Spinoff 1976

A BICENTENNIAL REPORT

NASA

National Aeronautics and
Space Administration

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National Aeronautics &
Space Administration
Technology Utilization Office

by Neil P. Ruzic, National Space Institute

SP5121

TECHNOLOGY UTILIZATION PROGRAM REPORT

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This report is divided into three sections: 1. The Research Payoff, 2. Technology Twice Used, and 3. Technology Utilization at Work. The first describes a wide variety of current space spinoffs of use to you in your business or personal life, as well as the space explorations from which they have been derived. The second provides information on specific examples of technology transfer that are typical of the spinoffs resulting from NASA's Technology Utilization Program. The third briefly describes the different activities of the Technology Utilization Office, all of which have as their purpose the profitable utilization of aerospace technology. Please address inquiries to the director, Technology Utilization Office, NASA Scientific & Technical Information Facility, P.O. 8756, Baltimore/Washington Airport, Md. 21240.

foreword

As we celebrate our bicentennial year, we reflect upon the dramatic changes our nation has undergone during these two centuries. From a nation dependent upon Europe for its machinery and technology, we have grown to a position of preeminence that is the envy of the world. Our space program has been a demonstration of that preeminence.

Looking ahead, it is apparent that we cannot rest if we are to maintain our leadership. Other countries are rising rapidly to challenge our lead. Meeting this challenge requires all available resources—and technology is one of our primary national resources.

NASA's technology utilization program has been developed to assure that the benefits of technology are available to all sectors of our national economy. The process of space transfer began as an experiment. Written into the law that created NASA in 1958, the space agency was called upon to provide "the most effective utilization of the scientific and engineering resources of the United States." Could technology developed for one use be applied successfully to other fields? Would it pay for itself in time? Nothing of this scope had been tried before.

The mission of NASA was civilian from the start. Its primary goal, to explore space, already has made significant contributions to improved communications, weather forecasting, and to our understanding of the universe.

Its secondary mission, although less well-known, also has been successful. Technology developed by NASA has been applied to thousand of products and processes throughout the nation. Successful applications grow each year. But we believe that much more can be done to improve the transfer process, and are dedicated to making it happen.

Transfers of aerospace technology to non-aerospace use are all around us. And—yes—they have more than paid for the cost of space exploration. Describing these benefits, and how they affect Americans in this 200th anniversary year, is the purpose of this report.

Edward Z. Gray,
assistant administrator
Industry Affairs and Technology Utilization Office
National Aeronautics & Space Administration
January 1976

Spinoff 1976

a bicentennial report

Space exploration is a self-funding pursuit of the unknown, the most potential-filled endeavor in history.

The Research Payoff

the spinoff stimulus

Not only have men climbed the lunar craters. Not only have robot spaceships measured other planets. Most space benefits accrue directly to us on our own planet.

Today we educate the world via communications satellites. We prospect for oil with land-resource satellites. We keep the tundra frozen with spacecraft-derived heat pipes, making the Alaskan pipeline possible. Our damaged hearts are run by pacemakers, our ailments diagnosed by computer. Highways are grooved to prevent skidding. Bridges soon may be protected from corrosion. Better lubricants, more powerful solar cells, more efficiently designed railroad cars have been spun from space technology. Thousands of technical innovations are the payoff after 18 years in space.

Examples of how our national investment in space research and technology pays off will be described here, first as social, political, and economic stimuli and then in the exploration of space for its own purposes. The "research payoff" continues with current cases of space spinoffs that affect your job, your health, your mobility, your home, your environment, and your future.

Technology: currency of foreign affairs

Few human undertakings in the modern world are so important as the development of technology. And yet few subjects are so little understood. When you think of technology you think of machines. But it should be emphasized that technology, or the practical utilization of science, today is applied outside of industrial life too. Consider, as a start, how space technology has been spun off to improve our relationships with other countries.

Technology—of which the space program has become a leading generator—is now a currency of foreign affairs. It is a tool of advanced nations and a hope for underdeveloped ones. The National Aeronautics & Space Administration has helped at least 75 countries by exchanging technical information, launching their satellites, sharing communications and data derived from our own satellites, and conducting foreign experiments on our spacecraft.

Pace setters in a free society

A free society needs pace setters in multiple activities. The alternative is mediocrity. No other technological endeavor has set—and met—as high standards as are required in the space program. The term "zero defects" is an invention of space technology in which machines must function perfectly in the almost impossible environments of vacuum and temperature extremes.

And yet all that represents just some of the indirect benefits of space technology. Space has its own purposes, targets, and destiny. Space technology already is accomplishing things that cannot otherwise be done economically, or perhaps done at all. This is happening in satellite monitoring of the weather, global communications, navigation, oceanography, meteorology, geology, astronomy, and of course exploration of the solar system.

Dollar returns from our tax penny

If you ask the man in the street how much the space program costs the country, his guess is likely to be $20-billion a year. That's the figure he's heard and it sticks in his mind. That amount was the cost of *nine years* of the program to land men on the moon before the end of the decade of the sixties. As such, it was the primary cost of building our spaceport, tracking stations, and overall space capability.

It is a remarkable, often-overlooked fact that the pursuit of space goals generates innovations in virtu-

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ally all fields of science and technology, and therefore helps stimulate progress in areas not even remotely connected to the original program. The use of the words "virtually all" is intentional. It is difficult to imagine a scientific discipline or area of technology that has not contributed to the space program—and vice versa.

