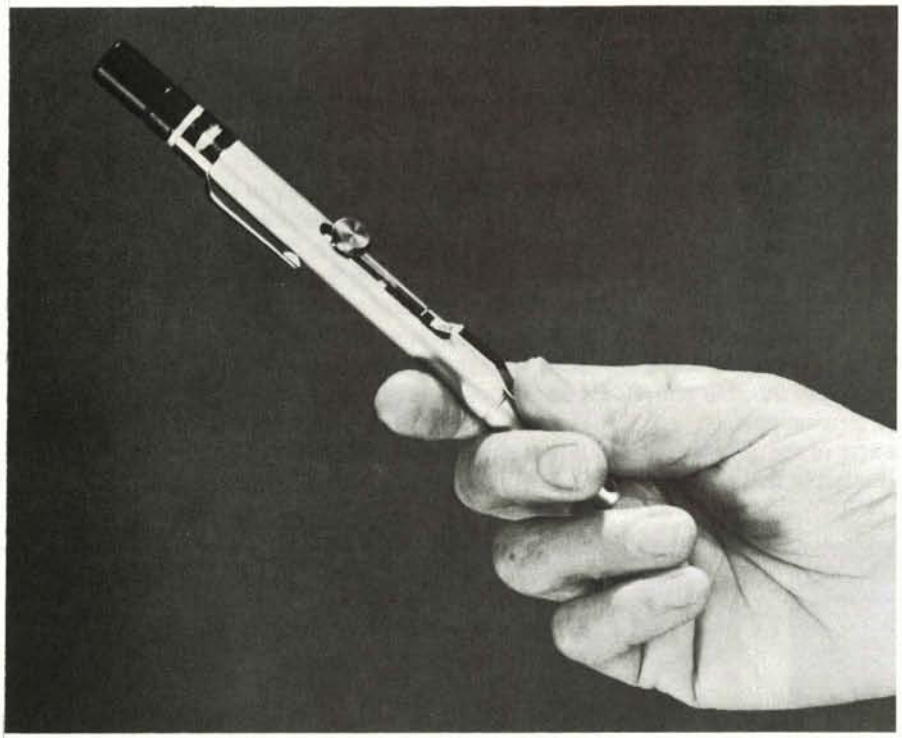
One of the major installations of the NASA-developed SCAN personal security system is at Independence Square, a California apartment complex for handicapped and elderly tenants. The residents pictured are wearing the SCAN signaling pen around their necks; in an emergency, they can summon assistance simply by pressing the pen clasp. The pen emits an ultrasonic signal which is transmitted to a constantly monitored master console (right). The lighted yellow button on the console indicates the location of the emergency.



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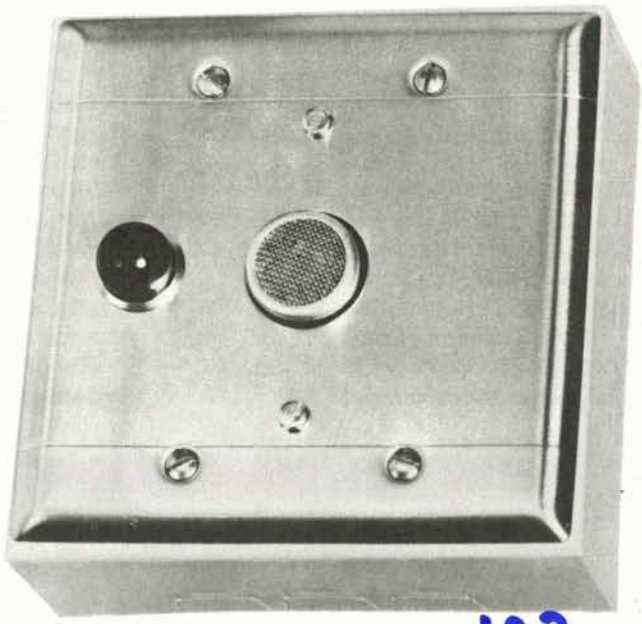
The SCAN pen shown weighs only two ounces, has no batteries or electronics and only one moving part. Its ultrasonic alert signal is picked up by a wall- or ceiling-mounted receiver (above right) and relayed to a master console such as the one pictured (right), located at Tubman II High School, Compton, California.



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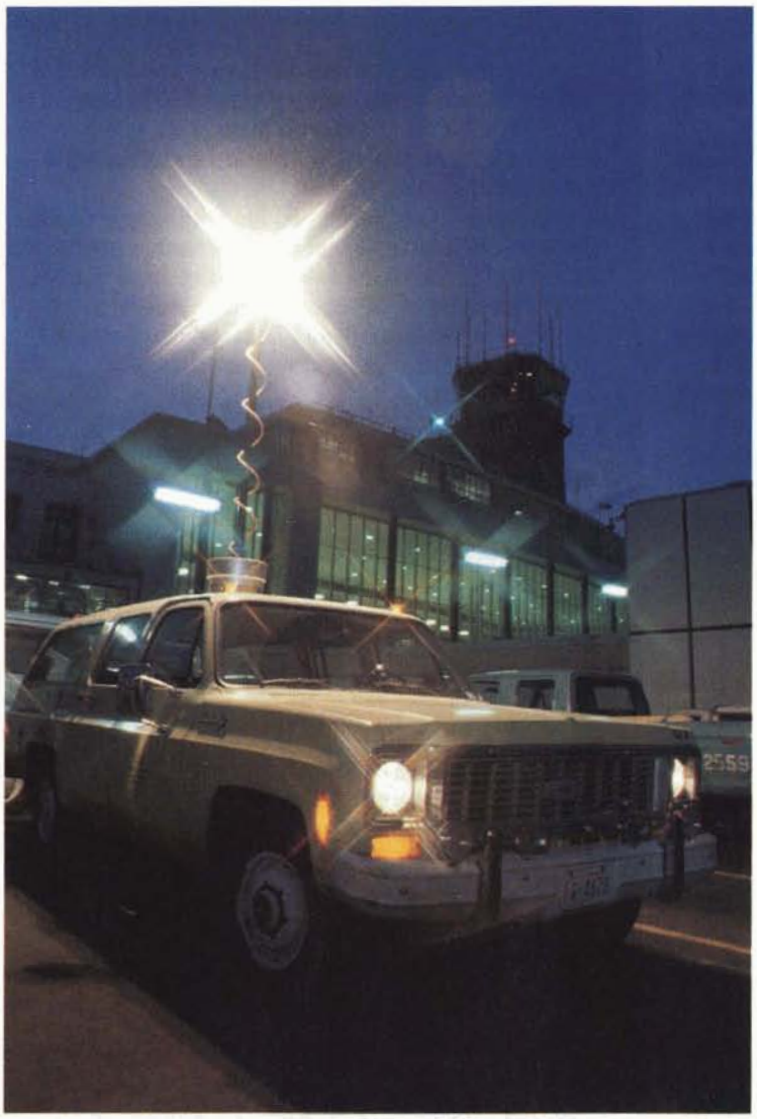
In this photo, a security officer at the San Mateo County Work Furlough Camp, Redwood City, California, is conducting a transmission test of his SCAN signaling pen.



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Emergency Lighting System

Shown in operation at Washington National Airport is Stem-Lite, an emergency lighting system widely used by fire, police, ambulance and other emergency service departments. The lights—four floodlights which provide 2,000 watts of daytime-equivalent visibility and a high-intensity flashing beacon—can be elevated 10 feet above the roof of an emergency vehicle by means of an extendible mast. The higher elevation expands the effective radius of the floodlights and increases the beacon's visibility to several miles, affording extra warning time to approaching traffic. When not in use, the lights can be retracted into the compact rooftop housing pictured below. In addition to the lights, the Stem-Lite system includes a generator, which can also serve to power such emergency equipment as pumps and drills, and a dashboard-mounted control panel for switching the lights and extending/retracting the mast.

The spinoff element of the system is the mast, originally developed by SPAR Aerospace of Canada to allow extension and retraction of antennas on NASA spacecraft, including Mercury, Gemini, Apollo and a number of unmanned satellites. Known as Bi-Stem, the mast is still manufactured for spacecraft use by Astro Research Corporation, a SPAR subsidiary located in Carpinteria, California. The device was licensed to Super Vacuum Manufacturing Company, Loveland, Colorado, which produces the Stem-Lite emergency lighting system.

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Fire Protection Materials

Plunging into Earth's atmosphere on return from space, the Apollo Command Module encountered friction temperatures as high as 5,000 degrees Fahrenheit on its exterior surfaces—yet the interior remained cool. The reason was the spacecraft's heat shield, coated with an "ablative" material applied to external surfaces. The material was allowed to burn and thereby dissipate heat energy; in addition, the burned material charred to form a protective coating which blocked heat penetration beyond the outer surface. The heat shield was designed and built by Avco Corporation, which subsequently—under a contract with Ames Research Center—applied the heat shield technology to the field of fire protection, specifically in development of fire-retardant paints and foams for aircraft and other applications.

Avco has also drawn upon its heat shield experience to develop a number of widely-accepted commercial fire protection materials, produced by Avco Specialty Materials Division, Lowell, Massachusetts. One such material is Chartek® 59 fireproofing, an intumescent epoxy coating specifically designed for outdoor use by industrial facilities dealing with highly flammable products—oil refineries and chemical plants, for example. The coating is applied—usually by spray gun as shown at right—to exterior structural steel, conduits, pipes and valves, offshore platforms and liquefied petroleum gas tanks, such as the one shown below. In the presence of fire, Chartek 59 fireproofing provides two types of protection: ablation, or dissipation of heat by burnoff, and "intumescence," or swelling; the coating swells to about five times its original size, forming a protective blanket of char which retards transfer of heat to the metal structure. This prevents loss of structural strength and possible collapse which would compound the fire-fighting problem. Chartek 59 fireproofing offers a bonus: because it is non-porous, it also serves as a superior anti-corrosion coating.

The technology developed for NASA provided a foundation for several other fire protection products: Fire-Flex® intumescent tape for protective wrapping of fuel lines, tubes and cables; Thermarest® foams for thermal insulation; and Flamarest® coatings, a line of intumescent paints for a broad variety of applications.

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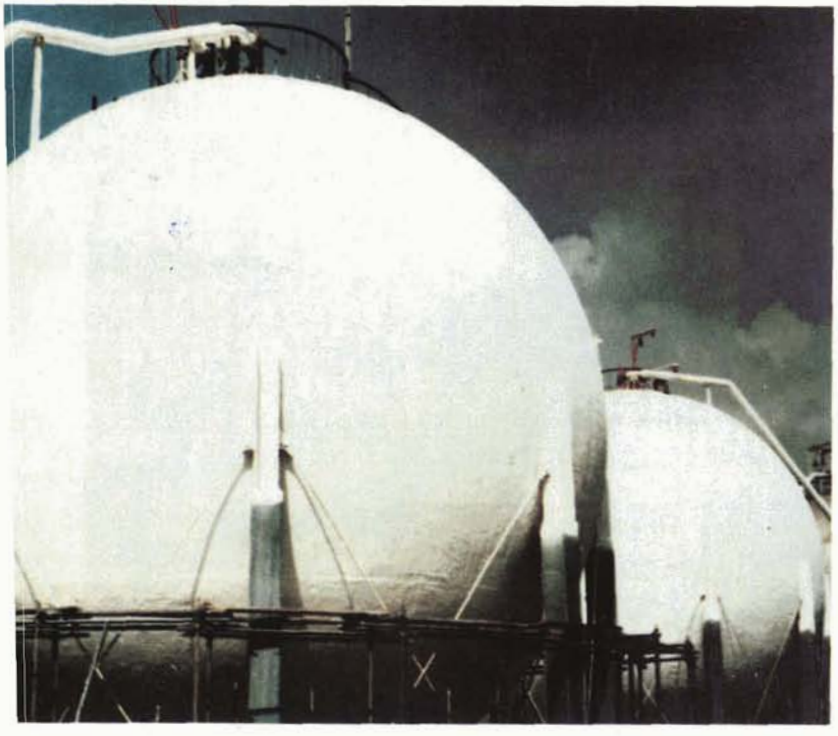

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Lightning Protection

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In the photo, an airplane's wingtip tank is being struck by simulated lightning in a test conducted by Lightning Technologies, Inc., Pittsfield, Massachusetts, a consulting firm specializing in design features to protect aircraft from the hazards of electrical phenomena. The firm's customers include several of the nation's leading manufacturers of private, business and commercial aircraft. Lightning simulations like the one pictured are employed to test the effectiveness of Lightning Technologies' protective measures.

Much of the technology employed by Lightning Technologies originated in NASA-sponsored studies. These studies, conducted with contractor assistance by Langley Research Center, Lewis Research Center and Dryden Flight Research Center, focused on the effects of lightning on aircraft structures, electrical systems and fuel tanks, and on means of protecting against hazardous effects. As an employee of General Electric Company's High Voltage Laboratory, a NASA contractor, J. Anderson Plumer acquired 12 years experience in lightning investigations. In 1977, he left GE to form Lightning Technologies, of which he is president. Plumer is thus an example of a personnel-type spinoff, wherein NASA technology is transferred to the private sector in the course of an occupational shift by a scientist or engineer once engaged in NASA research activity.


COAST GUARD

Firefighting Module 133 134

Shown undergoing test is a NASA-developed lightweight, portable firefighting module designed primarily for combating shipboard or dockside fires. At upper left, the unit is being tested on a derelict ship in Mobile Bay, Alabama. At left it is being used by the Miami (Florida) Fire Department aboard a surplus amphibious vehicle capable of reaching a fire location by either land or water routes. Now commercially available, the module—called Firefly—is manufactured by Aviation Power Supply, Inc., Burbank, California.

Beginning this year, Firefly will undergo a multi-year evaluation in demonstration tests and regular operational use at St. Louis, Missouri in a program jointly sponsored by NASA, the Maritime Administration and the U.S. Coast Guard. The aim of the program is to show the feasibility of reducing marine fire protection costs through emergency use of Firefly-equipped commercial tugs operating as auxiliary fireboats.

Originally developed by Marshall Space Flight Center for marine use by the Coast Guard, the module has other applications. It can be mounted on a light truck (above) for use by local fire departments, or it can be transported by helicopter (above right) to hard-to-reach fire scenes, for example, in forests, on high-rise buildings or on offshore oil rigs. It also has utility in nonfirefighting applications such as flood control or emergency pumping for municipal water supplies.

Completely self-contained in a compact package weighing less than 3,000 pounds, the Firefly can draw water from the sea, a river or other sources and pump up to 2,500 gallons a minute through two water "cannons." The two-stage pump, a derivative of liquid rocket engine pumps, was developed for NASA by Northern Research and Engineering Corporation (NREC), a division of Ingersoll-Rand; NREC also produces the pumps for the commercial version. Power for the pump is generated by an aerospace-type gas turbine built by Detroit Diesel Allison Division of General Motors Corporation. Aviation Power Supply, Inc., has teamed with NREC and Detroit Diesel to develop an advanced Firefly II capable of pumping 3,000 gallons a minute; the new unit is expected to go into production soon.

See So '83 p. 80
if someone wants
Licensing information
on Flat Conductor Cable

Innovation

Building Design

A cost-cutting flat cable system for building electrification leads a representative selection of technology transfers in the field of construction

The technician pictured is installing Flat Conductor Cable (FCC) beneath a flooring of carpet tiles. Long used in aircraft and spacecraft, FCC is now approved for installation in office buildings, offering cost savings in simplified building design, reduced installation time and ease of alteration.

Aircraft and spacecraft are marvels of compactness. They have to be. Equipment size and weight must be tightly controlled, even in the smallest components, or the craft's performance will suffer. To negate that possibility, aerospace designers have developed a multitude of ingenious weight-shaving, space-saving measures.

One such measure is the use of extremely thin flat wire—technically known as Flat Conductor Cable (FCC)—instead of the relatively thick and protrusive round cable. That doesn't sound like much of a saving until you consider the extraordinary amount of cable in a complex aerospace vehicle; the Apollo Command Module, for example, had 15 miles of wiring—and that was only one element of the three-segment spacecraft. So the cumulative gain FCC affords is of significant order.

Commercial buildings also have miles of wiring and FCC offers major advantages in design of building electrification systems. The big factor is that FCC, whose thickness approximates that of two business cards, can be mounted *on* walls and floors instead of *in* them; it can be installed beneath a carpet or along a baseboard, its essential sheathing designed to look like decor rather than plumbing. This makes possible elimination of the traditional ducting, under floors and elsewhere, necessary to accommodate conventional wiring; one study estimated that a ductless wiring system could reduce the construction cost of an office building by as much as 14 percent. And when electrification needs change, as they frequently do in commercial buildings, the surface-mounted FCC system is readily accessible. In short, FCC offers simplified building construction, reduced installation time and ease of alteration, all of which translate into substantial monetary savings.

More than a decade ago, NASA began considering ways to promote non-aerospace use of compact FCC systems. Under the Technology Utilization Program, intended to encourage secondary application of technology in the interests of national productivity, NASA funded a program in which Marshall Space Flight Center developed prototypes for several FCC applications, including a baseboard-mounted system.

Since industry participation was essential to large-scale adoption of FCC, NASA—in 1975—sponsored

formation of a consortium composed of a dozen firms engaged in electrical hardware and associated manufacturing activities. Using Marshall's early work as a departure point, the member companies pooled their resources and technology to develop complete FCC systems which encompass not only the cable but the sheathing, connectors, tools and other equipment necessary to facilitate FCC use by designers and builders.

Technology, however, was only part of the requirement. It was also necessary to secure acceptance of FCC in the National Electrical Code established by the National Fire Protection Association. NASA contracted with Technology+Economics, Inc., Cambridge, Massachusetts to focus attention on FCC safety and feasibility and to promote general acceptance of flat cable. This two-year effort resulted in a Tentative Interim Amendment to the National Electrical Code which allows use of FCC—so far only in commercial buildings.

Four members of the NASA-supported consortium are now actively marketing FCC systems. Western Electric Company, Princeton, New Jersey has developed two FCC systems, one to be installed beneath carpeting, the other inside a low-profile baseboard mounting. Similar systems are offered by two major electrical hardware firms: AMP, Inc., Winston-Salem, North Carolina and Thomas & Betts Company, Raritan, New Jersey. The Commercial Floor Systems Division of Collins & Aikman, New York, is marketing a modular carpet tile system, the only type of FCC floor covering approved by the National Electrical Code. The latter company describes the advantages of FCC:

"It requires no in-concrete cutting, access flooring or ceiling-to-floor utility poles. For the building owner, the cost savings can be $300-400 per desk; for the tenant, cost savings can range from $30 to $60 per installed or relocated desk, as compared with traditional under-floor or through-floor installations."

FCC has bonus value for designers of office arrangements. Elimination of ducts and other accommodations offers new latitude in designing airy, "open landscape" office layouts, which have become increasingly popular in recent years and may find wider acceptance under the impetus of the flat cable innovation.

Flat cable permits elimination of ducts and other accommodations traditionally required for building wiring systems, thus gives designers new latitude in planning attractive "open landscape" office layouts. The plan shown was designed by Vogel-Peterson Company, manufacturer of partitions.

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Liquefied Natural Gas Transfer

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The tanks and associated piping shown are parts of a system operated by Distrigas Corporation of Massachusetts in Boston for transferring liquefied natural gas (LNG) from ship to shore and storing it. The installation is typical of a number of similar systems built by Chicago Bridge and Iron Company, Oak Brook, Illinois. In establishing design criteria for these systems, the company benefited substantially from NASA technology.

LNG is a "cryogenic" fluid, meaning that it must be contained and transferred at very low temperatures—about 260 degrees below zero Fahrenheit. This presents a problem: before the LNG can be pumped from the ship to the storage tanks, the two-foot-diameter transfer pipes must be cooled, in order to avoid difficulties associated with sharp differences of temperature between the supercold fluid and the relatively warm pipes. The cooldown is accomplished by sending a small, steady flow of the cryogenic substance through the pipeline; the rate of flow must be precisely controlled or the transfer line will be subjected to undesirable thermal stresses.

In designing the original system at Boston, Chicago Bridge and Iron searched for relevant information on cryogenic cooldown. The company found that extensive research had been accomplished by Los Alamos Scientific Laboratory under contract to NASA's Lewis Research Center; the work was part of a nuclear rocket engine research program. Four publications resulting from the rocket research constituted the principal body of available knowledge on cooldown of cryogenic transfer lines. These reports proved important in Chicago Bridge and Iron's design of LNG transfer lines for the original and subsequent installations; they also provided a departure point for the company's own extensive development of cooldown technology.


Bostongas
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Noise Protection

There is increasing effort in the U.S. to develop ways of controlling noise, particularly in industrial environments, due to federal and state laws, labor union insistence and new findings relative to noise pollution impact on human health. Among various noise protection techniques and systems being employed is a line of highly effective acoustic materials known as SMART Products, whose development stemmed from space research. SMART is an acronym for Sound Modification and Regulated Temperature; the products are manufactured by Environmental Health Systems, Framingham, Massachusetts.

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The basis of all SMART products is SMART compound, a liquid plastic mixture with exceptional energy/sound absorbing qualities. The basic compound—later refined for noise protection use—was discovered by Arthur Metzger, a former NASA employee once engaged in work on the guidance system for the Apollo spacecraft. An early version of the guidance system developed severe vibration problems which were traced to the plastic compound encapsulating the system's electronics; the compound did not absorb sufficient energy to dampen vibrations. In a search for a better compound, Metzger found a very elastic type of plastic which literally soaked up energy. Metzger recognized its potential for noise protection and, after he retired from NASA, he founded Environmental Health Systems, of which he is president, to develop and market the compound and associated products—noise-deadening adhesives, sheets and enclosures.