Whatever stimulates massive scientific inquiry in all disciplines will benefit all science, for what science mostly needs is a focal point that can command the attention, respect, and dollars of the world. With 90% of all scientists ever born still alive and working today, with the rate of scientific and technological advancement accelerating now in geometric progression, the real world of solvable problems cries for a standard bearer, a stimulus, and a goal.

If you accept this broad view of spinoff, then the many benefits attributable to the space stimulus are difficult to measure in their entirety, so thoroughly have they pervaded our lives. Yet, so many benefits have accrued that even the direct generation of new products, processes, and whole new technologies and industries is impressive.

In attempting to quantify the benefits to the national economy from secondary applications of space technology, economists last year traced the spinoff of four broad NASA programs. They estimated that secondary benefits in these areas will return $7-billion to the economy in a 14- to 20-year period—more than twice NASA's current annual budget. Another recent study showed that each new dollar invested annually on space research and development would return $23 over a 10-year period (see "Your Job," below).

Spinoff really works—but not as an isolated phenomenon. The research payoff is a fact of modern American life, interwoven with the direct benefits of space and our entire technology. Because of spinoff, we can define space exploration as a self-funding pursuit of the unknown, the most potential-filled endeavor in history.

Some day, spinoff may acquire an even more expanded meaning. It may include new crops hybridized with plants native to other planets. Or even knowledge transferred by communicating with intelligent life in other solar systems.

Before discussing some of today's specific products that have been spun off from space technology, it may be of interest to describe just what we are spinning off *from*.

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nd dollars of the world.

exploring the solar system

The exploration of the solar system began with observations from space of our own planet. It started 19 years ago shortly after Sputnik roared its way into the consciousness of people throughout the world. Since then thousands of satellites built by dozens of countries have been launched, with the U.S. maintaining space leadership by a wide margin.

It's not who's first that counts, as Columbus proved. It's who's first with a difference. The fact that Soviets were first with a satellite or that we landed men first on the moon is of little relative importance.

The difference is that we landed men six times, returning human observations that will keep scientists busy for years, and that our satellites now assist in solving a multitude of world problems. We have built a space capability and have begun the exploration of the solar system, opening a new era of civilization.

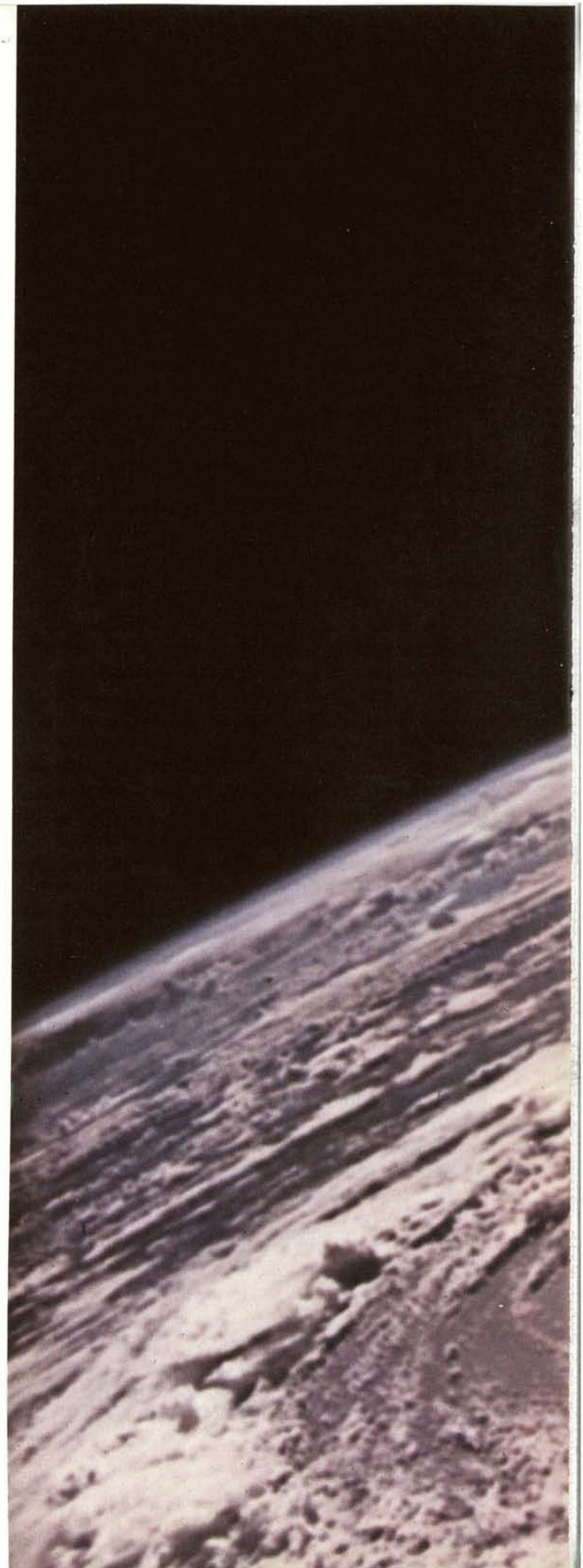
Servants in space

If outerspace exploration represents knowledge for tomorrow, the earth satellites are the workhorse machines of today. At the beginning of 1976 there was a swarm of about 750 satellites operating in earth orbit, 375 of them launched by the United States.

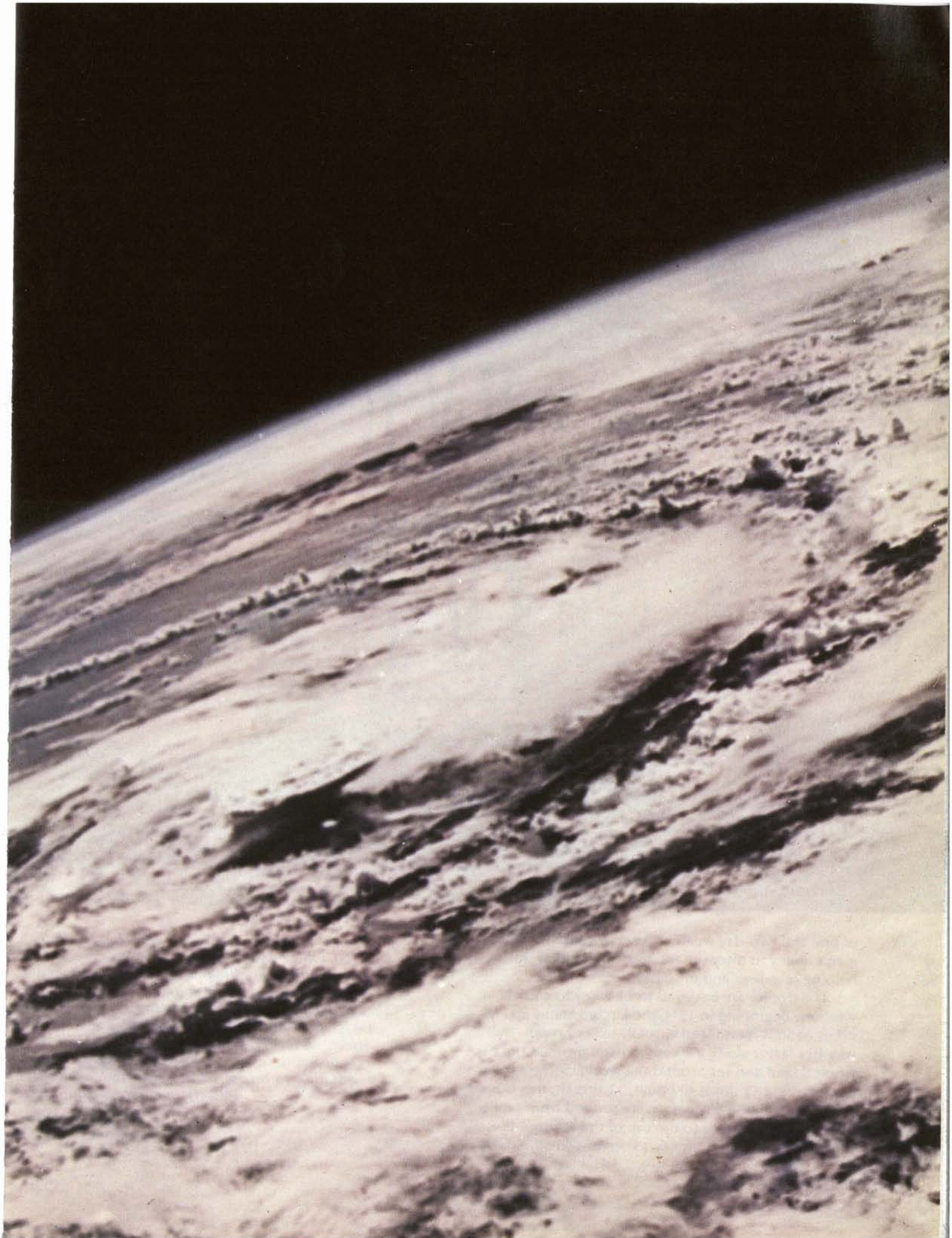
Among the many uses of these servants in space are weather forecasting, communications, scientific data gathering, solar observation, and prospecting and management of natural resources.