The photos illustrate two examples of SMART applications. Above, the noise-blocking green wall encloses a manufacturing operation at General Electric Company's Providence, Rhode Island plant where 60-ton automatic presses stamp out light sockets at extremely high noise levels. Testimony to the noise-reducing effectiveness of the SMART enclosure is the fact that GE had to install a warning light to indicate that a press has malfunctioned and stopped operating; it is uniformly quiet outside the enclosure, so plant workers could not tell that a press was not operating without the light signal. At left, SMART screens atop a Polaroid Company building in Waltham, Massachusetts block noise from rooftop machinery so that it does not carry to a nearby residential area. In addition to industrial use, examples of SMART applications include soundproofing for discotheques in Hilton hotels and a hospital "quiet room" for audiological tests. Environmental Health Systems is working on formulations for aircraft cabins, subways, tunnels, farm machinery and a variety of other applications.

Ship Design

The ship pictured is the *S.S. Herbert C. Jackson*, a Great Lakes ore carrier owned by Interlake Steamship Division of Pickands, Mather and Company, Cleveland, Ohio. Built in 1958, the *Jackson* was converted in the latter 1970s to a self-unloading ship, one capable of discharging its cargo by means of its own on-board equipment rather than shore-based unloading systems. During the engineering stage of the vessel's conversion, the Cleveland firm Marine Consultants & Designers, Inc. applied the computer program SHCP (Ship Hull Characteristics Program) for estimating hull shear forces and bending moments to insure structural adequacy of the *Jackson*. One of many computer programs made available to industry by NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia, SHCP is a composite program designed to solve basic naval architecture problems and to assess the integrity and stability of a ship design.

Marine Consultants & Designers, Inc., is a leader in development of innovative designs for self-unloading bulk cargo carriers. The company also performs engineering services related to design of tankers, tugboats and other forms of marine transportation. In its engineering work, the firm makes extensive use of COSMIC's SHCP, which provides highly accurate results, helps improve process efficiencies and contributes to increased product safety and reliability. Marine Consultants & Designers, Inc. reports that its use of SHCP has improved the firm's structural design capabilities and reduced design development time, with consequent annual savings of substantial order.

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Piping Analysis

Burns & McDonnell, Kansas City, Missouri provides architectural and engineering services in planning, design and construction of a wide range of projects all over the world. In its design analysis work, the company regularly uses computer programs supplied by NASA's Computer Software Management and Information Center (COSMIC).

Above, an engineer is studying a model of the steam and water lines to be incorporated in the design of a power plant. In computer testing the piping design, Burns & McDonnell uses COSMIC's Pipe Flexibility Analysis Program (MEL-21) to analyze the stresses due to weight, temperature and pressure found in proposed piping systems. Individual flow rates are put into the computer, then the computer calculates the pressure drop existing across each component; if needed, design corrections or adjustments can be made and rechecked.

Burns & McDonnell uses the same MEL-21 program to analyze structural steel stresses in designing aircraft hangars, such as the Boeing 747 hangar shown under construction at left.

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Cellulose Insulation 145

The workman pictured is loading onto a truck bags of fire-retardant cellulose insulation produced by All-Weather Insulation Company, Springfield, Kentucky. Made by shredding old newspapers and treating them with a combination of chemicals, the insulating material is blown into walls and attics to form a fiber layer which blocks inflow or outflow of air.

All-Weather Insulation is a new company whose establishment was aided by the NASA Technology Applications Program at the University of Kentucky, a group known as NASA/UK-TAP. This type of spinoff is one in which NASA provided technical assistance of an informational nature rather than aerospace technology.

Interested in starting an insulation production facility, All-Weather Insulation's founders asked NASA/UK-TAP's help; they wanted to know what chemicals added to shredded newspapers would produce an insulating material capable of meeting federal specifications, and in what proportions the newsprint and chemicals should be mixed for best insulating qualities. NASA/UK-TAP researched the query and furnished extensive information obtained from government agencies, industry associations and other sources. The information contributed to successful development of the product and helped launch a new small business enterprise which is now growing rapidly. NASA/UK-TAP is one of nine NASA dissemination centers which provide information retrieval services and technical assistance to industrial firms and government organizations.

A New Image for the Water Hyacinth

Among environment improving technology transfers is a method of treating sewage by employing aquatic plants to remove pollutants

In tropical and subtropical areas where water hyacinths grow, including the southern United States, these aquatic plants are generally considered a colossal nuisance. They are extraordinarily prolific, virtually indestructible, and their rapid growth clogs rivers and streams.

However, in a small but growing number of American communities, the glossy green, violet-flowered water hyacinth is developing a new image as a useful and beneficial plant. Its upgraded status stemmed from the discovery—in a NASA technology application project—that water hyacinths thrive on sewage; they absorb and digest wastewater pollutants, converting sewage effluents to relatively clean water. Thus, the plants have exciting promise as a natural water purification system, which can be established at a fraction of the cost of a conventional sewage treatment facility. Water hyacinths are serving that purpose in several locales and a number of other communities are considering adoption of the technique.

For maximum effectiveness, pollution-gorged water hyacinths must be harvested at intervals, but this apparent drawback offers potential for additional benefit. Harvested plants can be—and are being—used as fertilizer. They can also be heat-treated to produce consumer energy in the form of methane gas. And if an economical way of drying the plants can be developed, they may find further utility as high-protein animal feed.

NASA launched its initial water hyacinth experiment in 1975 at the National Space Technology Laboratories (NSTL), Bay St. Louis, Mississippi. With the cooperation of Bay St. Louis officials, NSTL fenced off seven acres of the city's 40-acre sewage lagoon and planted water hyacinths. The plants flourished on the sewage and the once-noxious test area became a clean aquatic flower garden.

On the basis of this and other experiments, NSTL described the method and results in a study report which has been widely used as a basis for further application of water hyacinth technology. One of the earliest users was the town of Rio Hondo, Texas, population 2,000. Seeking alternatives to construction of a costly conventional sewage facility, town Mayor Juanita Brodeky learned of NASA's work, contacted NSTL and obtained literature and personal guidance. Rio Hondo decided to adopt the NASA system, dug lagoons and imported water hyacinths. For more than four years, the plants have proved an effective, year-round means of treating sewage. The initial cost of the facility came to only one-twentieth the quoted estimate for a conventional system.

Similarly, the community of Orange Grove, Mississippi shelved plans for an expensive mechanical system and opted instead for a combination of wastewater treatment methods in which water hyacinths play a leading role. In Florida, the Coral Springs Improvement District used NSTL's research as the basis for a 150,000-gallon-a-day water hyacinth pilot plant which has been operating since 1978; installation costs were 40-70 percent below those of a conventional system and ongoing costs run 25 percent less. The city of Lucedale, Mississippi plans a program which will include

water hyacinth treatment of sewage together with methane generation from harvested plants.

Last year Walt Disney World, Lake Buena Vista, Florida activated a prototype 100,000-gallon-a-day sewage treatment plant using NSTL's water hyacinth technology. The plant is part of the Experimental Prototype Community of Tomorrow (EPCOT), being created to provide a site for demonstration of new technological, social and artistic concepts. Among the sponsoring organizations of this project—along with the Environmental Protection Agency, the Department of Energy, NASA and private companies—is the state of Florida, which is studying the possibility of using water hyacinth technology on a statewide scale. Florida has a need for improvement of its rural sewage treatment procedures, and it is estimated that water hyacinth systems could halve the $330 million cost projected for upgrading the state's sewage facilities by conventional means.

The city of Hercules, Georgia has built a 350,000-gallon-per-day water hyacinth wastewater treatment plant. This unique facility has a greenhouse cover which permits year-round operation. It can be expanded to treat almost two million gallons of raw sewage wastewater daily.

The largest application of water hyacinths yet initiated is a million-gallon-a-day pilot plant recently approved for the San Diego (California) Water Utilities Department (SDWUD), which handles sewage treatment for more than two million area residents. SDWUD contemplates a recycling system in which water hyacinths, combined with a mechanical system for separating solid waste, will restore wastewater to a certain level of purity; further treatment by other means would make the water pure enough for drinking and general use. Interested in broader application of water hyacinth technology, the California Water Resources Control Board has established an Aquaculture Studies Section to investigate the matter.

A number of other state and local governments are looking into water hyacinth sewage treatment and there are also several experiments under way to explore the plant's byproduct potential as a source of methane gas or animal feed. For example, United Gas Pipe Line Company is one of the sponsors of the Disney World EPCOT program; in addition to its EPCOT study of separating methane from heat-treated water hyacinths, the company has been considering construction of a pilot plant in Louisiana to investigate large-scale production of methane from a combination of water hyacinths, Bermuda grass and municipal sewage.

Using harvested water hyacinths as animal feed was researched by the Louisiana State University Agricultural Experiment Station. In one test, conducted with NSTL cooperation, researchers fed chopped, solar-dried water hyacinths to a herd of dairy cows for four weeks; it was found that the cows produced as much milk—and of comparable quality—as did cows fed their customary hay ration. LSU dairy scientists feel that the plants could become an alternative livestock feed when land now used to grow forage may have to be used to produce food for humans.

Additional research is needed before water hyacinths become practical, economical sources of methane or animal feed, but the plants have already demonstrated their efficacy in sewage treatment and wider application for that purpose seems likely.

Shown being harvested at Florida's Walt Disney World, water hyacinths are being used in several locales to clean wastewater by absorbing and metabolizing pollutants, an economical sewage treatment method developed by NASA's National Space Technology Laboratories. The plants have byproduct potential as sources of consumer energy or livestock feed.

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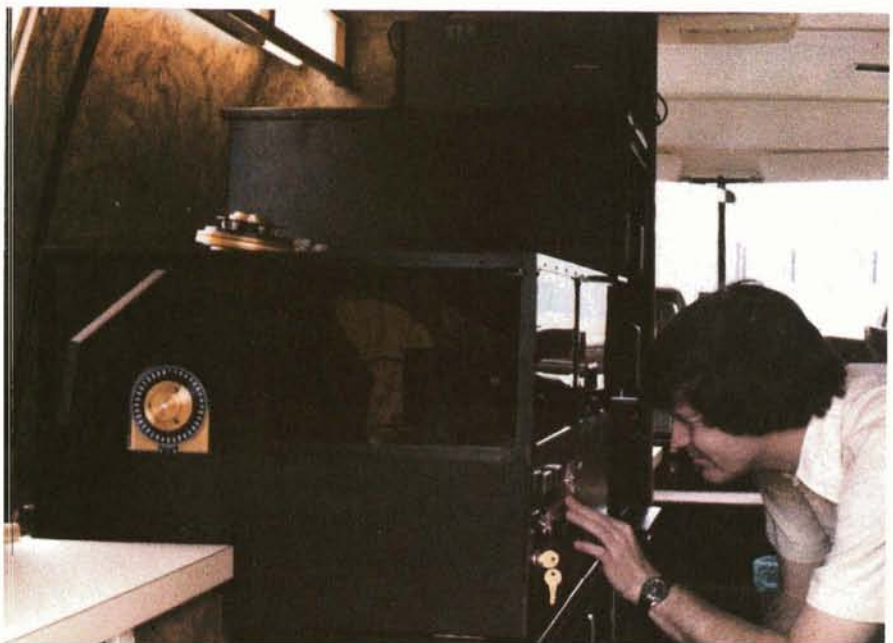
Smokestack Monitor

The Environmental Protection Agency (EPA) monitors emissions from industrial smokestacks to obtain such information as how much pollutant material is being discharged into the atmosphere, how rapidly it is being discharged, and how the smoke plume disperses after leaving the stack. Until recently, this was a costly and time consuming job. EPA had to make arrangements with plant officials to avoid disrupting operations, install sensors on the smokestacks, take samples for later analysis, then remove the sensors. These multiple steps have been eliminated by an aerospace spinoff called the Mobile Laser System, which EPA put into operation last year.



Installed in a van, the system uses a laser beam to monitor smokestack plumes from as far away as 3,000 feet.

The Mobile Laser System is an offshoot of Laser Doppler Velocimeter (LDV) technology originally developed by Marshall Space Flight Center for measuring airflow disturbances in wind tunnels and in flight. One of Marshall's LDV contractors was Raytheon Company's Equipment Division, Wayland, Massachusetts. Marshall and Raytheon teamed to adapt LDV technology to EPA's need; Raytheon designed and built the new system.

The upper photo—taken during 1979 acceptance tests at Duke Power, North Carolina—illustrates how the Mobile Laser System works. In the photo, an invisible laser beam is measuring emissions from one of the stacks; aimed from the van's interior (lower photo), the beam is projected from the roof-mounted scanning pod near the rear of the vehicle. Particles in the smoke coming out of the stack reflect the beam back to light-detecting equipment in the van. The frequency of the returned beam is different from that of the outgoing beam; analysis of the difference in frequencies—called the "doppler shift"—allows determination of the velocity of the material being discharged, together with the amount and size of the particles emitted. The laser also measures wind velocity and direction, enabling computation of smokestack plume dispersion downwind of the power plant. The system offers multiple advantages: it is economical, provides instant data, is self-contained and easily movable, and can be used at any time without interfering with plant operations.

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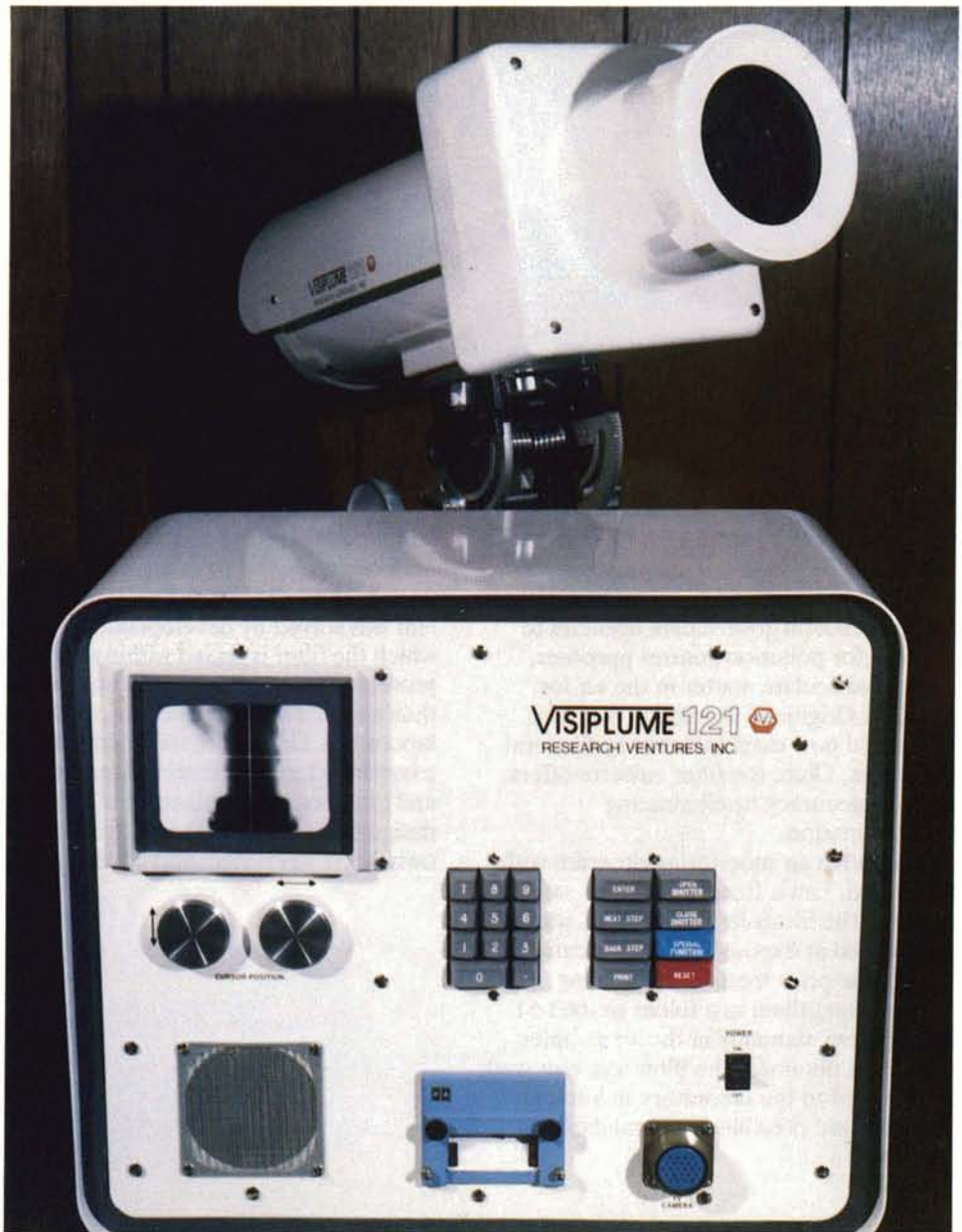
Pollution Measuring System

Another means of monitoring smokestacks remotely (see opposite page) is the Visiplume system pictured. Visiplume is a portable, microprocessor-controlled air pollution monitor for measuring sulfur dioxide emissions from fossil fuel-fired power plants and facilities that manufacture sulfuric acid. It observes smokestack plumes at a distance from the stack, obviating the expense and difficulty of installing sample collectors in each stack and later analyzing the samples. Invented by Langley Research Center, Visiplume is manufactured under NASA license by Research Ventures Incorporated, Williamsburg, Virginia.

The most widespread type of air pollution is sulfurous smog, which results from discharge into the atmosphere of sulfur bearing compounds, principally sulfur dioxide. Sulfurous smog interacts with aerosols in the air to affect human lungs. Acid rain—precipitation containing sulfuric acids—has been found to kill fish, destroy plant life and erode building materials. Thus, it is important that environmental agencies and private industry carefully monitor sulfur dioxide emissions to plan corrective measures. Visiplume offers a new, cost-effective means of doing it, and it can also be useful in checking the efficacy of desulfurizing techniques, such as "scrubbing."

Visiplume's major components are an optical "plume viewer" (at top in the photo), an electronics unit including a television monitor, and a power supply. By means of the optical system, Visiplume visualizes the smoke plume, observing the absorption of ultraviolet radiation by sulfur dioxide against a normal sky background. The system measures the concentration of sulfur dioxide in the plume and the velocity of the gas by tracking fluctuations in the concentration; these two inputs allow automatic computation of the emission rate, the ultimate measure of pollution. The TV monitor in the electronics box displays the smoke plume and the locations within the plume where the measurements are taken. Final results are also displayed on the monitor and, for a permanent record of the measurements, Visiplume provides a printer output.



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Air Sampling Filter

In the photo, a technician is replacing a filter paper cartridge, or cassette, in a high-volume air sampling system known as Accu-Vol. Used by many municipalities and state or federal government agencies to monitor air quality for pollution control purposes, the cassette traps particulate matter in the air for laboratory analysis. Originally developed by Lewis Research Center and now manufactured by General Metal Works, Cleves, Ohio, the filter cassette offers improved sampling accuracy by eliminating inadvertent contamination.

During a cooperative air monitoring program with the city of Cleveland, Lewis Research Center saw a need for improving the filters in air samplers, which are typically deployed at exposed outdoor locations such as rooftops. The prior method of handling filters involved carrying them in a folder to the test site and inserting them manually in the air sampler; when the sample was obtained, the filter was removed by hand and delivered to the laboratory in a folder. This procedure allowed possible test-invalidating contamination from materials other than particulate pollutants, caused by manual handling or by penetration of windblown matter during transit. The problem was solved by development of the cassette, in which the filter is sealed within a metal frame, protected in transit by a snap-on aluminum cover, thus handled only under clean conditions in the laboratory. General Metal Works fabricated the cassette to Lewis Research Center's specifications and later began manufacture of a modified version, designated GMW-3000, for use in the company's own Accu-Vol system and other types of air samplers.

Pollution Detection Devices

The instrument shown in the photo at right is sensing, from a considerable distance, the emissions from a volcanic eruption in Mexico. Called COSPEC IVB—short for correlation spectrometer—it was originally developed by Barringer Research, Inc., of Golden, Colorado and Rexdale, Ontario under contract to Johnson Space Center; for aircraft or spacecraft use, Johnson needed a remote sensor capable of measuring sulfur dioxide and nitrogen dioxide in the atmosphere. The Barringer system, based on the firm's earlier work in measuring smokestack pollutants, was used by Johnson to prepare air pollution profiles of several American cities. Barringer markets a refined version—COSPEC—which is in service with many pollution control agencies in the United States and a number of foreign countries.

An associated Barringer product (below) is GASPEC—a compression of Non-dispersive Gas Filter Spectrometer—used by such customers as research agencies and oil/mineral exploration companies. GASPEC is an infrared/ultraviolet gas analyzer which can be used either as a ground-based detector or in aircraft/spacecraft applications. Extremely sensitive, it is useful in air pollution investigations for detecting a variety of "trace" elements, vapors which exist in the atmosphere in very small amounts. Barringer built a special version of GASPEC for Langley Research Center's Monitoring Air Pollution from Satellites project, a forthcoming effort to measure various trace gases in the atmosphere above Earth's central latitudes.

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Environmental Analysis

Above, a technician of the engineering-architecture firm of Burns & McDonnell is taking aircraft noise readings as part of an airport environmental control study. Burns & McDonnell, Kansas City, Missouri is engaged primarily in design of such facilities as electric utilities, industrial plants, wastewater treatment systems, dams and reservoirs, and aviation installations. In addition to design and engineering work, the company conducts environmental analyses and advises clients as to the environmental considerations of a particular construction project.

Field data gathered for environmental impact studies is computer processed at Burns & McDonnell's data processing center, a portion of which is shown at left. The center makes use of computer programs supplied by NASA's Computer Software Management and Information Center (COSMIC)®; in environmental analyses, Burns & McDonnell uses COSMIC's Program for Contouring Randomly Spaced Data. Use of the COSMIC software has allowed substantial savings and contributed to an increase in the number of Burns & McDonnell customers requesting environmental analysis services.

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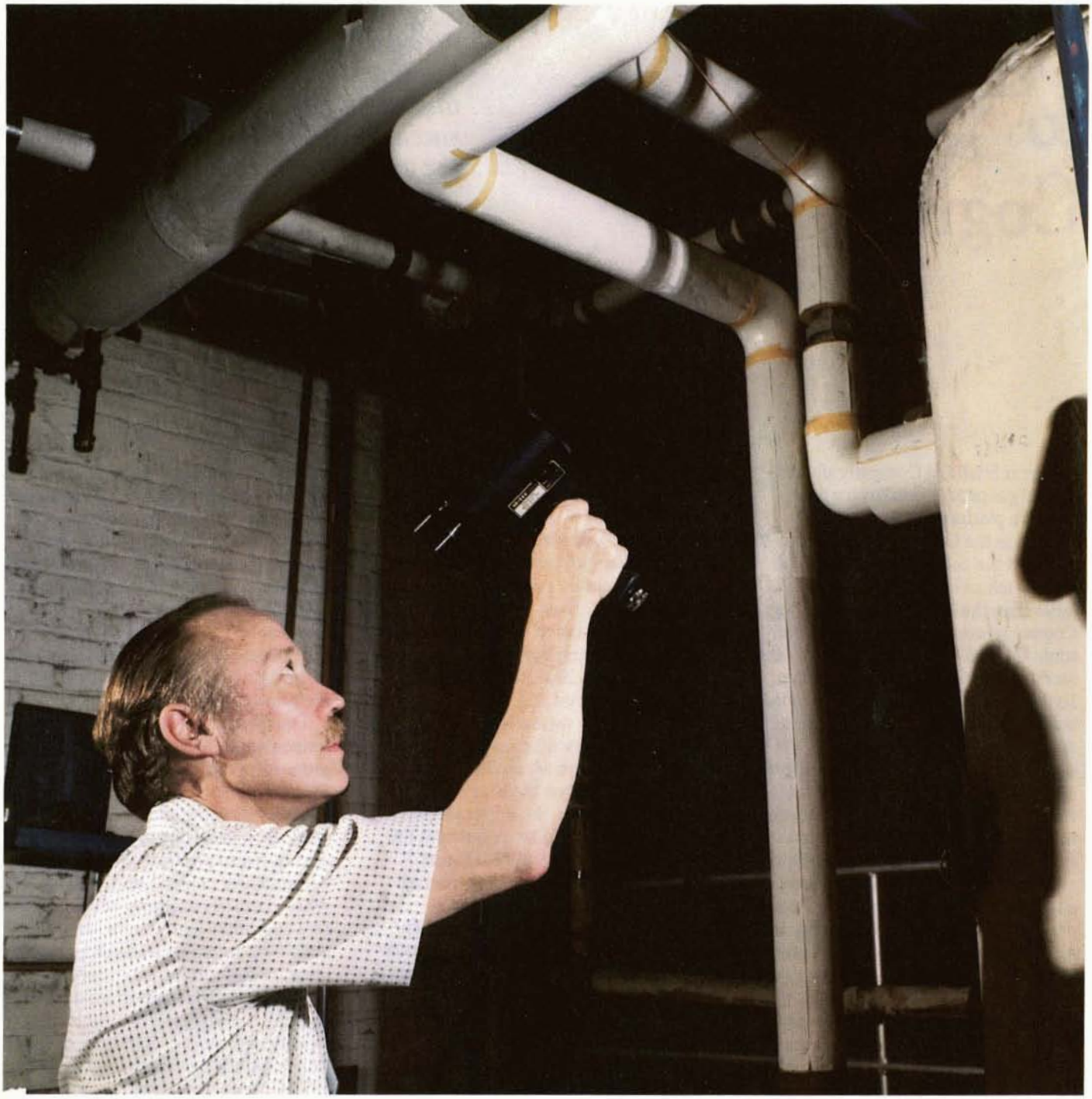

Leak Detector

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In the photo, a technician is demonstrating use of a portable device capable of detecting radioactive leakage. If there were a leak, the radioactivity would illuminate the unit's viewing screen and identify the source of the leak; in the absence of radioactivity, the screen shows nothing. Built by Ni-Tec., Inc., Niles, Illinois, the device is in use as a radiation detector at Argonne National Laboratories, the government nuclear research facility in Argonne, Illinois.

The Ni-Tec unit is a modified version of the LIXIscope, a small, battery-powered, portable x-ray instrument developed by Goddard Space Flight Center. Adapted from a technique for studying x-ray sources in space, the LIXIscope employs a small amount of radioactive material to produce the x-ray image; the radioactive source is not needed in the Ni-Tec radiation detector. Ni-Tec is one of several companies licensed by NASA to market the LIXIscope, which has high potential for use in medicine, dentistry and industrial operations. Broad application of the system hinges on government approval for general use of an instrument containing radioactive material.

From Apollo to Cognac

An aerospace-derived training simulator, an important aid to successful installation of the world's tallest oil platform, highlights spinoffs in the field of energy

Last year Shell Oil Company started oil and gas production from a new offshore platform called Cognac, located in the Gulf of Mexico about 20 miles off the coast of Louisiana. The world's tallest oil platform, slightly taller than the Empire State Building, Cognac represents an investment of some $800 million by Shell and 14 other members of the Cognac consortium. Its emplacement, at an unprecedented water depth of more than 1,000 feet, involved more than six years of development and construction effort, a job termed by a trade journal "as much a breakthrough in the offshore industry as (Neil) Armstrong's first step on the moon was to space exploration."

Coincidentally, space technology played an important part in the Cognac project. Like NASA's landings on the moon, deepwater siting of a structure as large as Cognac was something that had never before been done. The magnitude of the job dictated use of a number of high technology systems, including a training simulator which allowed installation crews to practice beforehand the complex tasks they would have to perform. Shell awarded the simulator contract to Honeywell's Marine Systems Center, Seattle, Washington. In the resulting Cognac Crew Trainer and Simulator, Honeywell incorporated technologies earlier developed under NASA contract for a lunar landing simulator.

Because of Cognac's great size, it was necessary to build the support "jacket" in three sections—the top section alone is larger than any previous Gulf structure—and move them by barge to the Cognac site. The installation plan called for four major operations. First, the jacket's base section, suspended between two derrick barges by multiple cables, was to be water-ballasted and lowered to a precise spot on the sea floor; there it would be anchored by 24 huge piles driven deep into the seabed by a massive underwater hammer remotely controlled from the primary barge. Next, the midsection was to be lowered and mated to the base section by means of a docking mechanism—docking poles in the legs of the midsection which fitted into "mating guides" on the base section. In similar fashion, the upper section of the jacket would be mated with the midsection. Finally, the 2,000-ton working deck would be constructed atop the completed jacket.

Although it sounds simple enough in brief outline, the installation job was enormously complex. It required an elaborate array of informational and display equipment, a key element of which was a Honeywell acoustic position reference system, wherein computer measurement of signals from transponders on the seabed allowed continuous determination of the relative positions of the derrick barges, the jacket sections and the target site on the sea floor. A radar ranging system insured that the derrick barges were always properly positioned with respect to each other. For docking sections together, the acoustic system provided initial reference information and underwater video cameras permitted visual sighting for final alignment. A telemetry system relayed data from a variety of sensors on such vital considerations as surface winds, wave heights and current strength; the amount of water ballast in the legs of a section being lowered; the tilt angle of a submerged section, which had to be controlled within a fraction of a degree; the status of the barge-mounted winches, how fast they were paying out cable and the amount of tension on each cable. Processed by several computers, all this information was fed to displays in the control center on the primary barge.

The Honeywell-developed crew trainer was capable of simulating each event involved in the installation task, for example, positioning the surface vessels, ballasting and lowering the sections, pile driving and maneuvering a section into position for docking. All simulator controls and displays reacted exactly as they would in the real operation. The system also simulated emergencies to prepare the crew for such abnormal occurrences as unexpected changes in wind or current, the snapping of a cable, loss of critical sensors or improper operation of ballasting valves. Beginning in 1977, Cognac installation crews used the trainer/simulator repetitively to familiarize themselves with the vast amount of data displayed in the control center and to practice the sequence of events involved in each of the major operations.

Cognac's base section was positioned in the summer of 1977; installation of the mid and top sections of the jacket was completed a year later, then the two-acre deck and a pair of drilling rigs were added in the latter part of 1978. With the completion of a pipeline in mid-1979, oil began flowing from Cognac to Shell's facilities at East Bay, Louisiana. Not until 1983, however,

At a site in the Gulf of Mexico, one section of the huge Cognac oil platform is launched from its transport barge. The section was then water-ballasted and lowered by cables to an underwater mating with another, previously submerged section.

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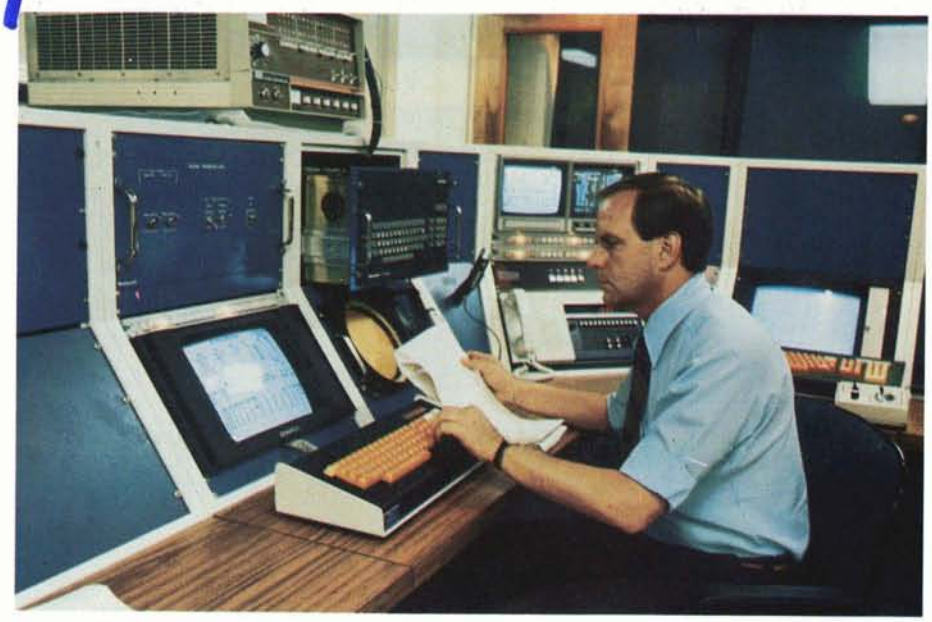
will Cognac reach full production, estimated at 50,000 barrels of oil and 100 million cubic feet of natural gas each day.

Considering the extraordinary nature of the job, Cognac's installation was carried out in remarkably smooth fashion. The Honeywell trainer was a major contributor, according to many of those involved, because it instilled in installation crewmembers confidence in their ability to handle the exacting tasks assigned them. In fact, some said, the actual operations seemed easier because the training sessions had been so demanding.



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The highly complex job of installing Cognac's support "jacket" under water more than a thousand feet deep was directed from this barge-based control center. To enable crews to practice in advance difficult tasks never before accomplished, Honeywell Inc. developed a system for simulating the various underwater operations. In training sessions, the displays and controls pictured reacted exactly as they would in a real operation.

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Taller than the Empire State Building, Cognac was built in several sections at Morgan City, Louisiana. Here the 8,000-ton midsection—one of three segments of the support jacket—is being towed through the Louisiana bayous to the Cognac site.

At the Gulf of Mexico installation site 20 miles off the Louisiana coast, Cognac's midsection is readied for launching. The structure was lowered by winches on the two derrick barges and joined to the base section anchored to the sea floor. Later the topmost section of the jacket was similarly lowered and mated. Operations were remotely controlled from the primary barge shown in the foreground.

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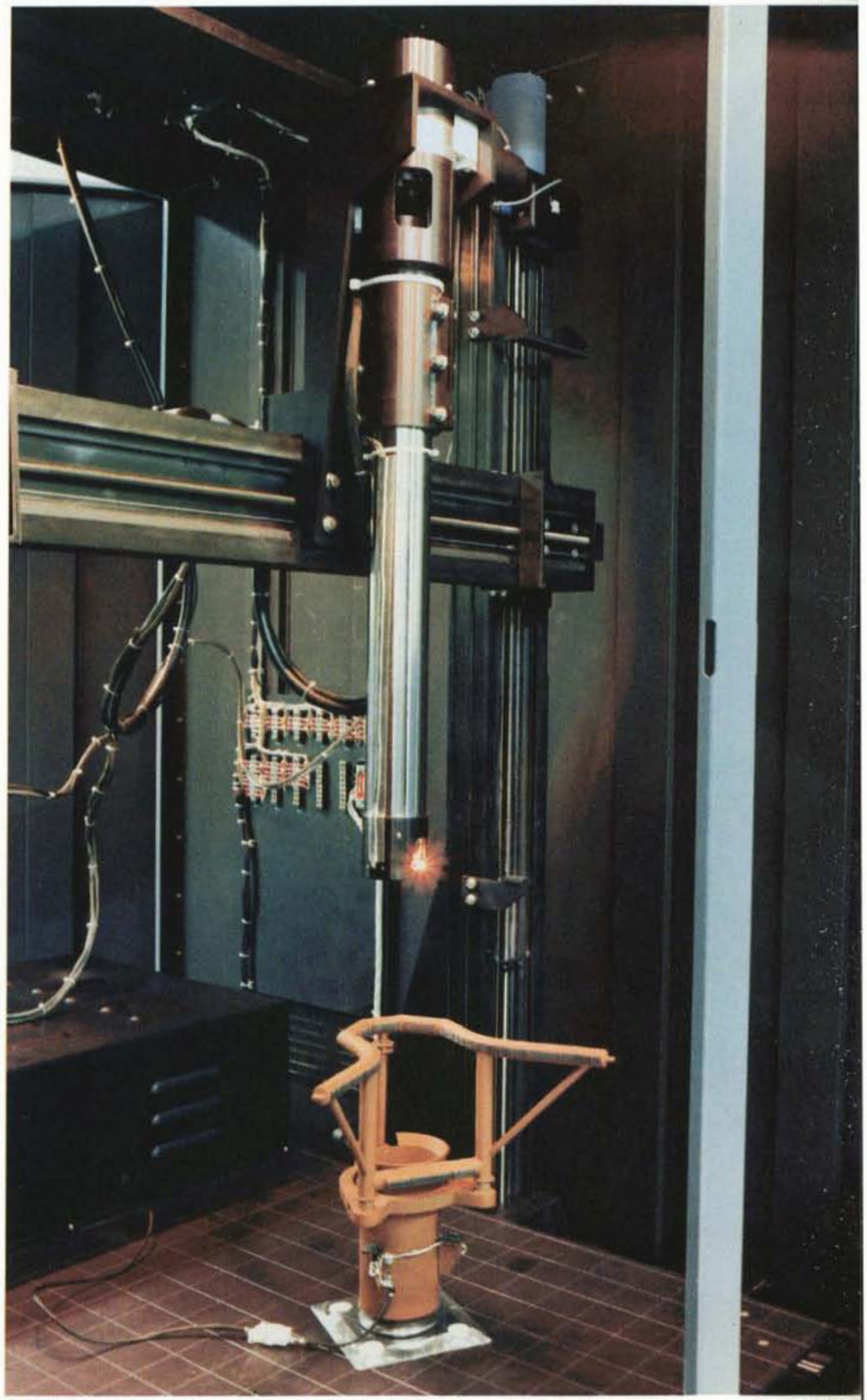
These photos illustrate one of the many simulations performed by the Honeywell crew training system. The device at right models the method by which 24 giant piles—each more than 600 feet long—were driven deep into the seabed to serve as anchor posts for Cognac's support structure. The piles had to be lowered by a special elevator and maneuvered by operators in the control center to a mating with guide frames on the sea floor. The elevators were equipped with instruments whose signals reported the position of the descending pile relative to the guide frame. A television camera fixed to the pile provided visual confirmation on the console shown below. Repetitive simulations of this and other operations contributed significantly to Cognac's successful emplacement.



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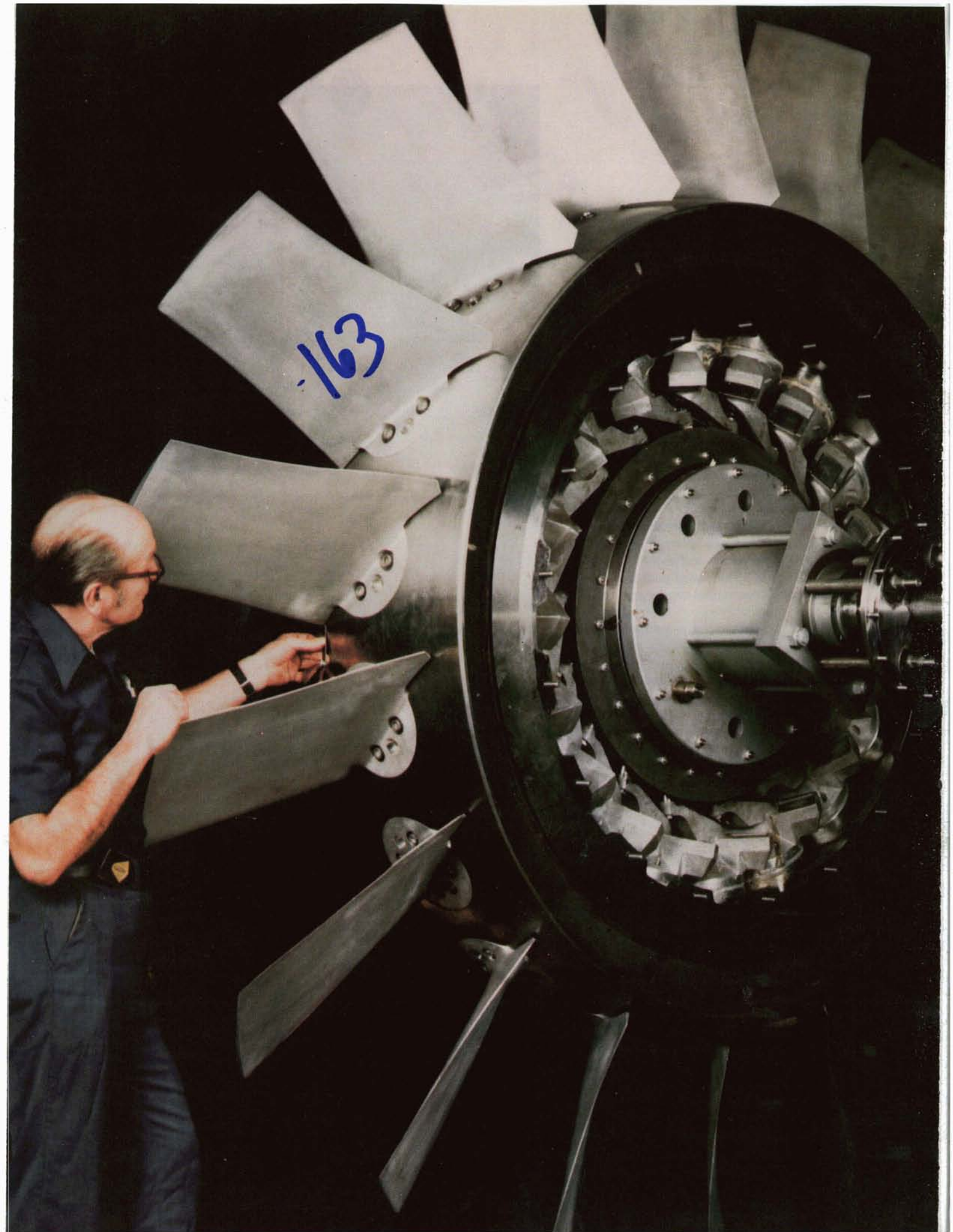
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Industrial Turbine Fans

The Westinghouse engineer at left is examining the blades of an advanced, controllable-pitch axial fan used in electric power generation, first of its type designed in the United States. Now operating as part of Oklahoma Gas and Electric Company's generating system, the fan is the product of a five-year development program conducted by Westinghouse Electric Corporation's Research and Development Center, Pittsburgh, Pennsylvania. Development of this and similar fans was aided by four computer programs supplied to the Center by NASA's Computer Software Management and Information Center (COSMIC)®. The COSMIC programs were used to determine the sensitivity of large industrial turbines and fans to particulate matter—such as ash and dust—which can cause turbine damage by erosion. Use of the programs contributed to improved product reliability by helping the Research and Development Center design fans less prone to erosion. The programs also enabled the Center to realize substantial savings in development costs.