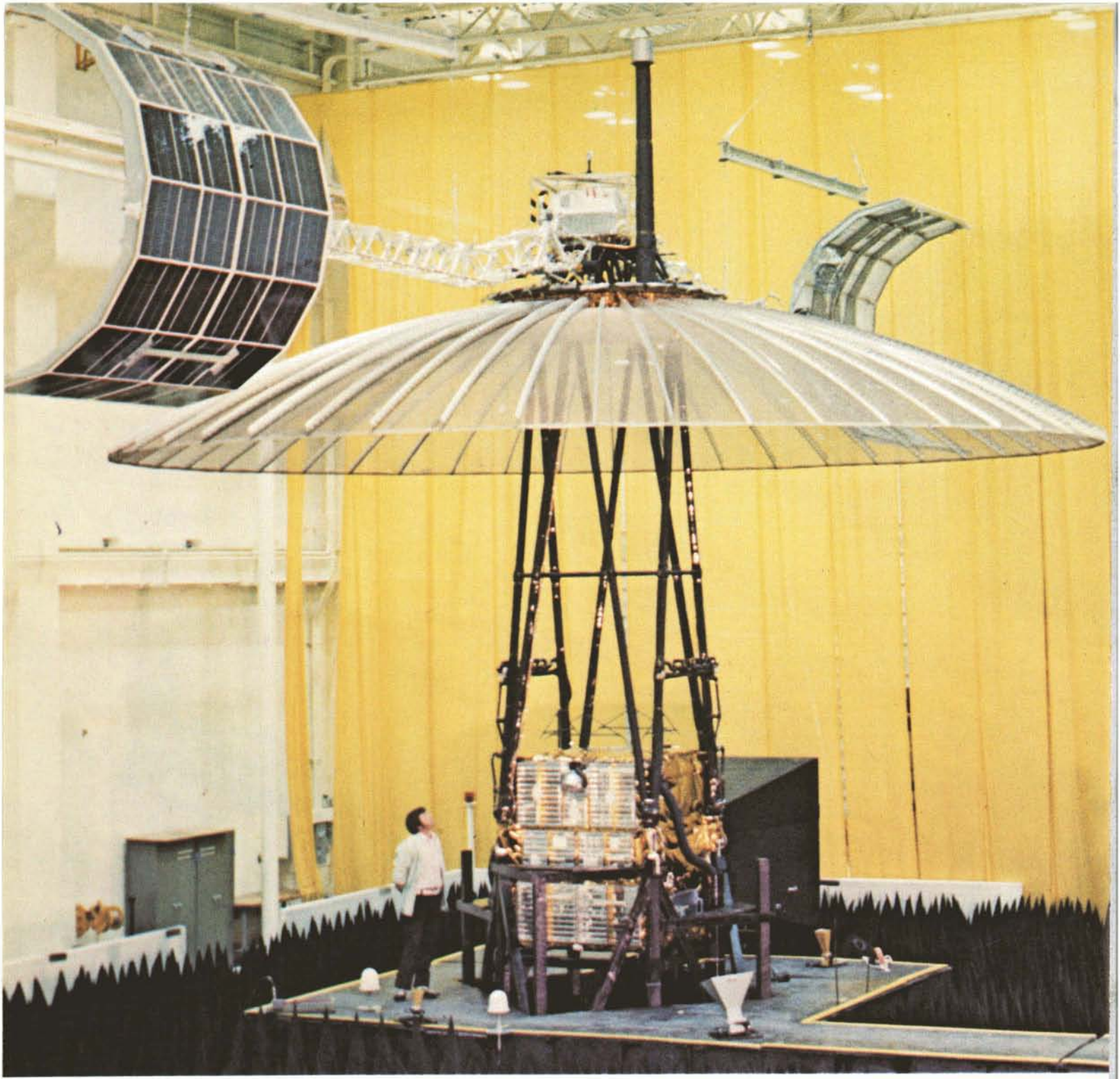
Good weather forecasting saves money. An accurate five-day forecast, which may be possible as satellite technology progresses, has been estimated to save up to $5.5-billion yearly in the U.S. alone, and as much as $15-billion for the entire world. The savings would be in agriculture, construction, transportation, recreation, and other industries.

Today's satellite system of weather watchers provides pictures of cloud cover over the globe both day and night. It contributes significantly to accuracy



First virtually continuous day-night photographs of a hurricane in the making were taken in 1974 by meteorological satellite in fixed orbit. Satellites are helping unravel how hurricances and tornadoes form as first step in their possible control. Dramatic photo is hurricane Gladys stalled near Naples, Fla. in 1968. A vigorous updraft hid the storm's eye by flattening cloudtops against cold stable air of the tropopause and forming a pancake of cirrostratus 10 miles wide.





The versatile Applications Technology Satellite (ATS), which now hovers 22,300 miles above the equator in fixed position relative, to earth, shows its 30-ft parabolic mesh antenna. The satellite takes as long to orbit as it takes the earth to rotate on its axis—a "synchronous orbit." For the first time, with ATS-6, enough radiating power and beaming capability have been packed into a satellite to broadcast directly from orbit into TV sets in rural communities.

of one and two-day weather forecasts and increases man's ability to discover and track hurricanes, thus helping save lives and property.

The tropics are believed to be a key to earth's weather. Beginning in 1974, the United States and 69 other nations monitored virtually every known weather factor along a 20-million-square-mile rim of tropical land and sea around the world. Some 4,000 people using 41 ships, 40 buoys, 12 aircraft, five U.S. satellites, and one Soviet satellite probed from a mile below the sea surface to the top of the atmosphere. From stationary orbit, our synchronous weather sat-

ellites maintain a 24-hour watch on most of the Western Hemisphere, transmitting data to produce a picture every 30 minutes.

Improved communications through satellites have enabled ships and airplanes to find faster, safer routings around storms, ice, and other obstacles. Communications satellites have widened television coverage, extended education and medical care to remote regions, and even have reduced the cost of overseas phone calls.

The Intelsat, or International Telecommunications Satellite System, continues to grow in capability. This organization of 91 nations has brought the advantages of telecommunications to most of the world. The system today consists of more than 6,000 telephone circuits among 110 earth-station antennas located in 66 countries, and it is growing with new launches of improved satellites each year.

Larger applications technology satellites, powerful enough to broadcast directly from orbit into countless television sets, are being placed in geosynchronous orbit so that they'll hover, in effect, over a fixed spot on earth. The latest, the ATS-6, was launched in May 1974 and has performed flawlessly since. It has enabled physicians to conduct medical consultations in remote areas and brought high school and college courses to students in isolated Appalachian and Alaskan communities.

Dr. Wernher von Braun, president of the National Space Institute and vice president of Fairchild Industries Inc., which built the satellite, describes a typical scene. A seven-year old girl in a remote Alaskan village of 425 people had caught her hand in the wringer of an old-fashioned washing machine.

A doctor at a hospital in Tanana, several hundred miles distant, flipped a few switches and the badly frightened little girl appeared on the screen.

"Hold up your sore hand," the doctor said. "Now hold up your other hand and let me see if you can wiggle your thumbs."

Both could see each other. The isolated girl no longer was isolated. Not only could the doctor allay the girl's fear, but he could diagnose and treat her almost as well as if they were in the same room. He prescribed to the native nurse how to clean, bandage, and resplint the broken thumb.

Last May, a year after its launch, the 1.5-ton satellite was moved 8,000 miles to serve the people of India. Here, where a great many of the half-billion population live in villages and rural areas and almost none has ever seen a TV set, educational and medical telecasting may be the only realistic answer to improving the lives of an eighth of the people on earth.

The Indian government now has begun using ATS-6 to beam instructional television programs to some 5,000 villages and cities in seven states. India views satellite education as the *only* means to break the back of its widespread illiteracy.

Our lunar legacy

Both satellites and men have special roles in exploring the other worlds of our solar system. Where it is feasible for man to go, it is difficult to conceive of an instrument more capable. The human body has been defined as "a 10-cycle closed-loop, sensing, computing, and performance system in a 0.1-ton chassis with a 0.1-horsepower motor." Only such "equipment" could grasp the significance—and the adventure—of the moon's many complex phenomena.

When Neil Armstrong and Buzz Aldrin landed in the Sea of Tranquility the morning of July 20, 1969, about 1.5-billion people—almost half the population of the earth—were able to watch it by satellite-relayed television. Never before (or since) had so many human minds been concentrated at the same time on one activity. Man's first expedition to another world had enormous psychological and philosophical impact. It was a symbol of both human aspirations and inter-dependency. When we see our planet televised from the moon, the fact that it is finite, beautiful, and a single object, instead of 145 distinct nations, becomes overpowering. It may be trite to say, but true, that if spaceship earth sinks we all sink with it.

A second, even greater result of the expeditions to the moon was its prominent role in the beginning of a vast scientific awakening. Like all scientific endeavors, the practical benefit to us in our homes and lives will occur in the future. But we already have learned more about the moon and the origin and evolution of the earth through the six manned lunar missions than has been learned since the dawn of history. This abundance of scientific understanding, supplemented by robot probes to the planets, is rapidly advancing the earth sciences through a new field of comparative "planetology." With the world running out of oil and other minerals, the new knowledge couldn't come at a better time.

A third part of our lunar legacy reflects the primary intention of the Apollo flights. They were first steps, "travel engineering" missions, if you will, carried out to design and improve the equipment, to learn how to travel to the moon and back safely, to conduct what were essentially interplanetary expeditions—in short, to build a manned space capability.

To expect more than that psychological impact, more than that bountiful scientific harvest, and more than that engineering capability would be as though we lived at the end of the 15th Century and complained that Columbus failed to return sufficient quantities of gold from his first trips. No one dreamed of limiting future voyages then.

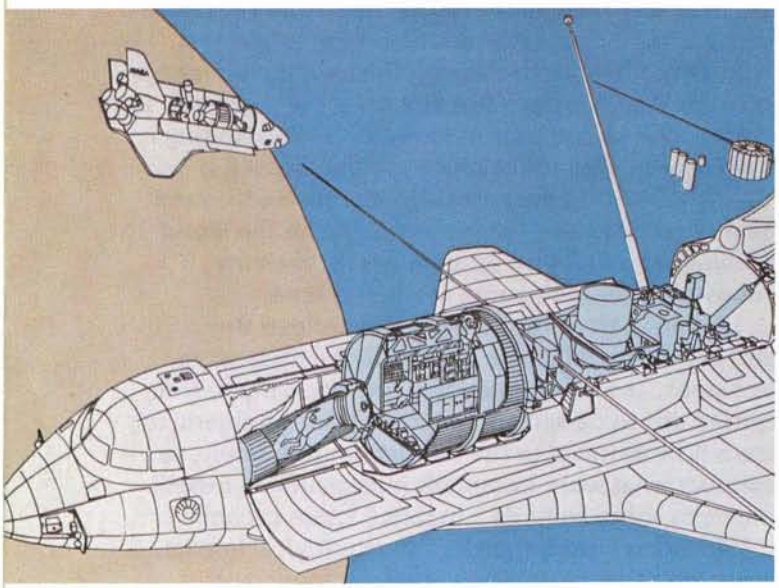
Shuttling to orbit

Following the lunar landings and using essentially the same hardware, the 100-ton Skylab space station was launched in 1973. Three missions that year and the next proved that man can live and work in space for prolonged periods. Last year, the joint U.S.-Soviet, Apollo-Soyuz linkup provided experience in docking with dissimilar equipment and languages and preparing for future space-rescue missions if needed.

These flights also saw the beginnings of men conducting experiments in space to develop manufacturing processes in weightlessness, observe the sun from space, and monitor earth resources. One day we will make electronic components, thin films, optical devices, and even pharmaceuticals in space. And space will be the *primary* location for astronomy.

But a better method will have to be devised than building multi-million-dollar ship-sized rockets and then throwing them away after one use. Few considerations kill an otherwise desirable plant site quicker than lack of suitable transportation.