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Solar Collectors

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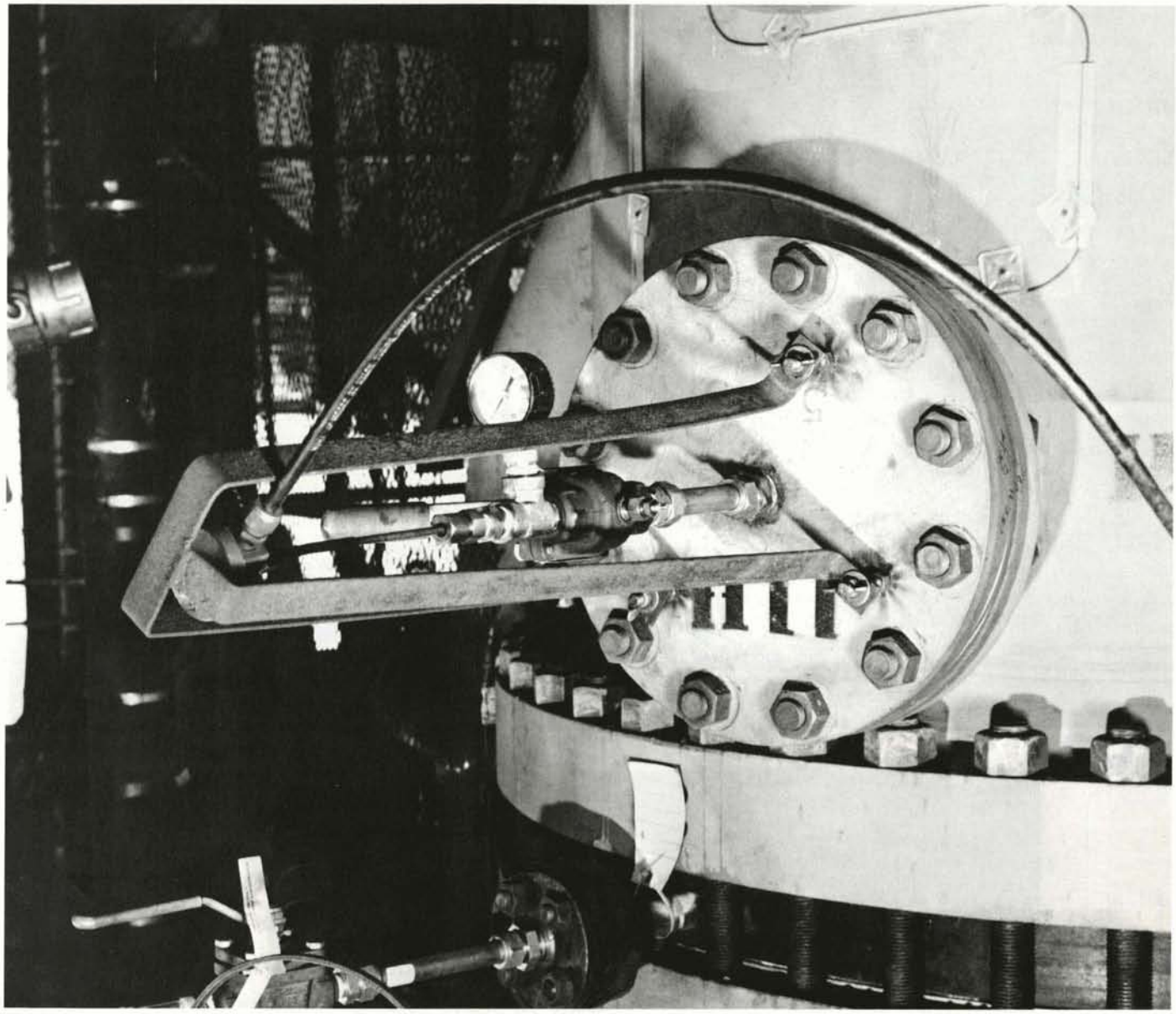
In this photo, the panels at left are collectors for a solar energy system which provides heating for a drive-in bank in Akron, Ohio. The collectors were designed and manufactured by Solar Energy Products Company, Avon Lake, Ohio, a firm established by three former NASA employees. Company president Frank Rom, an example of a personnel-type technology transfer, was a research director at Lewis Research Center, which conducts extensive solar heating and cooling research, including development and testing of high-efficiency flat-plate collectors. In the course of his service at Lewis, Rom acquired solar energy expertise which helped the company develop two types of collectors, one for use in domestic/commercial heating systems and the other for drying grain. Solar Energy Products Company licensed production rights for the grain dryer but continues to produce installations for homes and commercial buildings.

Electric Power Monitor

This photo shows the control center of SAMAC (System Automatic Monitor and Control), a sophisticated dispatch computer system operated by Philadelphia Electric Company, Philadelphia, Pennsylvania. SAMAC monitors and controls the generation and distribution of electric power throughout the Philadelphia Electric network. It enables human operators to isolate and correct power distribution problems more rapidly than was possible with earlier dispatch systems without centralized computer control.

SAMAC incorporates technology developed for NASA's Apollo program by Rockwell International, prime contractor for the Apollo spacecraft. In the 1960s, Rockwell developed a major part of the extremely complex checkout system which analyzed and tested the many Apollo subsystems at each step of their progression from manufacture to launch. Rockwell subsequently established what is now known as the Communication Switching Systems Division (CSSD), Anaheim, California to develop commercial products based on the computer systems expertise and technology the company had acquired in its work for NASA. SAMAC is one such product and CSSD has built a number of similar systems for other utility companies. The SAMAC digital color television display, shown in the photo, is a spinoff from technology separately developed by Philco-Ford Corporation for information displays at Johnson Space Center's Mission Control Center. Rockwell later acquired the display product line from Philco-Ford.



Temperature Sensor

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Weed Instrument Company, Inc., Elgin, Texas, produces a line of thermocouples—temperature sensors—for a variety of industrial and research uses. One of the company's newer products is a thermocouple specially designed for high accuracy at extreme temperatures—above 3,000 degrees Fahrenheit. It contributed to solution of a problem encountered by Westinghouse Electric Corporation's Advanced Coal Conversion Department, Madison, Pennsylvania, which develops systems for converting coal to cleaner and more efficient forms of energy. The problem was the difficulty of obtaining precise measurement of the very high temperatures involved in the conversion process; the Westinghouse group experienced many thermocouple failures because of severe temperature changes resulting from the sensors' alternating exposure to hot flame and cold purge gas, and because of sensor-degrading chemical reactions occuring at temperatures sometimes exceeding 2,200 degrees.

The Westinghouse remedy was design of a new thermocouple/thermowell assembly which incorporates Weed Instrument's high-temperature sensor. The assembly is used to acquire test data on the combustion process within such facilities as the coal gasification pressure vessel shown in the accompanying photo. The assembly is the equipment extending outward from the bolted hatch; encased within the tubular element and extending into the pressure vessel, the Weed thermocouple reports internal temperature.

Development of the Weed Instrument sensor was aided by technical information supplied by Lewis Research Center. Lewis provided several reports based on the Center's own investigations of materials subjected to very high temperatures and this information contributed to the thermocouple's ability to withstand extreme temperatures. Introduction of this product brought substantial increases in Weed Instrument's sales and employment.

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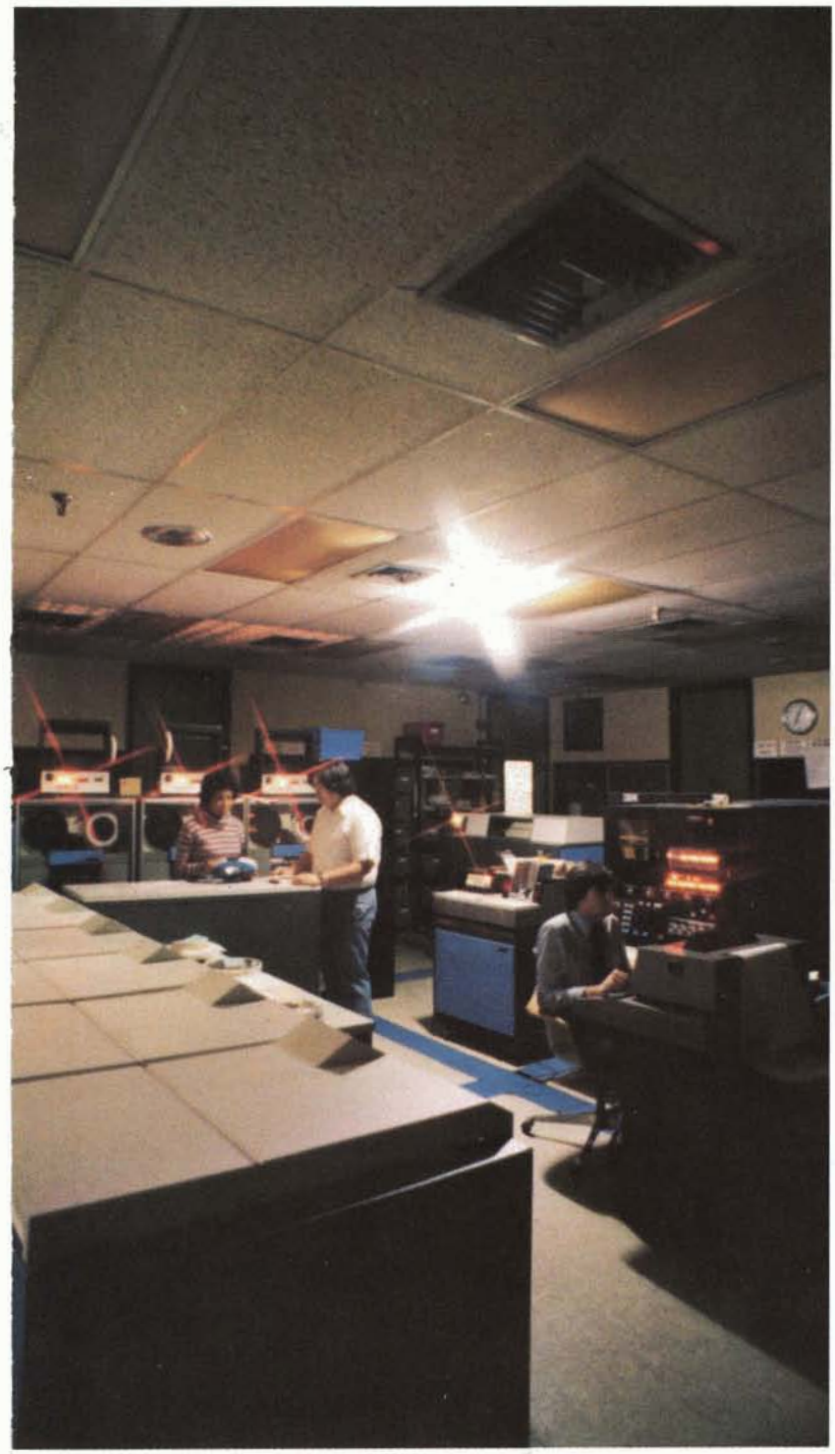
Emergency/Night Lighting

A highly efficient lighting system, an offshoot of technology originally developed for the Skylab manned orbiting laboratory, is finding wide acceptance among industrial and commercial firms as an energy-saving means of providing emergency and night lighting. The Skylab system, which consisted of small, high frequency fluorescent light fixtures powered by solar cells, provided a base for formation of a company—UDEC Corporation, Waltham, Massachusetts—which has refined the original technology and developed an expanded product line. The advantages of UDEC's lighting systems stem from the qualities required for the Skylab installation: high reliability and high light output with very low energy drain.



The principal components of the UDEC systems are long-life fluorescent lamps operated by electronic circuitry, a sealed gelatine cell battery that needs no maintenance for as much as eight years, and a solid-state automatic battery charger. A typical installation consists of a master module with battery and an eight-watt lamp, plus as many as 18 "Satellight" modules powered by the master's battery. The emergency lights turn on automatically if the primary lighting system fails due to power outage, insuring employee safety. As a night lighting system, the fixtures can bypass the battery and operate on normal current for a fraction of the energy demand of conventional night lighting. UDEC also produces supplemental systems, such as "always on" stairwell lights, illuminated exit signs, elevator and rest room lights; for the latter applications, the company offers a timing device that turns off the lights when the elevator or rest room is not occupied. A new feature, introduced this year, is a system which automatically tests every battery and every lamp each 24 hours and notifies the building superintendent or plant engineer if a malfunction has occurred since the last test.

UDEC systems, says founder and president John F. Morten, have attracted many customers because they usually pay for themselves—in energy savings—within a year or less. An example is Morton's Shoe Stores, Inc., Boston, Massachusetts, whose investment was paid back in six months. Installation of a UDEC emergency/night lighting system in the company's six-and-a-half acre warehouse/office facility cut Morton Shoe's night lighting electric bill from $8,000 a year to $300. The upper photo on the opposite page shows the level of light available in the Morton lobby from the night light fixtures. Below it is a night-lighted portion of the warehouse. At left, the view of the company's office area represents a simulated blackout of the primary lighting system; a single emergency light provides ample illumination for the employees to continue their work.

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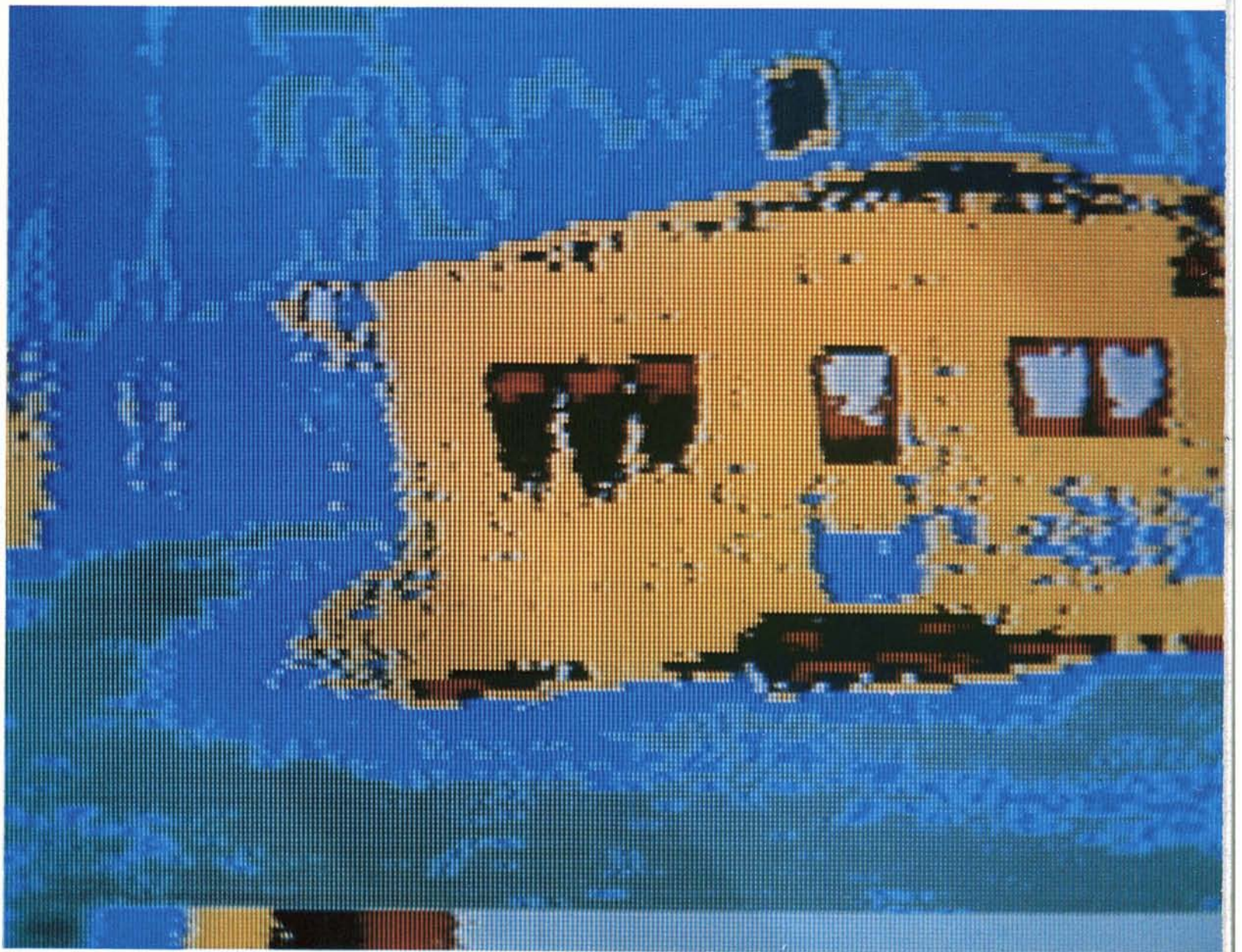
Infrared Imagers

Earth objects emit natural radiation invisible to the unaided human eye but visible to infrared scanning devices. Such devices serve a number of purposes, ranging from detection of heat loss in buildings for energy conservation measures to examining heat output of industrial machinery for trouble shooting and preventive maintenance. Among infrared systems commercially available is a product line manufactured by Inframetrics Inc., Bedford, Massachusetts, which traces its origin to NASA technology.

As an aid to automated testing of aerospace electronic components, Marshall Space Flight Center developed a series of especially sensitive infrared microscope systems which incorporated computer processing and TV display capabilities. The systems were used to examine electronic units for purposes of quality control and for detection of flaws correctible by design modification. The Marshall technology provided a base for further, company-



sponsored development which resulted in Inframetrics' sophisticated, TV-compatible infrared imaging equipment.

Representative of Inframetrics' systems is the Model 525 shown, a small, lightweight field instrument that scans infrared radiation and translates its findings into a TV picture of the temperature pattern in the scene being viewed; an accessory device permits viewing the thermal radiation in color. The accompanying "thermograms" show various applications of the instrument and the type of information displayed on the video screen. On the opposite page, the system is examining a house to detect heat loss and show where additional insulation is needed. The colors at the bottom indicate different temperature ranges; analysis of the color key shows where and to what extent heat is being lost, for example, the three windows at the left of the house are better insulated than the two at right. The photo below shows an intricate temperature pattern on a plastic molding die; the thermogram tells technicians that the mold is being improperly heated and identifies the problem area for corrective action. At bottom is a thermogram of a paper processing machine which informs analysts of a cooling problem. Another example, not illustrated, is use of infrared imaging by highway maintenance authorities as an inspection tool; truck-mounted Inframetrics equipment can identify incipient problem areas before signs of road deterioration are visible to the naked eye.

Industrial process control and preventive maintenance applications constitute the principal use of Inframatrics systems. The company's lengthy list of customers includes many of the largest U.S. industrial firms, foreign companies and organizations, survey firms which provide infrared thermography services, civil and military research facilities, and state/federal government agencies.

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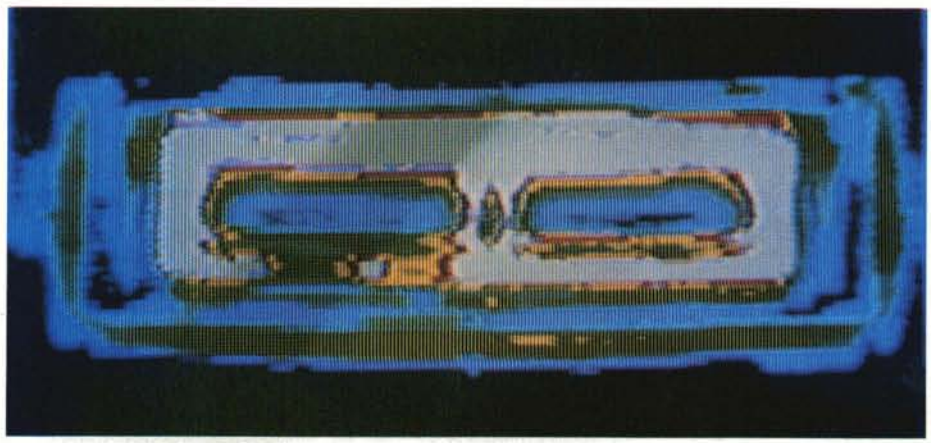

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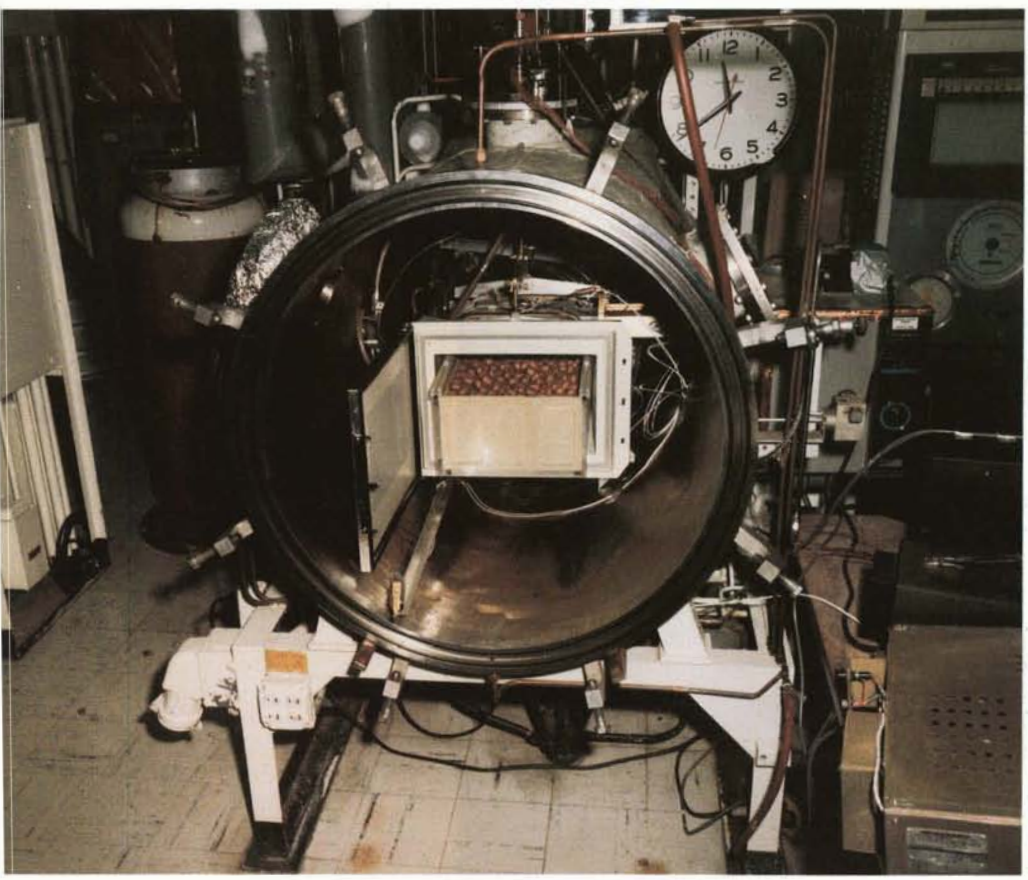
Space Technology for Crop Drying

A new system for drying farm produce, derived from the space simulator, leads a sampling of food and agriculture spinoffs



In early trials, McDonnell Douglas Corporation used this space environment simulator to test the feasibility of vacuum-drying farm produce.

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NASA's major contractors operate vacuum chambers for testing spacecraft and components under the airless conditions they will encounter in space. Such systems, designed for research in an environment totally unlike Earth's, would seemingly have little utility beyond their original purpose. Yet they have proved surprisingly useful in secondary applications.

Drying documents, for example. Important, sometimes irreplaceable documents often get water-soaked by floods, storms, fire-fighting activities or pipe ruptures. Drying them by conventional methods is time-consuming and extremely expensive. But, since moisture evaporates rapidly in the near vacuum of the space simulator, the vacuum chamber serves as a highly effective, relatively inexpensive dryout tank. For several years, aerospace companies have been using their chambers to provide this unique spinoff service. A company with extensive experience in document drying—McDonnell Douglas Corporation, St. Louis, Missouri—went a step further and came up with a spinoff from the spinoff: a rapid, energy-conserving method of drying agricultural crops by means of a new system derived from vacuum chamber technology. Called MIVAC—a compression of Microwave Vacuum Drying System—it is in experimental operation at the Department of Agriculture's Coastal Plains Station, Tifton, Georgia.