The space shuttle will provide low-cost transportation to earth orbit. Now under construction to be operational in 1980, the shuttle will take off like a rocket and land like an airplane. It will be the major part of a reusable space transport system that will replace most current U.S. launch vehicles.



Reusable spaceship will shuttle men and materials between earth and orbiting space stations beginning in 1980. The first of five 122-ft delta-winged ships now being assembled at Rockwell International is about size of conventional DC-9 jet, but double its weight. The shuttle will lift payload of 65,000 lbs, reducing cost to orbit per pound of payload from $600 to $160. "Spacelab" payload, shown in drawing above, will enable scientists to work in shirtsleeves for up to 30 days in earth orbit.


UNITED STATES OF AMERICA
USA

In addition to the shuttle, the system includes an upper stage or "spacetug" and a spacelab. The shuttle will enable a space crew to place, repair, and retrieve satellites, as well as carry the spacelab to orbit. The spacetug, a propulsion vehicle, will remain in space to move payloads, such as the spacelab, from one orbit to another. The spacelab will provide scientists the opportunity to accompany and conduct their experiments in space. With its capability to return payloads from space and to be used over and over again, the space shuttle system will make spaceflight more routine and considerably less costly.

Pioneering the planets by robot

For some time at least, manned flights will be confined to the earth-moon region of space. But our direct exploration of the solar system continues even so, using comparatively small robot flybys, orbiters, and soft-landers.

Following the Mariner mission to Venus and Mercury beginning in 1973, Pioneer 10 stretched mankind's influence through the asteroid belt and across the half-billion miles to the giant Jupiter, arriving late that year. In December 1974, Pioneer 11—renamed "Pioneer Saturn" after it flew within 26,000 miles of Jupiter and proceeded on to Saturn —will pass near or through the rings in 1979.

Meanwhile, Pioneer 10 headed on a course that will carry it completely out of the solar system, passing the orbit of Pluto in 1987. In 40,000 years it will have coasted to the distance of the nearest star, but in the direction of the constellation of Taurus, the Bull.

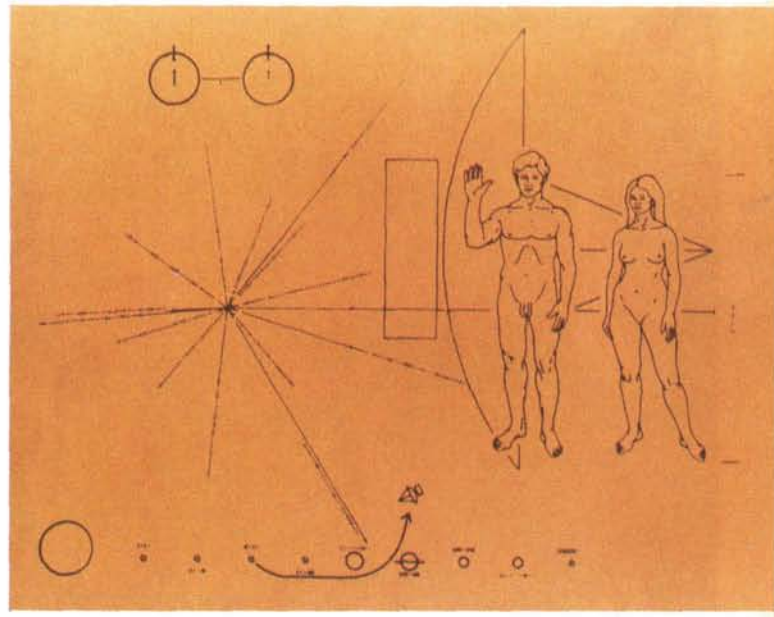
If it should encounter intelligent life in some other solar system, its final mission will be accomplished, some 40 centuries later. The little 570-lb spacecraft carries a gold-plated 6- by 9-in. message graphically and mathematically telling of man and from where he came.

Jupiter is so large and massive, containing two-thirds of the matter of the entire solar system except the sun, its gravity affects the orbits of the other planets. Jupiter, thus, is an important key to understanding the behavior of the smaller planets, including earth.

The Pioneers found that the magnetic field of

Red spot of Jupiter (at Left) boils beneath tiny Pioneer II, which flew within 26,000 miles of the giant planet in December 1974 and now is enroute to Saturn. The Great Red Spot, large enough to swallow three earths, is believed to be a 20,000-mile-wide permanent hurricane. Pioneers found blue sky at the poles and an erratic magnetic field surrounding Jupiter some 10,000 times more intense than earth's Van Allen belts.

If it should encounter intelligent life in some other solar system, it's final mission will be accomplished, some 40-centuries later.



Gold plaque (above) on Pioneer 10 tells of man and from where he came, in case the tiny spacecraft encounters intelligent life perhaps thousands of years after passing Pluto in 1987 and exiting the solar system. Drawing shows, at upper left, a schematic of the hyperfine transition of neutral atomic hydrogen—a universal "yardstick;" below, the position of sun relative to 14 pulsars and the center of the galaxy; figures of man and woman in size proprotionate to the spacecraft; at bottom, planets of the solar system with binary relative distances; and other information of use to possible extraterrestrials in identifying the spacecraft.

If life does exist on Mars we will have much more than a new science.

Jupiter, unlike the earth's, may be created by several ring currents—like electric dynamos—deep within the planet. Earth and Jupiter are the only planets known to have substantial magnetic fields. Jupiter's field sometimes stretches across 9-million miles of space, only to shrink in volume by three-quarters or more of that distance.

Despite these unearthly fields, enormous pressures, and high temperatures, Jupiter has conditions that could be suitable to the evolution of life—but not on its surface. If life exists on Jupiter, it would have to swim in the atmosphere, much as life in our oceans. Jupiter may provide the same kind of primordial "soup," consisting of hydrogen, methane, ammonia, and water, in which life probably originated on earth.

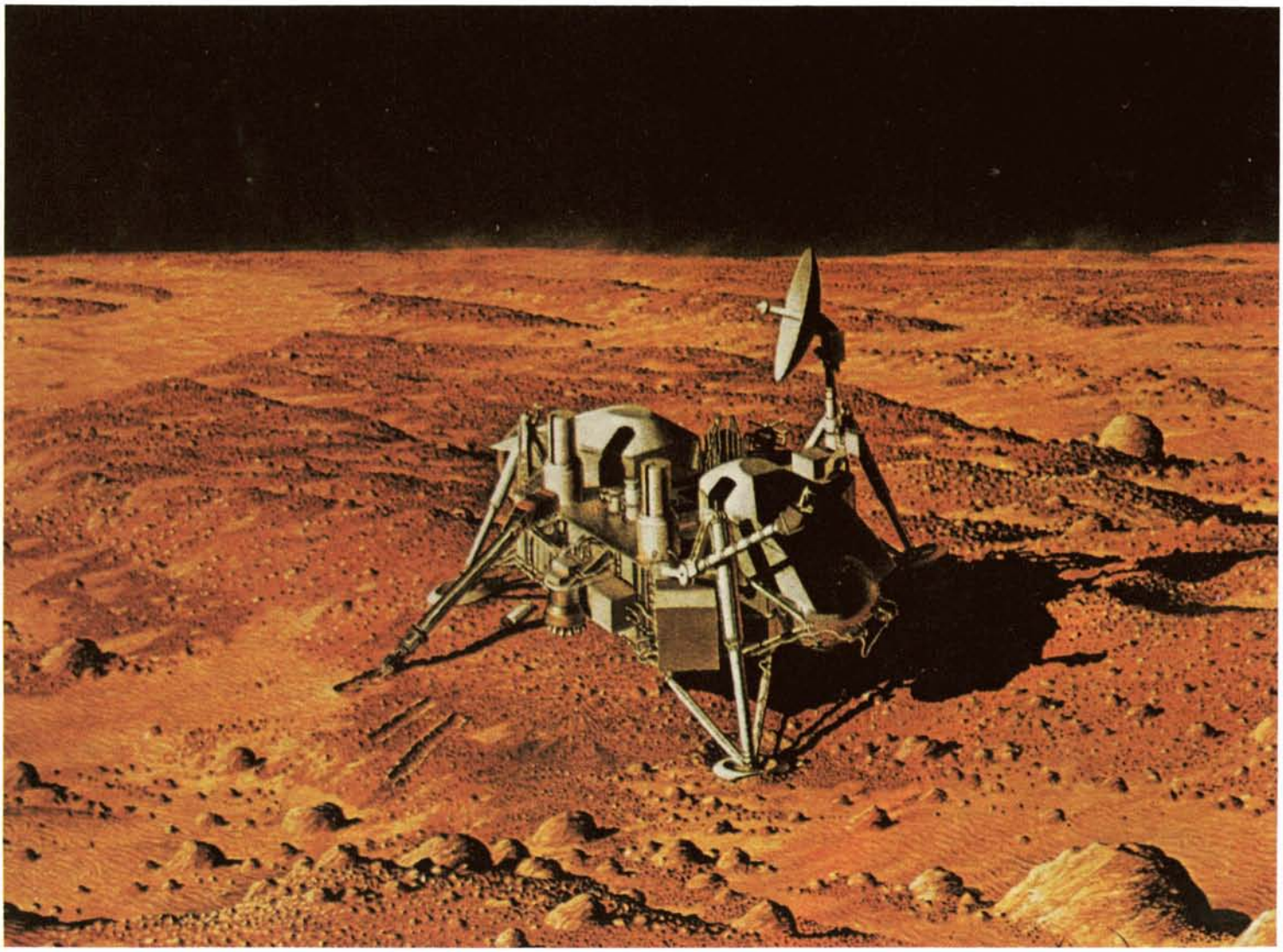
If life does exist in the Jovian sky, or on any of the moons of Jupiter or Saturn, it will take at least a soft-lander to find it. Our quest for life on other planets shortly will use that approach—on Mars.