MIVAC's development was sponsored by the Department of Energy because it offers potential for reducing the enormous amounts of energy required for drying harvested crops so they will not rot. Most farmers and warehouse operators now use hot air drying equipment powered by fuel oil, gas or electricity; drying is accomplished by blowing heated air over the produce, a relatively inefficient use of energy.

A distant cousin of the home microwave oven, MIVAC dries by means of electrically-generated microwaves introduced to a crop-containing vacuum chamber. The microwaves remove moisture quickly and the very low pressure atmosphere in the chamber permits effective drying at much lower than customary temperatures. Thus, energy demand is doubly reduced—by the lower heat requirement and by the shorter time electric power is needed.

MIVAC, its developers say, offers bonus value in that it does a better job of drying more easily damaged crops—rice, for instance. The hot-air-blowing process often hardens the outer surface of the seed, making it difficult for internal moisture to escape; this may cause cracked grains of reduced quality. Microwaves heat rice—and other products—evenly from the inside out without hardening the outer coating, thereby obviating possible damage to kernels or grains.

At the Tifton pilot plant, MIVAC is being used to dry a number of agricultural products, such as rice, wheat, peanuts, soybeans, corn and pecans. Change of product entails no change of equipment. A small scale experimental facility, the MIVAC unit at Tifton has limited capacity. Corn, for example, is dried at the rate of seven bushels per hour. But it is possible, within existing technology, to scale up the system for a capacity of 1,000 bushels hourly. With anticipated development of advanced technology, capacity could be increased substantially further.

MIVAC is undergoing a two-way evaluation. The Department of Agriculture is examining results from the standpoint of product quality and processing cost. The Department of Energy is determining what energy savings MIVAC affords in comparison with existing systems.

Successful initial crop drying experiments led to development of the Microwave Vacuum Drying System (MIVAC). At left is an interior view. The long cylinder is the vacuum chamber; wet crops enter through the top funnel and emerge dried through the exit hatch near bottom. At surface level is the microwave generating equipment.

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Farm Equipment

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The tractor and combine pictured are representative of a line of farm vehicles manufactured by Deere & Company, Moline, Illinois, which also produces the John Deere diesel engines that power the vehicles. Deere & Company is one of many users of computer programs supplied by NASA's Computer Software Management and Information Center (COSMIC)®. In the interest of national productivity, COSMIC makes available to industry already-developed computer programs which have secondary utility.

Deere & Company used a COSMIC program called FEATS—for Finite Element Analysis of Thermal Stress—in computer analysis of diesel engine pistons, connecting rods and rocker arms. The company reports that its use of FEATS afforded considerable savings and improved analytical accuracies, process efficiencies and product reliability. Deere & Company is also using COSMIC's NASTRAN® (NASA Structural Analysis) program in analyzing engine components.

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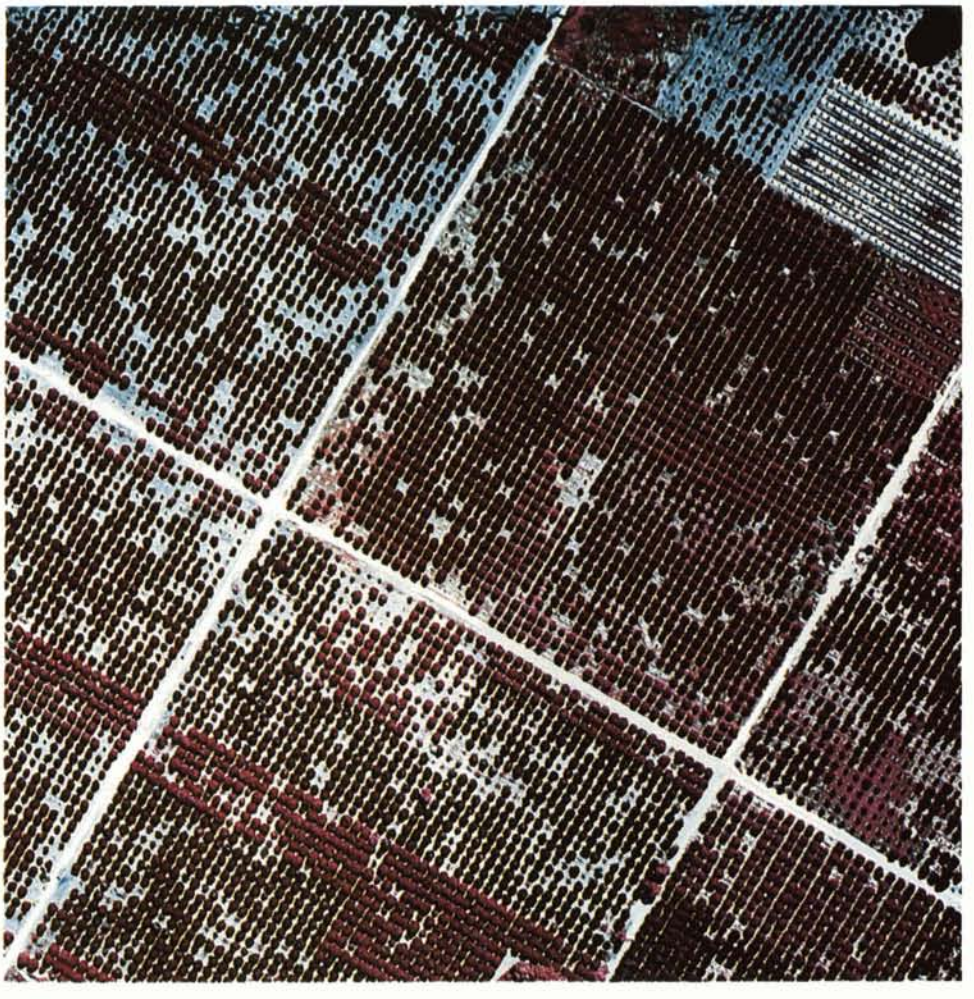
Citrus Grove Mapping

Citrus growers have long used aerial photography to inventory the number of groves in production. A new development—aerial mapping of groves with color infrared (CIR) film—affords an important advance in grove management by detecting and locating unhealthy trees long before they could be detected by ground survey methods. The technique has been known for years, but earlier experiments failed to produce a viable system for a variety of reasons, principally inadequate knowledge of the special requirements for photographing citrus groves, such as the best times of the year for taking pictures and the proper sun angles and exposures. Additionally, photo interpretation procedures needed improvement and there were difficulties associated with handling and processing of the sensitive CIR film. A new CIR mapping system, developed by Kennedy Space Center (KSC) in cooperation with the University of Florida's Institute of Food and Agricultural Sciences (IFAS), bridges the knowledge gap and provides a means of monitoring the vigor of every tree in a grove with 99 percent accuracy.

Aerial CIR photography picks up light reflected from foliage—light not visible to the human eye—and enables differentiation between healthy and "stressed" (diseased) trees, as shown in the accompanying photo of a Florida orange/grapefruit grove. Taken during KSC/IFAS tests, the photo shows healthy trees in red; the gaps in the tree rows indicate varying degrees of stress. Computer-aided photo interpretation techniques permit grading diseased trees—lightly, moderately or severely stressed, or dead. The KSC/IFAS system employs enlarged aerial CIR photographs as a mapping base for follow-up ground survey of a grove in about one-tenth the customary time.

Last year the new system was demonstrated on a large-scale basis. Citrus growers from four Florida counties financed and participated in a program involving CIR photography of some 70,000 acres. With KSC support, workshops were conducted to familiarize growers with photo interpretation procedures and ways of translating CIR information into computer-compatible formats for rapid data analysis and storage.

The KSC/IFAS system has aroused considerable interest in Florida. This method of grove mapping offers advantage to citrus growers in early disease warning, possible savings through water regulation, and provision of a permanent record of grove growth patterns. It also interests others doing business with citrus growers. For example, a county tax appraiser is testing the system as a means of evaluating tree losses due to disease or frost, and a nursery manager is using CIR photographs of his customers' groves to anticipate the number of replacement trees he will have to plant.



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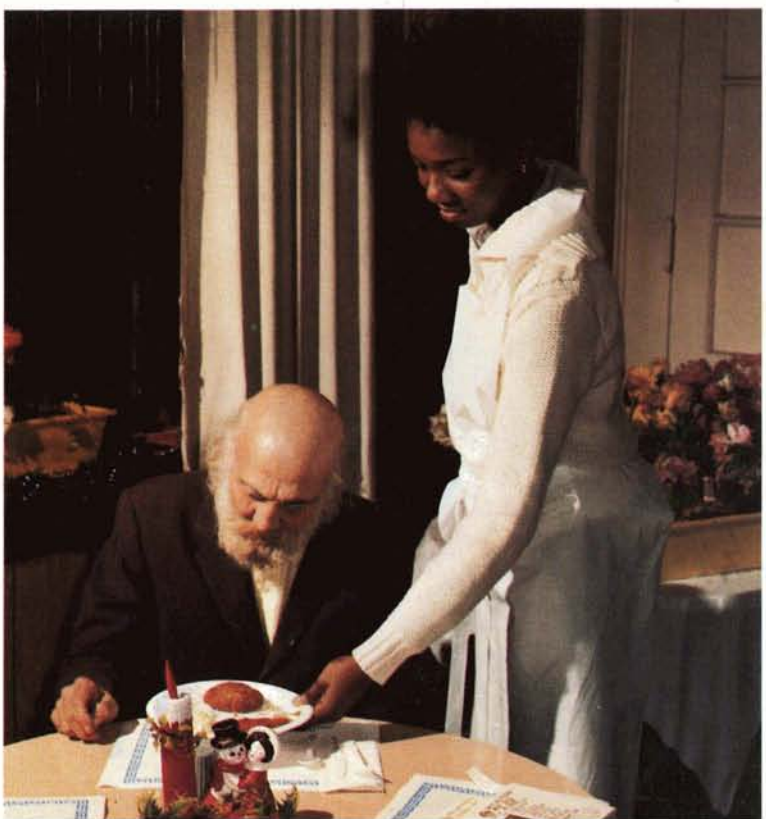

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Meals for the Elderly

Meals for spacecraft crews must be tasty and nutritionally balanced yet light in weight, compactly packaged, storable without refrigeration and easy to prepare, due to the dictates of spacecraft design. These requirements prompted NASA research in food technology that spawned several types of space meal systems. Among them are various compressed and freeze-dried foods—developed by the Army's Natick Laboratory under contract to Johnson Space Center—which served as the basis for a 1975-77 demonstration project managed by Johnson and called Meal System for the Elderly. The aim of that multi-agency cooperative project was to make the simple but nutritious space meals available to handicapped and otherwise homebound senior adults unable to take advantage of existing meal programs sponsored by federal, state and private organizations.

As a spinoff of Meal System for the Elderly, commercial food processing firms are now producing astronaut-type meals for public distribution. An example is Sky-Lab Foods, Inc., Elmsford, New York, formed in 1978 to market food packages modeled on the NASA meal system. The company offers a broad

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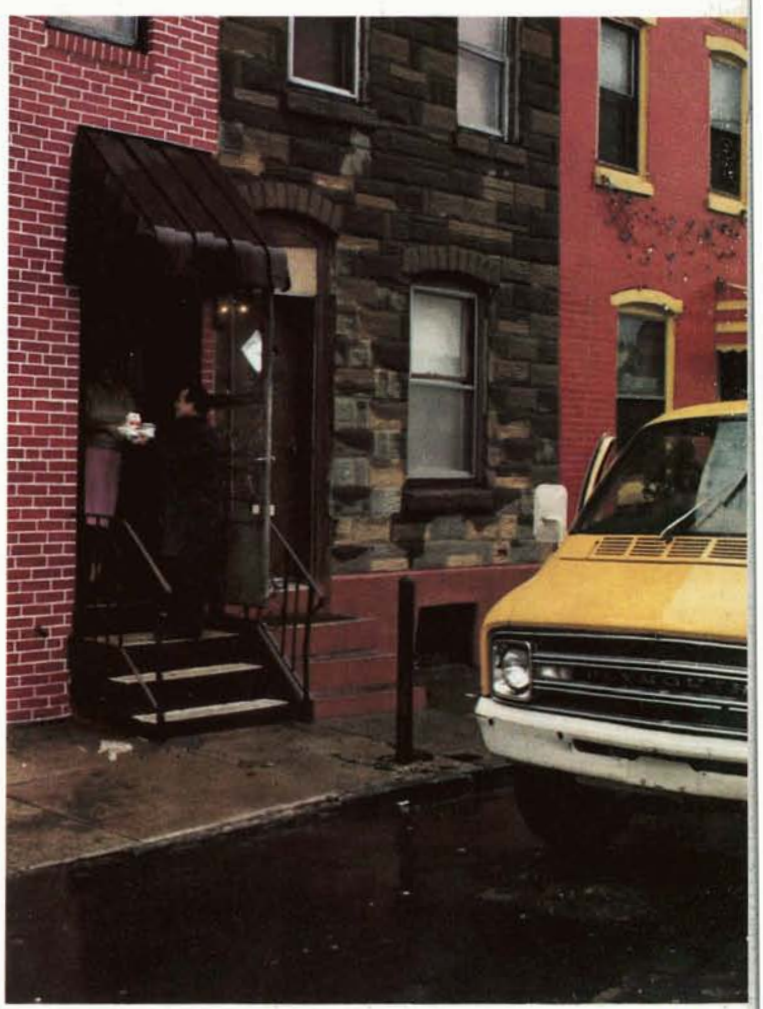
variety of freeze-dried foods, which are reconstituted by addition of water, and "retort pouch" meals which need no reconstitution, only heating; the retort pouch is an innovative flexible package that combines the advantages of the metal can and the boil-in bag. These foods retain their natural flavors, minerals and vitamins, can be stored for long periods without refrigeration, and are lightweight for easy transportability.

Sky-Lab Foods markets its products to public and private agencies serving the elderly, handicapped and disadvantaged. Typical of the company's customers are a number of senior citizen service centers in Philadelphia, Pennsylvania, whose activities are funded by the Philadelphia Corporation for Aging. The woman and man pictured on the opposite page are dining on Sky-Lab meals provided by the Spring Garden Senior Citizen Center. In the top photo, staff members of the Council of Spanish Speaking Organizations are examining Sky-Lab menus. The Council serves meals at its church-based facility, distributes packages for home use (above) and delivers meals to homebound clients (right).



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Management Technique

Aerospace spinoffs usually involve hardware, software or industrial processes, but there are other types of technology transfers. One of them is the highly efficient management method known as the "total integrated systems approach," a technique developed of necessity for managing extremely complex aerospace programs involving integration of a great many individual systems. These systems, developed at different times by many different companies, must not only work perfectly when separately tested, they must also perform compatibly when integrated into the complete prime system. The systems approach is essentially a carefully-considered, painstakingly-executed master plan for coordinated design, development and assembly of the multitude of elements that constitute the end product. Its intent is to eliminate the problems that may occur when the specific parts of a total functioning system fail to come together to provide the requisite performance of the prime system.

The systems approach has obvious applicability to management of similarly complex non-aerospace programs, and it is being applied by a number of companies which developed their project management and systems analysis techniques in work for NASA and other government agencies. One example is Ball Corporation, Muncie, Indiana, whose Ball Aerospace Division has been a major contractor on a number of space projects. The techniques developed and refined by Ball Aerospace are being applied by the parent company's Agricultural Systems Division in planning, designing, developing and managing major agricultural programs in the U.S. and developing countries.

The accompanying photos illustrate Ball Agricultural projects wherein the systems approach was employed. Shown below is an agricultural development in New Mexico. In the other photos, wheat and green crops dot once-barren areas of the Sahara Desert, made fertile by the largest center-pivot irrigation project ever undertaken in the North African desert.

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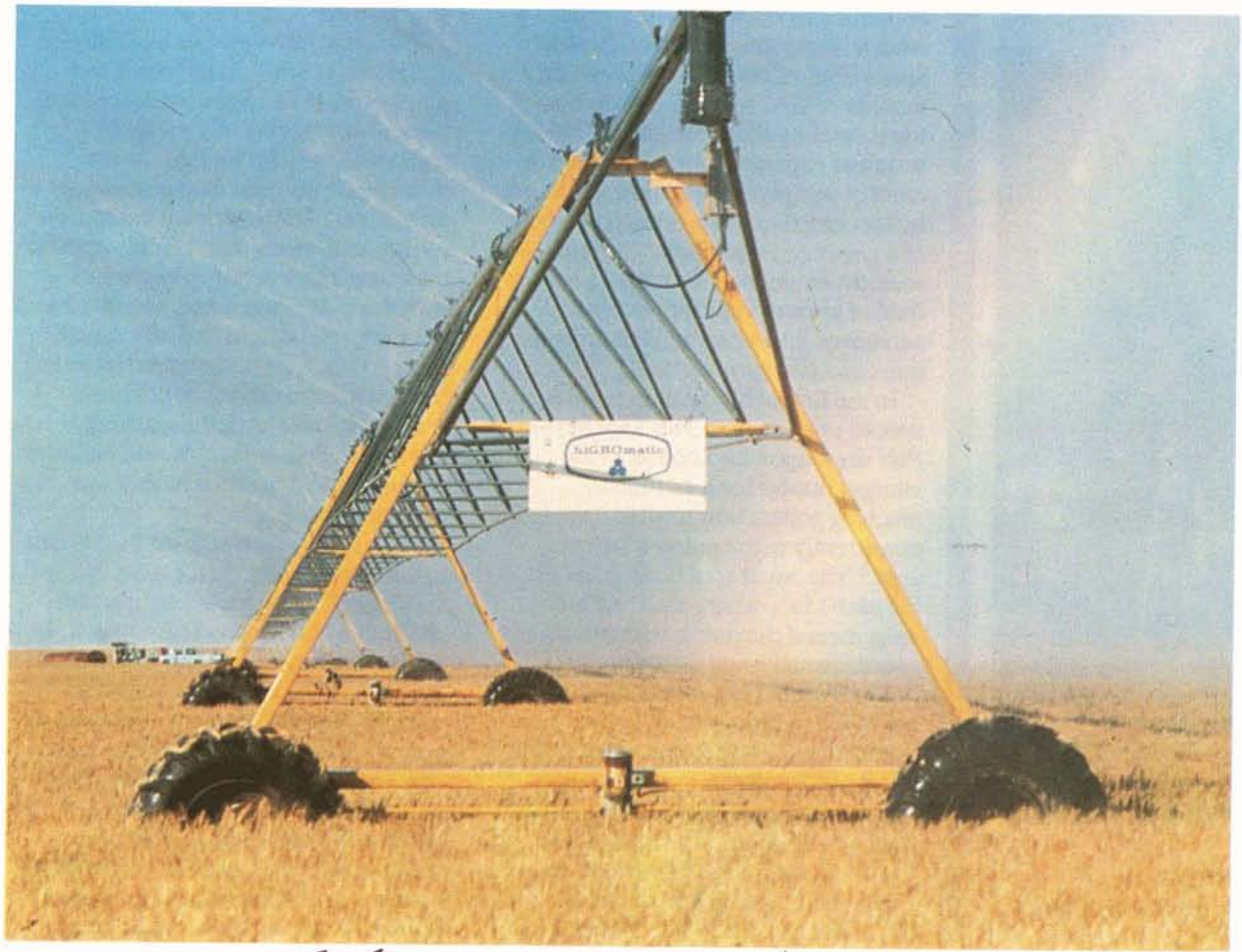

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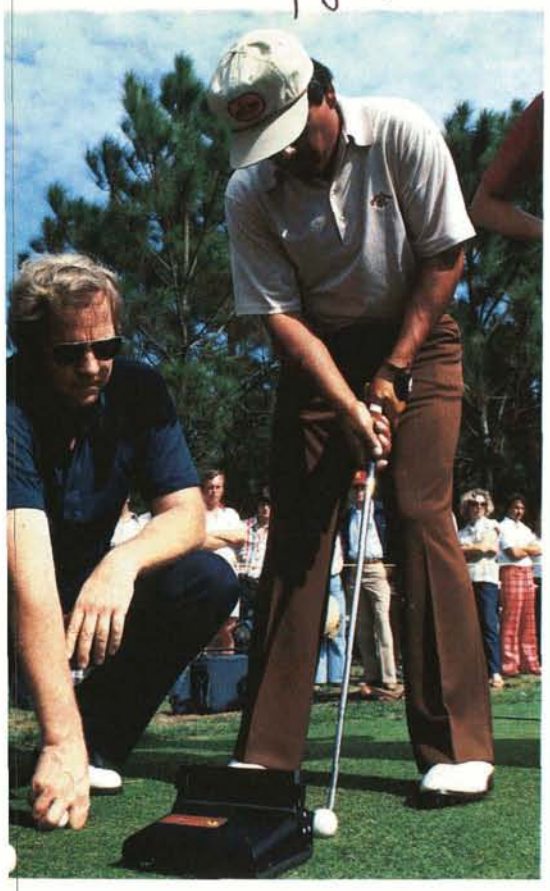
Saving Strokes with Space Technology

Among spinoffs for home and recreational use are a pair of instructional aids for golfers



Pro circuit gallery favorite Lee Trevino tests the Teacher Alignment Computer, which he uses regularly.

Golfers, attention.

Are you one of the many devotees of the game who feel that putting, which seems to the uninitiated the simplest part of golf, is actually the most difficult? Have you ever thought, "If they can send men to the moon, why can't they invent something that would make me a better putter?"

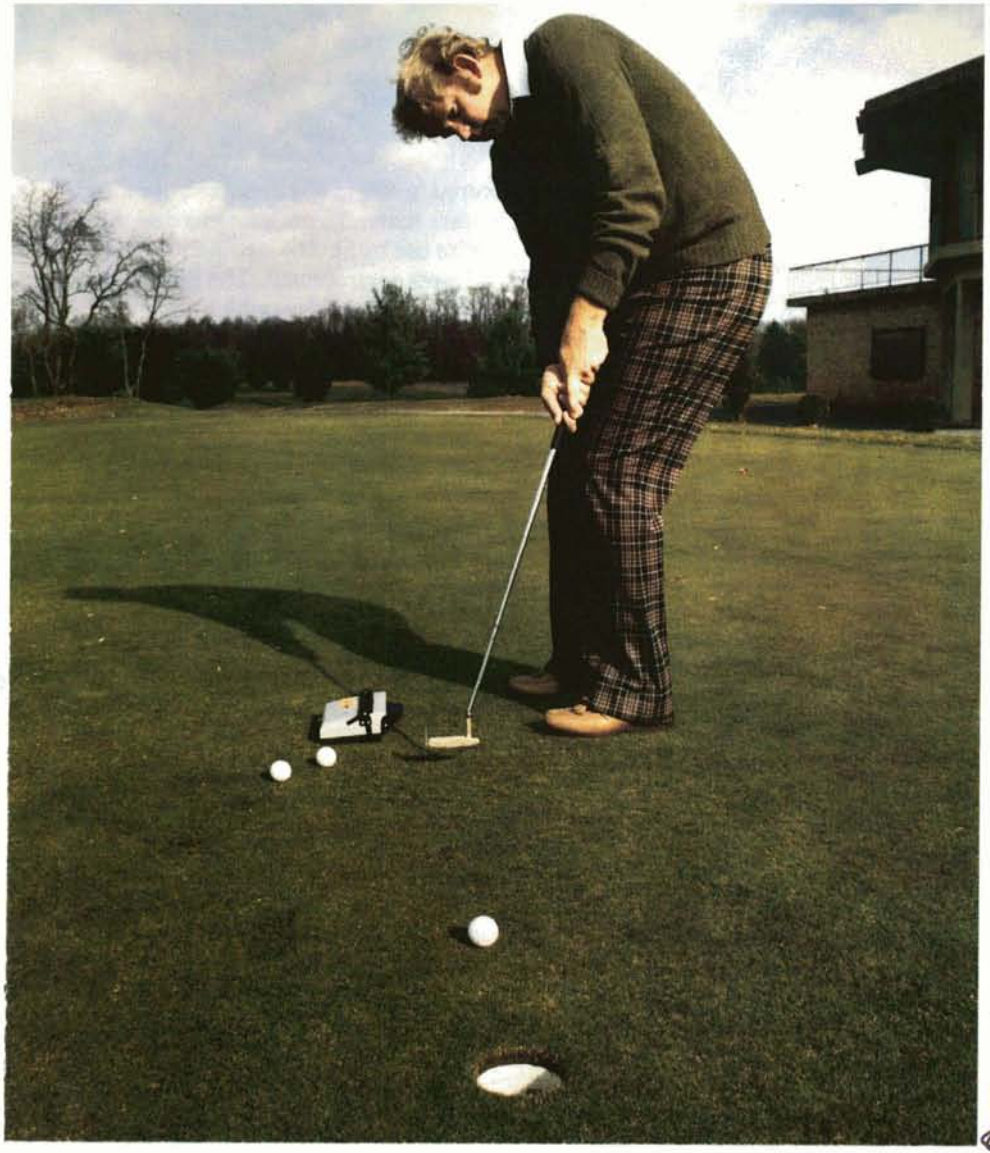
Someone has—and space technology is involved. The someone is David T. Pelz, president of Sunmark Division, Preceptor Golf Limited, Laurel, Maryland, a former physicist with Goddard Space Flight Center who worked on a number of NASA satellite programs. A top amateur golfer, Pelz put his NASA-acquired expertise to work in development of two putting aids now marketed by his company. He is thus an example of a personnel-type spinoff, wherein a scientist or engineer moves to a new field of endeavor and applies his aerospace know-how to invention of non-aerospace products.

In the first of his developments—a special putter called The Teacher—Pelz drew upon his knowledge of energy transfer for a method of teaching golfers how to stroke the ball consistently in the putter's "sweet spot." The sweet spot is the point on the club's face where club and ball must meet if the putt is to attain proper speed, distance and direction.

The Teacher is a simple device. It has a pair of prongs on the putter face bracketing the sweet spot. The idea is to stroke the ball within the prongs, which are only slightly farther apart than a ball's width. The novice will find it almost impossible to do so; the ball will hit a prong and skitter away. But, says Dave Pelz, The Teacher shows you why you missed, enabling correction. With time and practice, you develop a consistently smooth putting stroke, impacting at the sweet spot regularly. To use the club in normal play, you remove the prongs and snap them into grooves on the back side of the putter, thus your game club has the same weight and same sweet spot as the practice tool. Pelz has a fat file of testimonials, including many from touring pros, to the effect that The Teacher really works.

The other Sunmark putting aid—called the Teacher Alignment Computer (TAC)—is somewhat more complex, involving several aerospace technologies—electronics, optics, data acquisition and data processing techniques. The device is a computerized system which tells a golfer whether his putter's face is properly aligned with the hole—and if not, whether he is aiming left or right and how much. Many otherwise good golfers, including tour pros, have aiming difficulties; regular practice with the teaching computer, Pelz maintains, will cure the problem and dramatically improve putting technique.

The TAC, which sells for $1,000 and upward depending on the model, can be plugged into a socket or used outdoors in a battery-powered version. It works this way: a sighting mechanism is employed to align the computer exactly perpendicular to the target—a golf hole or a spot on the home carpet. A small mirror is affixed to the outer edge of the putter blade. When the golfer addresses the ball, the TAC emits a beam of light which is reflected by the mirror back into the computer's optical system. Computer measure-



A related putting aid is The Teacher shown here. The idea is to stroke the ball at the putter's "sweet spot," which is bracketed by metal prongs. Regular practice develops solid impacts for better putting.

Inventor Dave Pelz demonstrates his space-spinoff Teacher Alignment Computer, which helps golfers learn proper putting aim. The close-up at right illustrates how it works. The light beam, reflected into the computer, measures putter alignment and the lights atop the box tell the golfer he is on target (the three green lights) or off to either side and how much.

ment of the beam determines whether the putter is faced on target, or to left or right, at both address and impact. The information is displayed by a row of lights atop the device; a green light indicates perfect alignment, yellow means slightly off and red means far off. Within each color grouping, a specific light points out the degree and direction of misalignment.

The TAC is used by individual golfers, by teaching professionals, by 30 members of the male pro circuit and eight women pros. Here again Pelz has a wallful of testimonials, including many from people whose names are familiar to golfers—Andy North, Jim Simons, Tom Kite, Jerry Pate, Joe Inman, Tom Purtzer, Jan Stephenson, Carol Mann, Hollis Stacey and others. Famed teacher Bob Toski calls the TAC "the best device for teaching putting that I have ever seen." A particular enthusiast is Lee Trevino, who says:

"Before I used the TAC, I never knew *why* I missed a putt. This machine tells you why you hit the ball where it finished. It builds good muscle memory and helps improve your eye-hole coordination, insuring that the blade is square at all times. I feel that my putting has improved dramatically."

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Nikon Camera

The camera pictured, a Nikon FM compact, has a simplification feature derived from cameras designed for easy yet accurate use by Skylab astronauts working in a weightless environment. The innovation is a plastic-cushioned advance lever which advances the film and simultaneously switches on a built-in light meter; with a turn of the lens aperture ring, a glowing signal in the viewfinder confirms correct exposure. The Skylab cameras were developed under NASA contract by Nikon, Inc., Garden City, New York, which later incorporated the advance lever feature in its own product.

Loudspeaker Performance Aid

Hi-fi loudspeakers are electro-acoustical systems which convert electrical current variations into sound. In the process, they generate a lot of heat. In most speakers, the heat is increased significantly when the discotheque operator or home listener turns the volume knob to maximum output. The system's ability to function properly depends to considerable degree on dissipating the heat; an effective method of cooling enhances overall sound reproduction and reduces the incidence of loudspeaker failure.

Many manufacturers of loudspeakers, such as those pictured, are now using a magnetic liquid cooling agent known as ferrofluid, development of which originated in space research. Produced by Ferrofluidics Corporation, Nashua, New Hampshire, ferrofluid is a liquid material in which sub-microscopic particles of iron oxide are permanently suspended. Injected into the voice coil segment of the speaker system, the magnetic liquid serves as a superior heat transfer medium for cooling the voice coil, thus substantially increasing the system's ability to handle higher power levels and decreasing the chance of speaker failure. Ferrofluid offers several additional advantages which add up to improved speaker performance, lower manufacturing costs and fewer rejects.

NASA's ferrofluid research involved work at Lewis Research Center on a magnetic liquid for control of spacecraft liquid propellants under the zero gravity conditions of space. At Avco Research Center, Dr. Ronald Moskowitz and Dr. Ronald Rosensweig were working on an unrelated application of magnetic fluid. They obtained a license for the NASA technology, which served as a departure point for their further development of ferrofluid. They founded Ferrofluidics Corporation, which has significantly advanced the basic technology and developed a line of rotary shaft seals used in such applications as integrated circuit production, computer discs, medical equipment, visual displays, analytical instrumentation, automated machine tools and industrial processes.

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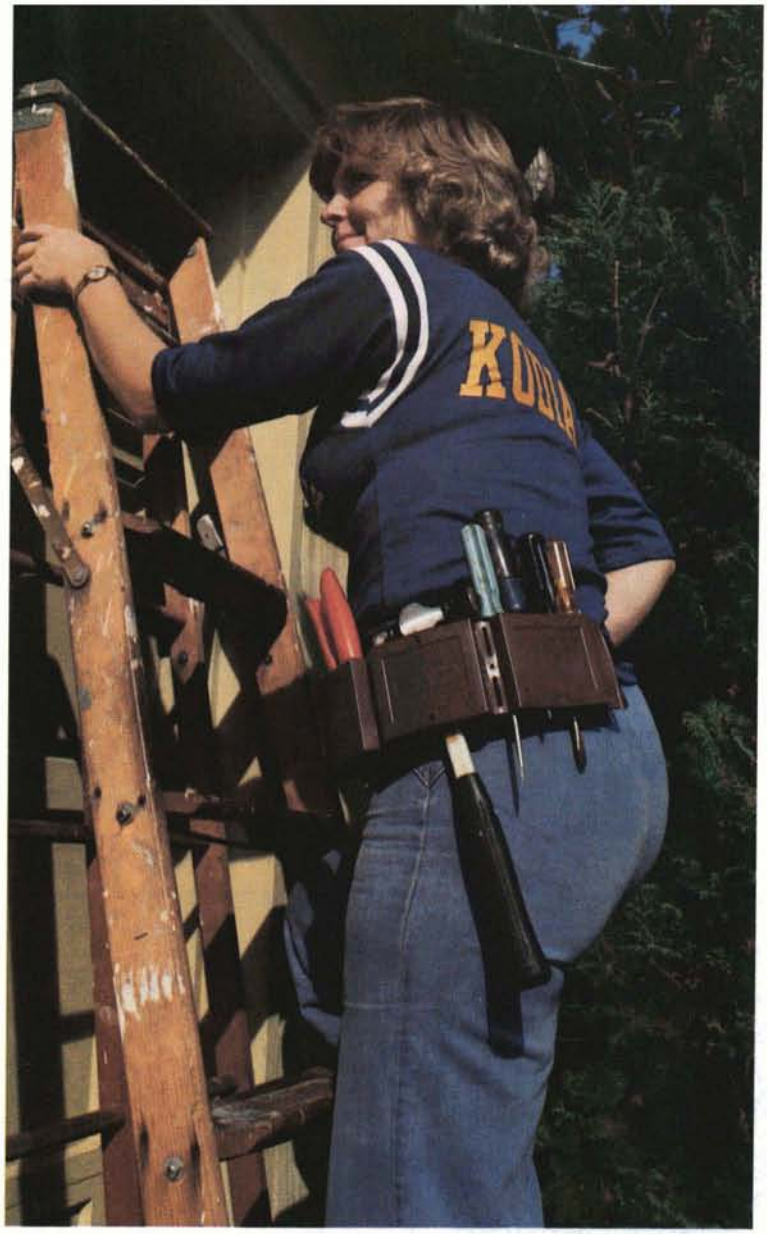

Tool Carrier

The handywoman shown is wearing a spinoff Tool Kaddy manufactured by GC Electronics, a division of Wallace Murray, Inc., Rockford, Illinois. The tool organizer accommodates a selection of hand tools on a waist or thigh belt or, alternatively, on wall, work bench or car trunk mountings. The Tool Kaddy is widely used by industrial maintenance personnel, TV technicians, mechanics, artists, draftsmen, hobbyists and homeowners. Its innovative feature is visible in the closeup photo: rows of flexible vinyl "fingers," like the bristles of a hairbrush, which mesh together to hold the tool securely in place yet allow easy insertion or withdrawal.

The tool carrier was originally designed under NASA contract—by Martin Marietta Corporation's Denver (Colorado) Division—for use by Apollo and Skylab astronauts performing minor repair tasks. The gripping fingers feature was incorporated to prevent tools from "floating" out of their slots in the weightless environment of space. NASA granted Martin Marietta-Denver a patent waiver for commercialization of the tool carrier and Martin Marietta subsequently licensed production rights to GC Electronics.

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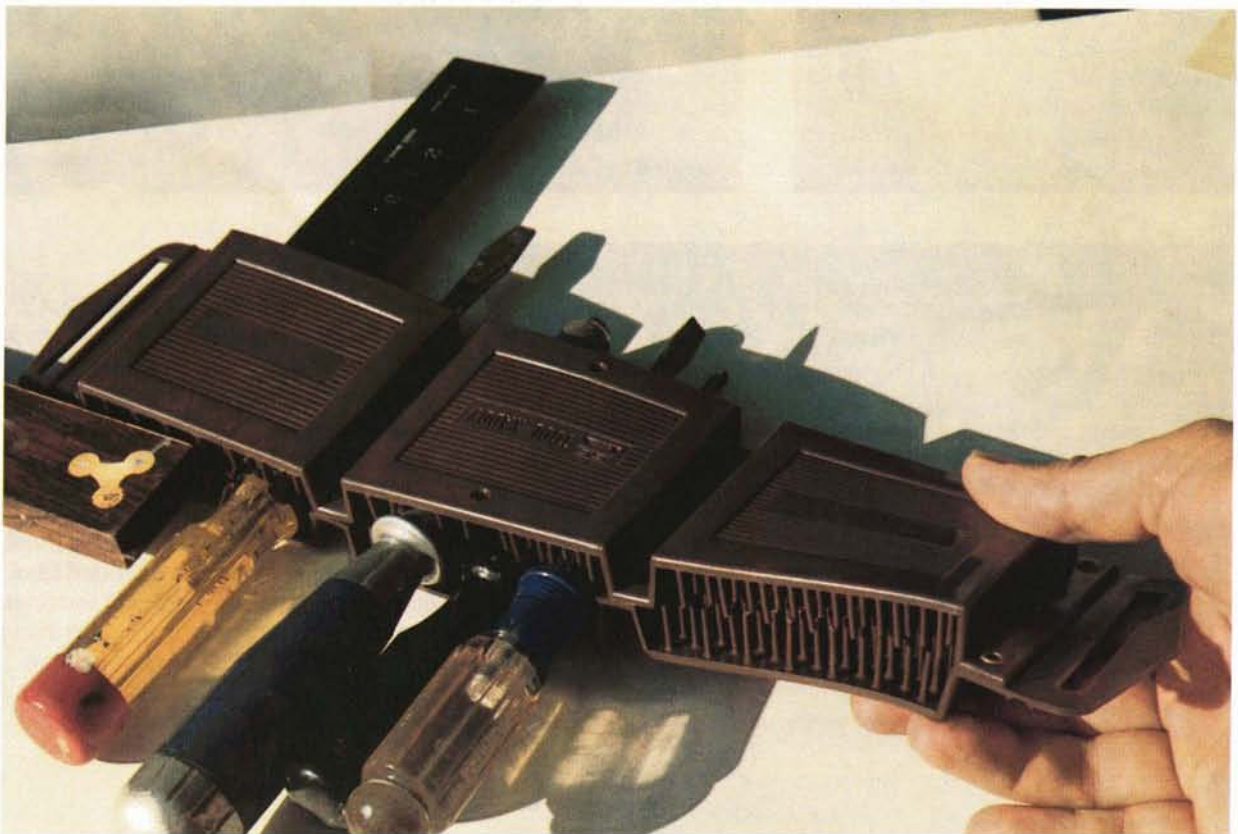

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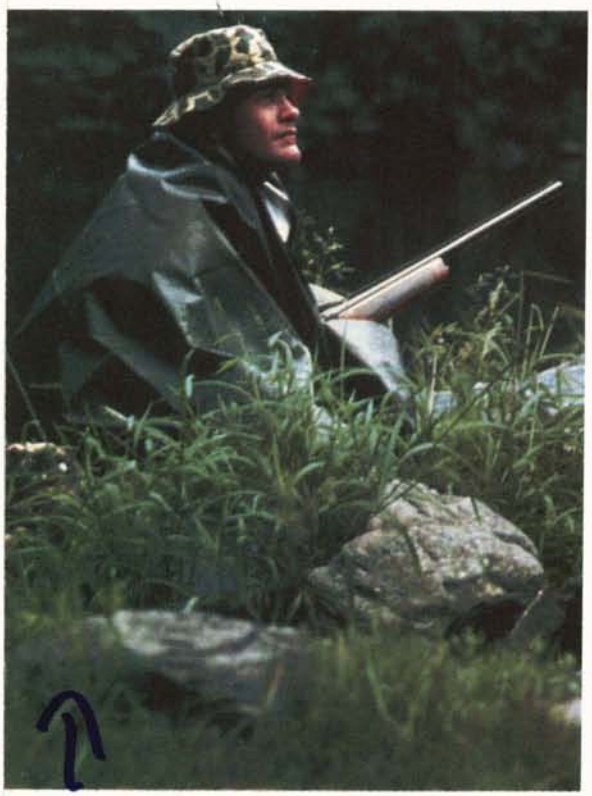

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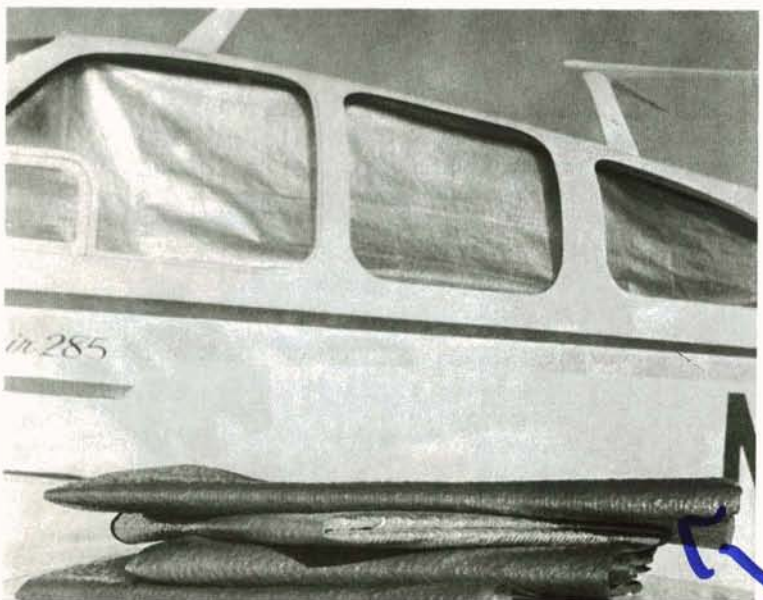

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Metallized Products

Since the early 1960s, virtually all NASA spacecraft have used metallized films supplied by King-Seeley Thermos Company, Winchester, Massachusetts for a variety of purposes, principally thermal radiation insulation (see prologue to Section II, page 52). As a result of its space work, the company has become a leader in research and development of vacuum metallized plastic films and its Metallized Products Division now manufactures a broad line of industrial and consumer-oriented metallized film, fabric, paper and foam in single-layer sheets and multi-layer laminates. King-Seeley markets its own products—through its Thermos® Division, Norwich, Connecticut—and also supplies sheet films and laminates to manufacturers of other products.

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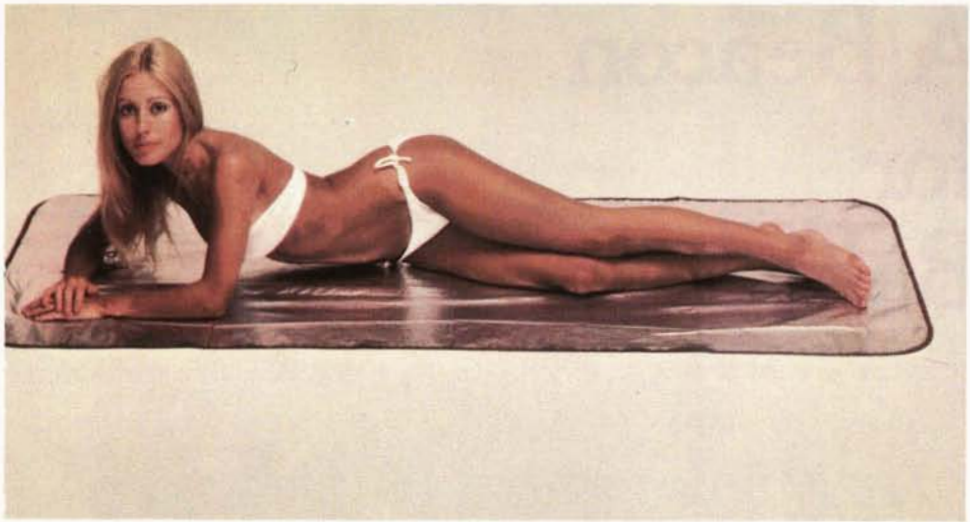

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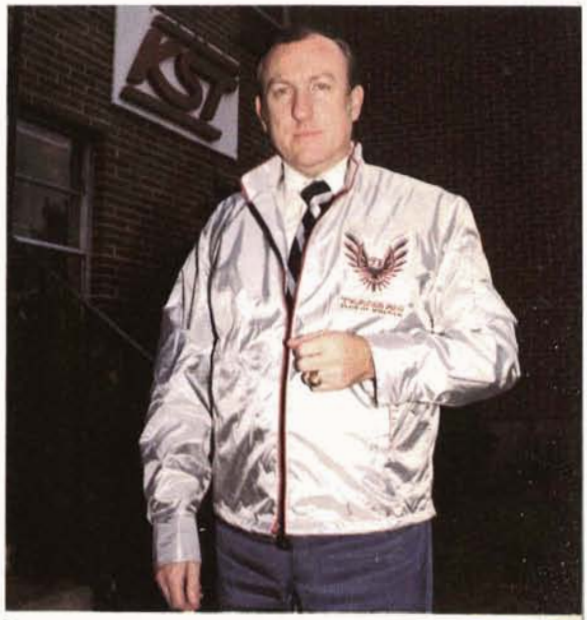

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Shown on these pages are a few examples of the wide range of metallized products. Among those marketed by King-Seeley are the compact, three-ounce Thermos Emergency Blanket (1), which reflects and retains up to 80 percent of the user's body heat, thus helping to prevent post-accident shock (2) or keeping a person warm for hours under emergency cold weather conditions; the blanket was used by all participants in last year's Boston Marathon (3) as a post-race measure to prevent loss of body temperature. Other King-Seeley products include the All-Weather Blanket (4) for outdoor activities, the Even-up Tanning Blanket (5) for faster sun-tanning by reflectivity, and a reflective club jacket (6).

Products sold by other companies include a reversible drapery liner (7), metallized on one side and plain vinyl on the other, which can be turned inward or outward to keep heat in or block it out, depending on the season; the liner is marketed by Wind-N-Sun Shield, Inc., Melbourne, Florida. Among other examples are the Thermacon Heat Screen (8), marketed by Morgan Stanford Aviation, Berkeley, California, which reflects sunlight and protects costly aircraft electronic equipment from heat damage while the airplane is parked; and an award-winning meat packaging design (9) featuring metallized gold film, produced by the Canadian packaging firm Condor Laminations, Agincourt, Ontario.

® Thermos is a registered trademark of King-Seeley Thermos Company.

A Beacon for Baltimore

NASA's community service effort, designed to promote technology awareness, is exemplified by a ship-tracking satellite beacon for monitoring the voyages of Baltimore's goodwill clipper

Last spring, the square-rigged schooner *Pride of Baltimore* failed to make a scheduled stop at Norfolk, Virginia on its goodwill tour of the United States. For several days, officials of the City of Baltimore—which owns the reconstructed 19th century clipper ship—tried without success to make contact with the *Pride*. Ships and aircraft of the Coast Guard, Navy and Air Force searched the Atlantic but failed to locate the schooner. She was feared lost.

After eight days out of touch, the *Pride* sailed into Delaware Bay intact, its crew unaware of the widespread concern about its fate. The *Pride*, reported Captain Charles F. Whitcomb, had been driven off course by severe storms, thus was unable to meet its schedule of port appearances. The ship's navigational system had been in good working order and her skipper knew the *Pride's* position at all times. Efforts to make contact had failed because the schooner had been blown beyond the relatively short range of the ship's radio equipment. So the *Pride* had not really been in serious trouble, but Baltimoreans had nonetheless been alarmed.

"That will not happen again," says Thomas F. Norton, executive director of Baltimore Operation Sail, Ltd., a non-profit corporation jointly financed by the City of Baltimore and private companies. Norton's organization operates the ship under a charter arrangement; it is used as a floating ambassador of goodwill to promote Baltimore's industries and tourism through open house inspections and business receptions held on board at the *Pride's* many ports of call.

The reason it will not happen again is that the ship is now equipped with a NASA-developed satellite beacon installed by Goddard Space Flight Center, a neighbor of Baltimore. The simple 10-pound beacon, affixed to the *Pride's* mainmast, allows Baltimore Operation Sail to keep track of the ship on its voyages to distant places. Once every minute, the compact, battery-powered unit sends a radio signal to NASA's Nimbus-6 research satellite. Nimbus relays the signals to Goddard, where the frequency shift of successive signals provides information for computing the ship's latitude and longitude.

Soon after its installation on the *Pride*, the beacon had an opportunity to demonstrate its utility. Returning from a tour of the Great Lakes and the St. Lawrence Seaway, the ship was overdue for a scheduled appearance at Stamford, Connecticut. It was hurricane season and storms were reported along the east coast of the United States, so Baltimoreans were once again concerned. Although the *Pride* now has a long-range radiotelephone—a gift from a business firm—Operation Sail's Norton was unable to contact the ship because of weather-induced radio interference. So he called Goddard Space Flight Center, requested a position fix and got it promptly; the *Pride*, it turned out, was sitting out a storm in

High on the mainmast of the clipper Pride of Baltimore, *crew members are installing a NASA-developed satellite beacon which enables continual tracking of the ship as she roams the seas on goodwill tours.*

another Connecticut port. The beacon has been extremely useful on many other occasions, Norton reports. When he has no urgent need to communicate with the ship but simply wants to know it it is maintaining schedule, a call to neighboring Goddard gets him a quick answer far less expensively than if he used the high seas radiotelephone.

The satellite beacon, manufactured by Handar, Inc., Santa Clara, California, was originally developed by Goddard for a major meteorological experiment in which Nimbus-6 gathered data from hundreds of instrumented balloons. It has since been used in a variety of spinoff applications, for example, tracking the Double Eagle II on the first successful balloon crossing of the Atlantic in 1978. It has also been used to track explorers and scientific expeditions in remote areas; on icebergs to predict drift routes as an aid to shipping; on buoys to trace current patterns for oceanographic and environmental studies; and as a means of following polar bears in their Arctic wanderings.

Use of the beacon aboard the *Pride of Baltimore* exemplifies a special area of NASA's technology transfer program: service to communities through demonstration of advantageous technology in the interests of broadening technology awareness. Such services—to community groups, state and local governments, medical institutions and other organizations—are intended to show how the application of new technology may help solve major problems or provide better ways of meeting public needs, thereby inspiring community sponsorship of beneficial technology applications.

The Pride of Baltimore, *a modern representation of the fast clipper ships that operated from Baltimore harbor in the 18th and 19th centuries.*

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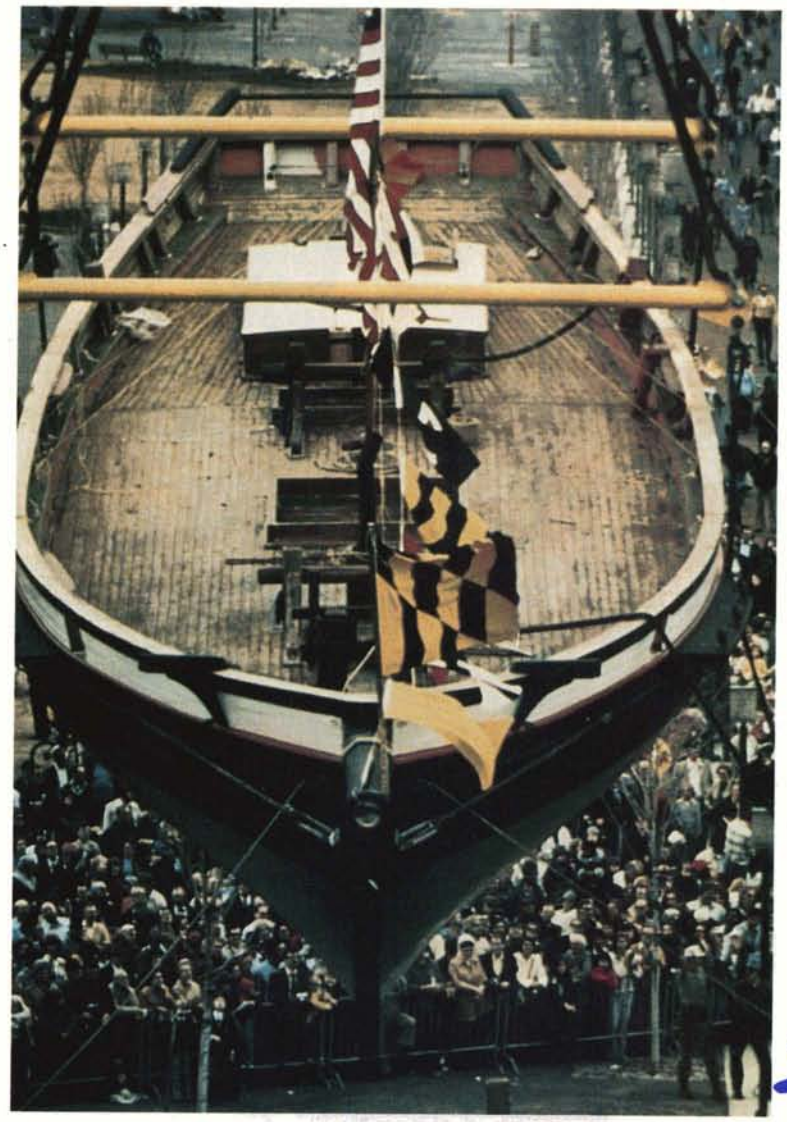
At Baltimore's Inner Harbor, the Pride *was launched in February 1977, crane-lowered into the water for later completion of her rigging and stowing of ballast; she was commissioned in May 1977. Built and owned by the City of Baltimore, financed by public funds and by contributions from business and civic organizations, the ship serves as a roving promotional vessel for the Chesapeake port city.*



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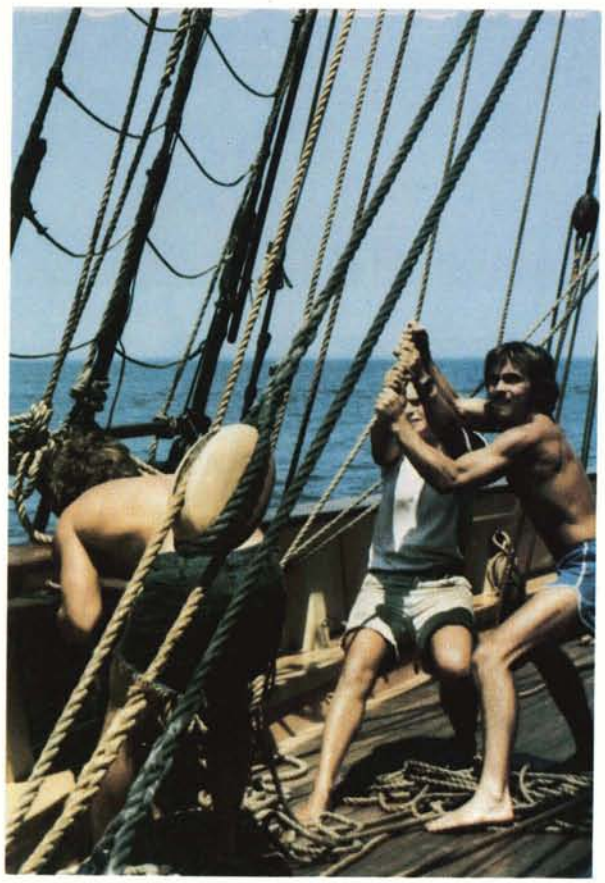

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Visiting scores of ports annually, the Pride of Baltimore *promotes the city's industry, tourism and convention business through open house days and private receptions on board wherever she sails. The* Pride's *crew is made up of young men and women, few beyond their mid-twenties, who live and work in the manner of privateer sailors of the War of 1812 era.*

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Emergency Medical Service

The city of Akron, Ohio now has an operational telemetry-aided Emergency Medical System (EMS) which eventually will include all of Summit and Portage counties in northeastern Ohio. Lewis Research Center helped design the complex EMS communications system, including the telemetry link between ambulances and hospitals for advanced life support (paramedic) services.

Extensively used in space operations, telemetry is the process wherein instrument-acquired data is translated into radio signals and sent to a receiving station where the signals are decoded and recorded. In emergency medical use, it allows transmission of physiological data—an electrocardiogram, for instance—from an ambulance to a hospital emergency room, where a physician reads the telemetered information and prescribes emergency procedures to ambulance attendants caring for the patient.

In Akron—and throughout the U.S.—there are only eight radio frequencies available for transmission of EMS advanced life support data, which creates the possibility of signal interference that might disrupt relay of an emergency patient's vital signs. Thus, one of Lewis Research Center's major tasks was development of a coordinated system in which each EMS unit and medical facility is routed to a frequency that can best be utilized at the moment without causing mutual interference with another station on the same frequency. The Lewis-designed system also includes provisions for central recording of all radio and telephone transmissions and defines strategic placement of antennas to eliminate radio "dead spots."

Another Lewis assignment was design of an electronically controlled and illuminated status board for the Akron Fire Department Communications Center (left), which serves as the regional communications control center for the eventual two-county system. The status board is essential to monitoring availability of all fire equipment, EMS vehicles and private ambulances; it also indicates the status of hospital emergency rooms in the area. Shown in closeup below, the status board is continuously posted on three electronic panels by fire department personnel. Lewis Research Center's Akron effort is a continuation of earlier, similar assistance provided other Ohio communities.

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Book Preservation

For several years, space vacuum chambers operated by NASA contractors—normally used to test spacecraft components—have been employed in a spinoff service: drying water-damaged books and other documents. In a program sponsored by the Library of Congress, the space chamber shown at left—operated by General Electric Company's Space Division, Valley Forge, Pennsylvania—is being used in a different but related manner; it is a facility for neutralizing the deterioration-causing acid content of valuable books in order to prolong their useful lives. Books produced since 1850 have a very high acid content, hence a shorter life expectancy than prior-published volumes. A means of "deacidifying" books on a large, economically-viable scale is of great interest, particularly to the research library community, which stores millions of valuable, often irreplaceable documents.

After years of research, the Library of Congress Preservation Office has developed an effective technique now considered ready for commercial application. The best deacidification agent found is diethyl zinc (DEZ), a highly volatile substance used as a catalyst in the chemical industry. The photo at upper right shows Library of Congress researchers carefully extracting DEZ from a sealed container in preparation for a deacidification test; they are working in a "fume hood" which would draw off the flame and noxious smoke that would result if DEZ were exposed to oxygen.

The General Electric vacuum chamber used in deacidification tests serves a dual purpose: it creates an environment in which the DEZ can do its job without the presence of oxygen, and it also dries the books, a preliminary step in the process; the extremely low pressure in the chamber causes evaporation of moisture. After the drying phase, DEZ is introduced to the chamber as a paper-penetrating vapor. The complete process typically takes eight days, four days for vacuum drying and four days of book exposure to DEZ.

Accelerated aging tests showed that the process can extend paper life almost fourfold. Deacidification has no detrimental effect on the paper, even on colored illustrations, as shown at right; half of the map was DEZ-treated, the other half not, and there is no difference in color. Library of Congress officials estimate that the process can be applied for less than three dollars per volume. The first commercial application is expected in 1980.

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MAR DO NORTE
IRLANDA DO NORTE
REINO UNIDO
INGLATERRA
GALES
DINAMARCA
MAR BÁLTICO
HOLANDA
ALEMANHA
REPÚBLICA DEMOCRÁTICA
BÉLGICA
REPÚBLICA FEDERAL
POLÔNIA
TCHECOSLOVAQUIA
FRANÇA
SUÍÇA
ÁUSTRIA
HUNGRIA
ROMÊNIA
IUGOSLÁVIA
BULGÁRIA
ITÁLIA
ALBÂNIA
MAR ADRIÁTICO
MAR LIGÚRICO
CANAL DA MANCHA
GOLFO DE LYON
MAR BALEARES
CÓRSEGA
ANDORRA
MÔNACO
SÃO MARINHO
CIDADE DO VATICANO
VARSÓVIA
BERLIM
PRAGA
VIENA
BUDAPESTE
BELGRADO
BUCARESTE
SOFIA
ROMA
PARIS
LONDRES
COPENHAGUE
BONN
Bremen
Hamburgo
Stuttgart
Munique
Frankfurt
Nuremberg
Estrasburgo
Lyon
Marselha
Toulouse
Bordéus
Nantes
Orléans
Dijon
Le Havre
Rouen
Reims
Barcelona
Valência
Nápoles
Gênova
Milão
Turim
Florença
Veneza
Trieste
Zagreb
Split
Sarajevo
Tirana
Skopje
Istambul
Constantinopla
Constança
Varna
Burgos
Kiev
Minsk
Riga
Kaunas
Gdansk
Poznan
Lublin
Cracóvia
Bratislava
Debrecen
Cluj
Iasi
Odessa
Brest
Kaliningrado

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Property Measurement

The van pictured is used by Land Inventory Systems, Inc., Newport, New Hampshire, to measure and map property for tax assessment purposes. A state law requires that all New Hampshire towns have tax maps and communities are looking for the most accurate property measurements attainable in order to maximize tax revenue. Specially designed to meet that need, Land Inventory's van employs technology adapted from the navigation system of the Lunar Rover, the wheeled vehicle in which moon-exploring astronauts traveled as much as 20 miles from their Lunar Module base.

The astronauts had to know their precise position relative to the Lunar Module at all times, so that in case of emergency they could take the shortest route back. The Lunar Rover's computerized navigation system kept a highly accurate record of the directional path and the distance traveled from the Lunar Module, thus providing a continuous position report. The distance measuring subsystem was a sophisticated and far more accurate counterpart of the odometer on an automobile, which counts the revolutions of the wheels. Encoders on a wheel of the Lunar Rover generated electrical pulses for each fractional revolution and the computer analyzed the pulses to determine the distance traveled in a given direction.

The distance measuring technique is the portion of the Lunar Rover navigation system adapted to property measurement. Land Inventory's van has encoding equipment on the left rear wheel (see photo). The encoders generate 180 pulses for each revolution of the wheel and a computer inside the van translates the pulse data into distance traveled with an accuracy of one-half inch in 500 feet.

Technology Transfer

A description of the mechanisms employed by NASA to encourage and facilitate new applications of aerospace technology

Putting Technology to Work

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

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. The instrument of this objective is the Technology Transfer Program.

The program's aim 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 effort embraces two major areas: (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 is a means of acquiring voluminous information about Earth's surface. When combined with information from conventional sources, satellite data offers vast potential for more effective management of Earth's resources. The Technology Transfer Program 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 the technology utilization element of the program, 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 reapplications. The mechanisms employed to meet program objectives include:

- Liaison and awareness activities with regard to remote sensing applications, whereby NASA establishes relationships and maintains two-way communications with the user community.
- The Applications Systems Verification and Transfer (ASVT) program, which involves representative demonstrations of remote sensing technology to verify processes, techniques and institutional approaches for the use of satellite data in specific applications.
- The Regional Remote Sensing Applications Program, designed to promote transfer of proven, low-risk remote sensing applications—already verified by ASVTs and other research and development programs—to a broader user community.
- The University Applications Program, an instrument for building university remote sensing capabilities, thereby creating additional sources of expertise for conducting research, training personnel and stimulating interest among state and local users.
- Applications engineering projects, wherein NASA, in cooperation with the private sector, undertakes adaptation of existing technology to specified needs of government agencies and public sector groups.
- Application teams, multidisciplinary groups of technologists who provide technology-matching and problem-solving assistance to public sector organizations.
- A network of dissemination centers, channels through which industrial firms and other organizations interested in secondary utilization of technology may avail themselves of NASA scientific, technical and management expertise.
- Publications and announcement media, designed to acquaint potential users with available technologies emanating from aerospace research and development.
- A specialized center which provides aerospace-developed and other government-generated computer programs adaptable to the needs of industry and government agencies.

Members of the SRI International application team inspect a model used in road vehicle crash impact studies. Problem-solving application teams represent one of several mechanisms employed to promote technology transfer.

Remote Sensing Activities

Satellite remote sensing offers extraordinary benefit potential in a great many areas—for example, agricultural inventories; land, water and forest resources management; monitoring urban growth patterns; mapping; flood study; and a variety of environmental/ecological applications. It is being used for these and other purposes by a growing number of private sector and government organizations, the latter including federal, state, regional and local agencies.

The Technology Transfer Program seeks to expand the potential benefits of remote sensing by establishing liaison with users and prospective users to generate greater awareness of the technology. Awareness is promoted through university programs, symposia, workshops, publications and direct contact with personnel of organizations which might employ remotely-sensed data to advantage.

A major mechanism is the Applications Systems Verification and Transfer project, or ASVT. Conducted in cooperation with a representative user organization, the ASVT is a demonstration of technology proven by two earlier steps in the transfer cycle: NASA research and development of concepts for specific applications, and Applications Pilot Tests which prove these concepts. ASVTs are undertaken when there is evidence of real user need, where the demonstration may inspire operational use of the technology, and where the potential benefits justify the demonstration. The emphasis in projects of this type is on adaptive engineering—refining the technology to make it compatible with the user's equipment and institutional environment, and working to reduce the cost to the user of operational employment of the technology.

NASA maintains continuing two-way communications with active users, keeping 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 natural and man-made resources. Nearly all of the 50 states have used remote sensing to some degree; a number of them have set up their own operational systems for extracting and employing information derived from satellite data. Technology Transfer Program personnel maintain direct contact with state officials and also make use of two other national channels as an aid to identifying user needs and acquiring feedback: the National Conference of State Legislatures and the National Governors Association.

Regional Program

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.

Ames Research Center, Moffett Field, California deals with user organizations in 14 western states, including Alaska and Hawaii. NASA's National Space Technology Laboratories, NSTL Station, Mississippi serves 17 states in the midwest, south and southeast. Goddard Space Flight Center, 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.

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 beginning 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.

University Program

Employed primarily as an instrument for building university capabilities in remote sensing, the University Applications Program is complementary to, but somewhat different from, such other user development activities as ASVTs or regional programs. Through grants to universities, NASA seeks to develop new sources of remote sensing expertise within the states, with the goal of facilitating independent state or local government use of the technology. NASA funds about 20 university programs a year and endeavors to spread the funding geographically, with the ultimate aim of creating university capabilities in all the states.

The university applications group is composed of faculty members and graduate students representing a number of different scientific/technological disciplines. It has a threefold assignment: to stimulate interest among prospective users of satellite-derived information; to conduct the research and development necessary to adapt remote sensing technology to solution of a specific problem; and to demonstrate the applicability of the technology. The groups search—within their states and usually at the sub-state level—for urgent problems which seem capable of solution by application of remote sensing techniques. Applications selected for demonstration are those which have not previously been tested and which, if successful, may inspire further use of the technology demonstrated. Projects are conducted on a one-time-only basis under NASA grant funding, but a successful application often results in follow-on projects of a similar nature, carried out with state funding or supported by user fees.

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, 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.

An example of an application team effort is the technical assistance provided the Metropolitan Dade County (Florida) Office of Transportation Administration (OTA) in the design phase of the 21-mile Greater Miami Metrorail rapid transit system, which is now under construction (below) and scheduled for operational service in 1983. NASA participation stemmed from discussions between OTA and Kennedy Space Center regarding applicability of NASA technology to the Metrorail project. Subsequently, the Technology Applications Team at SRI International, Menlo Park, California initiated a program to apply NASA engineering and management technology to Metrorail problem areas. SRI assigned an experienced, NASA-trained engineer to serve as full-time representative to OTA. His job was to examine transit design problems; identify areas where NASA had already achieved applicable solutions or could bring its general expertise to bear; contact the appropriate NASA center; and relay the information acquired to OTA. In the bottom photo, the NASA representative (left) is shown conferring with an OTA official.

From 1977 until NASA participation was concluded in 1979, the representative investigated and forwarded to OTA information on such management methodologies as risk and configuration control, and such hardware technologies as anti-corrosion

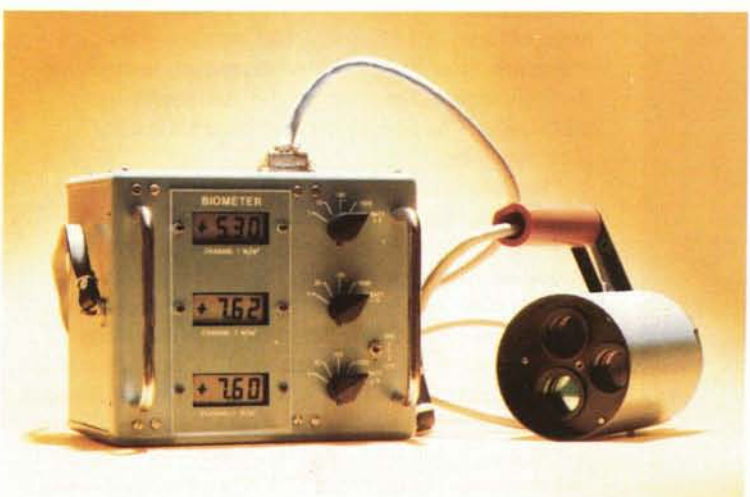
measures, fire and lightning protection, solar energy utilization and materials selection. When Dade County approved recommended actions in these and other areas, they were implemented with further NASA assistance supplied by scientists, engineers and managers from NASA field centers. This technology approach was described by OTA's Director of Transit System Development as one that "appears to have both workability and merit."

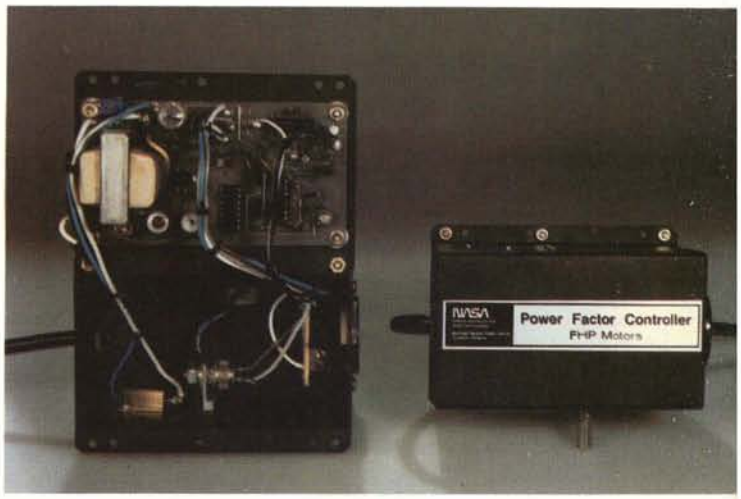
Another technology application example is a ground use adaptation of satellite remote sensing techniques, a nondestructive method of acquiring status information about agricultural crops. Called the Three-band, Hand-held Radiometer, the device is being developed by Goddard Space Flight Center in a cooperative NASA/U.S. Department of Agriculture project.

Shown below, the battery-powered system consists of a sensor which measures electromagnetic radiation reflected from plants and a biometer which provides a digital readout of radiation intensity. For examining taller crops, such as corn and sugar cane, the sensor can be mounted on an extension pole as pictured at right.

The instrument measures radiation in three wavelength bands—red, infrared and near-infrared—each sensitive to particular plant characteristics: chlorophyll concentration, leaf density and water content. The radiometer's readings provide a basis for determining the health status and yield potential of the crop canopy, the aboveground portion of a plant. Compared with current "eyeballing" methods, the system offers a more objective means of monitoring crop condition, assessing the degree of plant stress induced by drought, estimating crop green leaf area and predicting crop yield. The radiometer will be undergoing extensive field testing this year on different crops in a number of locales, by NASA, Department of Agriculture and university researchers.

A third example is an energy-saving device called the Power Factor Controller (right) invented by a Marshall Space Flight Center engineer as a means of reducing power wastage in alternating current (AC) induction motors. In this type of motor, a substantial percentage of the power consumed is cast off in the form of heat, hence wasted. The wastage is caused by the current flowing through the motor, the amount of which is established by the fixed voltage—120 volts in most American homes—on which the motor operates. Power companies supply 120 volts because that is the voltage needed by common household motors to pull the heaviest loads they are designed to carry. A motor usually does not operate under full load conditions, but even when it is idling it is still getting 120 volts; this creates essentially the same current flow and resulting heat loss experienced when the motor is working hard. In short, the AC motor does not always need 120 volts since its actual voltage need varies with the amount of work it is doing. But with voltage being supplied at the fixed level to multimillions of motors in the United States, the cumulative power wastage is of enormous order.





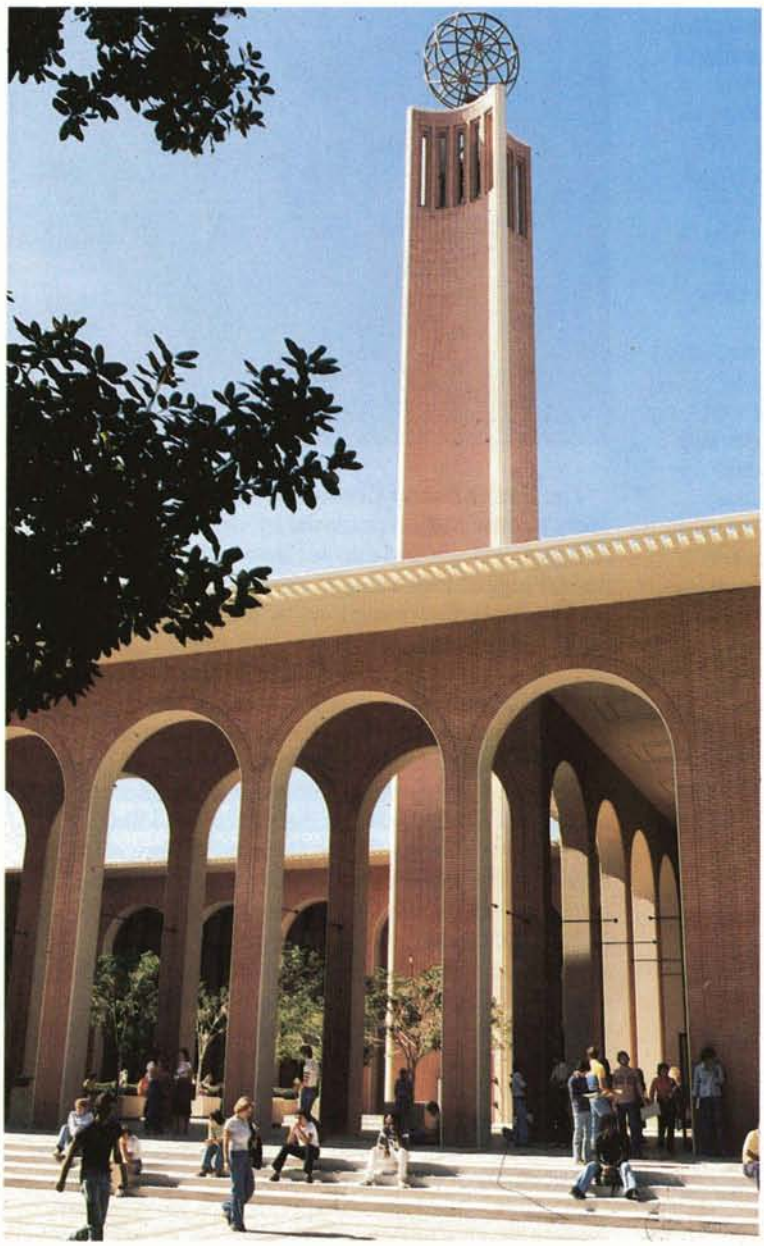
The Power Factor Controller offers extraordinary energy conservation potential by virtue of its ability to match voltage and current flow with the motor's need. Plugged into a motor, the device can continuously determine load by sensing shifts in the relationship between voltage and current flow. When the controller senses a light load, it cuts the voltage level to the minimum needed, which in turn reduces current flow and heat loss. Laboratory tests showed the device capable of reducing the amount of power used by up to 6-8 percent under normal motor load and up to 65 percent when the motor was idling.

The Power Factor Controller concept originated in Marshall Space Flight Center's solar heating and cooling work for the Department of Energy (DoE). DoE plans extensive laboratory testing and a service-use test of the controller in a large textile manufacturing facility which has hundreds of electric motors. Under technology utilization funding, NASA is conducting further development to broaden the potential of the device by increasing its reliability, reducing its size and expanding the types of motors to which it can be applied. NASA has approved about 100 licensees for manufacture of the Power Factor Controller and additional applications for licenses are pending for both domestic and foreign markets.

Dissemination Centers

To promote technology transfer, NASA operates a network of dissemination 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) affiliated with universities 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 NASA expertise and ongoing research and engineering with client problems and 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. Almost two million



of these documents are contained in the NASA data bank, which includes reports covering every field of aerospace-related activity plus the continually updated contents of 15,000 scientific and technical journals.

Intended to prevent wasteful duplication of research already accomplished, the IACs 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, 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 appropriate data banks 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 to the company's best advantage. The IACs charge a nominal fee for their services.

The 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.

Publications

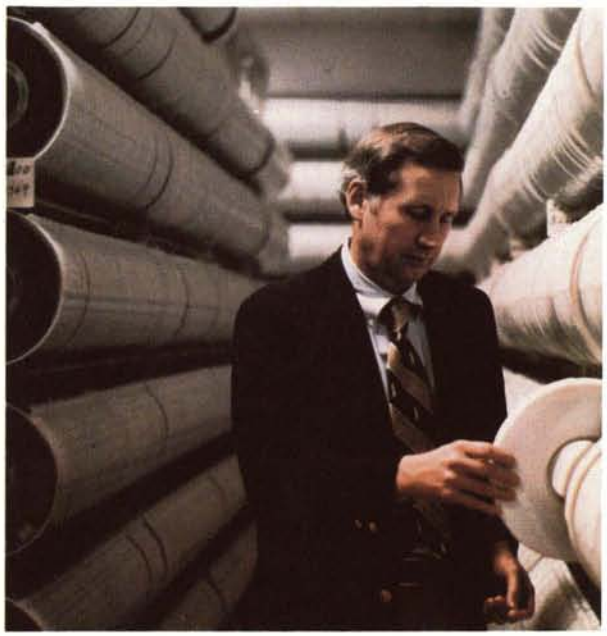
An essential step in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This is accomplished by means of several types of publications.

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 or problem-solving tools for its more than 60,000 industrial subscribers. Each issue contains information on approximately 150 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

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 almost 200,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader secondary use of NASA technology.

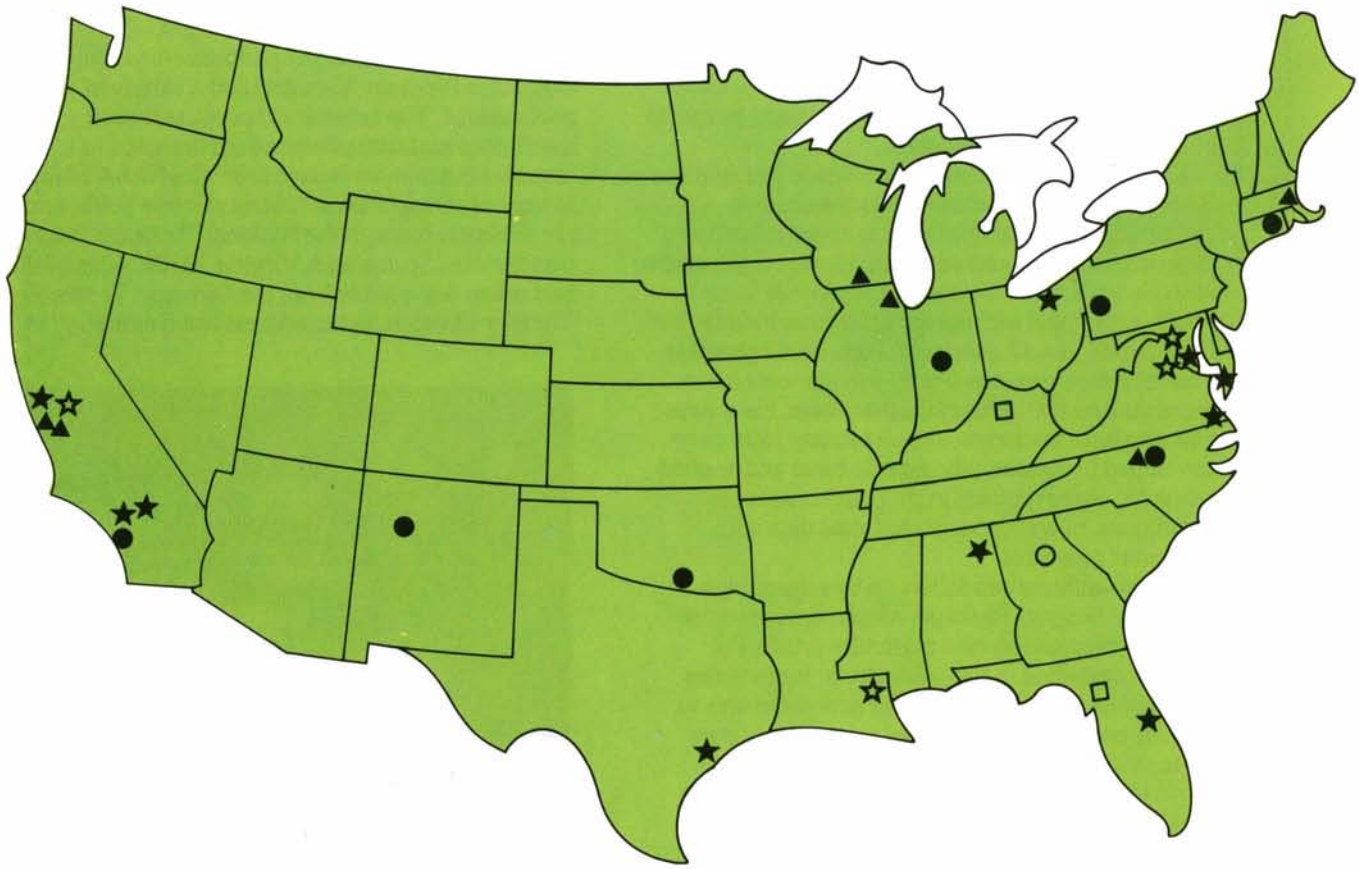
Subscription to Tech Briefs is free to engineers in U.S. industry, business executives, state and local government officials and other qualified technology transfer agents. The publication may be obtained by writing to the Director, Technology Transfer Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240.

NASA also publishes the announcement bulletin Computer Program Abstracts 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. Most of these publications are available through the National Technical Information Service, Springfield, Virginia 22161. A list of titles and prices 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 on COSMIC's services, contact the director at the address listed on page 146.



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.

For specific information concerning the activities described above, contact the appropriate technology transfer personnel at the addresses listed on the following pages. 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 8757, 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 Office: *Gussie Anderson (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 Utilization 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. 422

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

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

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, Ext. 201

Resident Office
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Technology Utilization Office: *John H. Warden*
Phone: (213) 354-4909

Regional Remote Sensing Applications Centers

Ames Research Center
Moffett Field, California 94035

Chief, Technology Applications Branch:
Dale Lumb, Ph.D.
Phone: (415) 965-5900

Goddard Space Flight Center
Greenbelt, Maryland 20771

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

National Space Technology Laboratories
Earth Resources Laboratory
NSTL Station
Mississippi, 39529

Chief, Technology Transfer Group: *Roy Estess*
Phone: (601) 688-2042

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
1201 East 38th Street
Indianapolis, Indiana 46205

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

Kerr Industrial Applications Center
Southeastern Oklahoma State University
Durant, Oklahoma 74701

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

NASA Industrial Applications Center
701 LIS Building
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Paul A. McWilliams, Ph.D., executive director
Phone: (412) 624-5211

NASA Industrial Applications Center
University of Southern California
Denny Research Building
University Park
Los Angeles, California 90007

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

New England Research Applications Center
Mansfield Professional Park
Storrs, Connecticut 06268

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

North Carolina Science and Technology Research Center
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
2500 Central Avenue, S.E.
Albuquerque, New Mexico 87131

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

State Technology Applications Centers

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

Ronald J. Thornton, director
Phone: (904) 392-6626

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

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

Computer Software Management and Information Center

COSMIC
112 Barrow Hall
University of Georgia
Athens, Georgia 30602

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

NASA Biomedical Application Teams

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

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

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

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

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

NASA Technology Application Teams

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

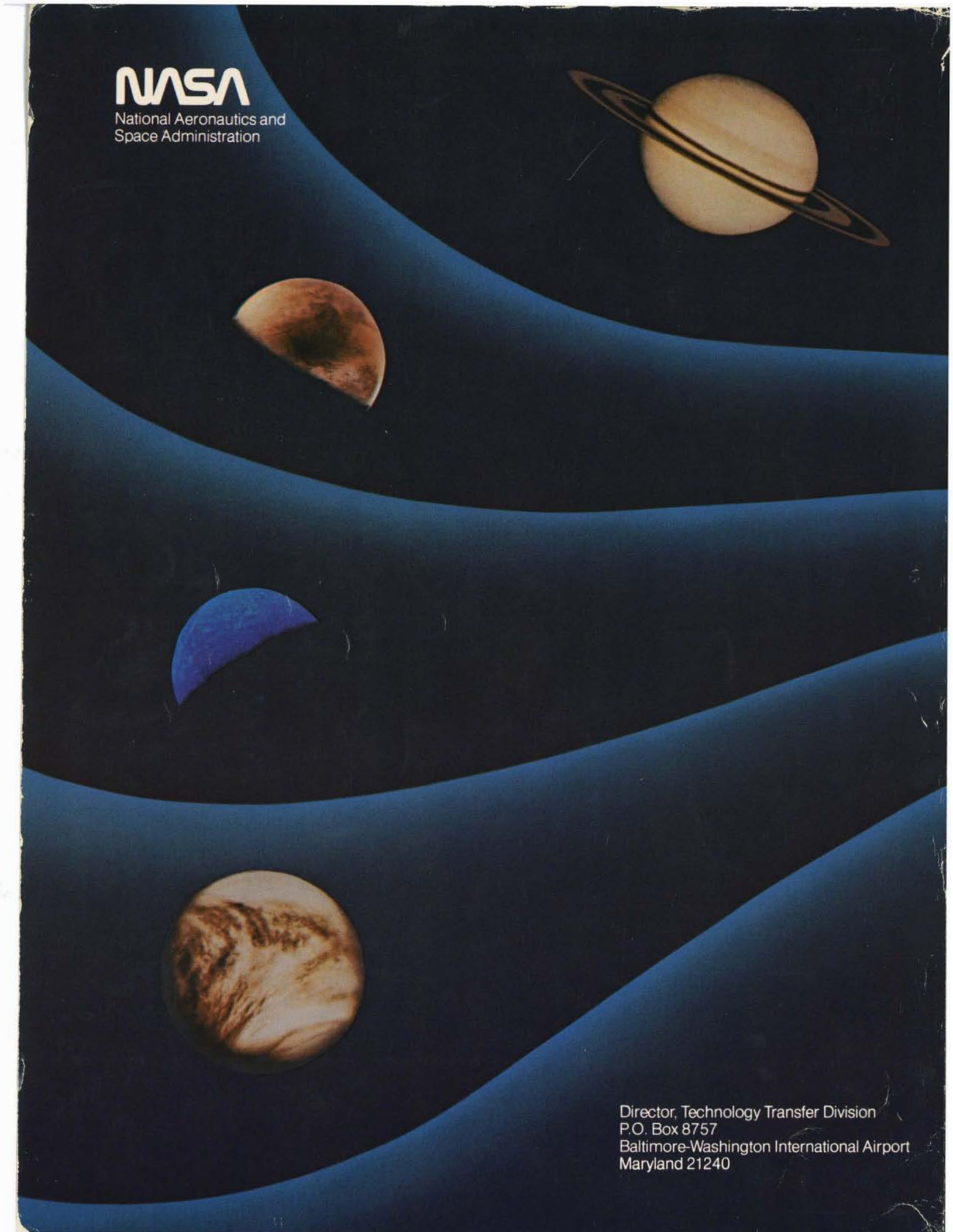
Edmund R. Bangs, director
Phone: (312) 567-4191

SRI International
333 Ravenswood Avenue
Menlo Park, California 94026

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

Technology + Economics, Inc.
2225 Massachusetts Avenue
Cambridge, Massachusetts 02140

David J. MacFadyen, director
Phone: (617) 491-1500



NASA
National Aeronautics and
Space Administration

Director, Technology Transfer Division
P.O. Box 8757
Baltimore-Washington International Airport
Maryland 21240