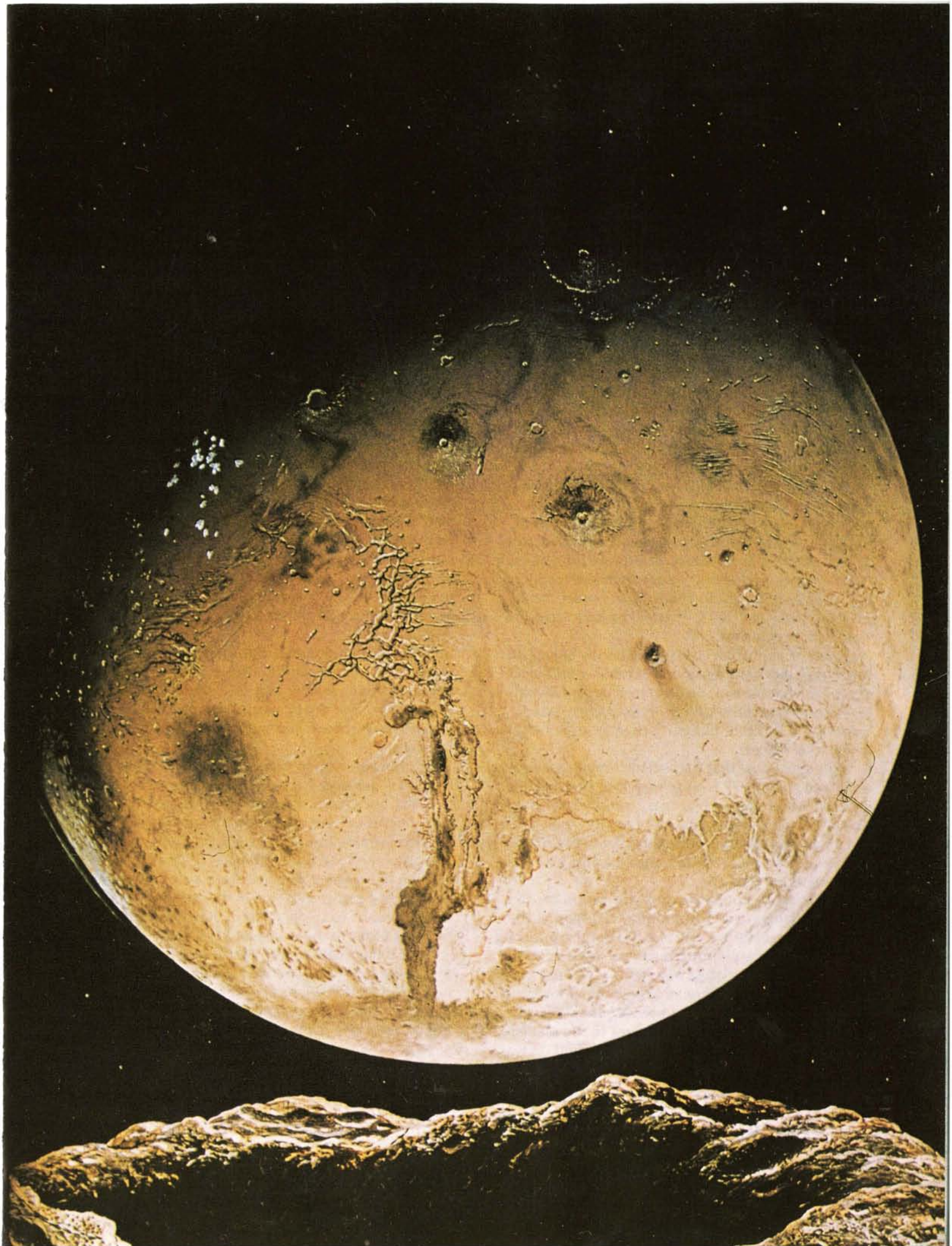
Next stop: Mars!

Visiting Mars on our country's 200th birthday is an appropriate achievement in the step-by-step exploration of the solar system, a fitting continuation of the pioneering spirit of '76.

In the year 1776, if a citizen of the new republic could be made to believe that this country would land a robot on Mars two centuries later, he would have assumed that the planet naturally would then become a territory of the United States.

Mars displays Great Equatorial Rift to its outer satellite, Deimos (right), and a Viking lands on crater-strewn red desert (below), both as depicted by noted space artist Don Davis. In painting above the great rift is shown stretching across 2,500 miles. Rift is 100 miles wide and, in some places, 5 miles deep, dwarfing earth's Grand Canyon.





The fact that we no longer take this selfish view, the fact that we seek cooperation with other countries in the peaceful development of space, and the fact that we perform our space feats openly on the world stage dramatize how our nation has matured over those 200 years.

Americans have taken many steps for mankind since 1776, but few as filled with excitement as the search for life on another planet scheduled to begin on Mars this summer. The surface exploration of Mars will yield new knowledge of the origin and evolution of our solar system, possible origins of life, and—again—new insights into the processes that have shaped the earth.

We used to think that of all the other planets in this solar system that Venus was the most like earth, even a sister planet. After all, the two planets are the closest in space and therefore the closest in distance from the sun. Both are almost exactly the same size, weight, and mass. Both possess heavy atmospheres. Lush tropical jungles and warm rivers awaited pre-1962 science-fiction characters on Venus.

But in that year the Mariner-2 flyby shattered hopes for a Venusian heaven. It discovered Venus was much more like hell: molten tin could flow in those rivers. Last October, the Russian Venus-9 soft-landed on the planet, erasing any doubt that the high temperatures existed not merely in the atmosphere but on the surface itself. The Russian lander measured the surface at 905 F. The atmospheric pressure was 90 times our own.

Mars, though, that little planet hardly bigger than the moon, that cold, apparently lifeless world orbiting so far from the sun, that cratered body with only a 67th the surface atmosphere of our planet—Mars turns out to be more like earth than any other planet in the solar system.

We now know that the surface temperature rises to at least a balmy 77 F on the equator shortly after midday. We know too that Mars' atmosphere and clouds contain a small amount of water vapor. While the polar ice caps are predominantly frozen carbon dioxide, the smaller caps left after this dry ice evaporates are water crystals.

What we do not know, and one reason the two four-ton Vikings have been sent to soft-land, is the nature of the water we see. Is it the last disappearing remnants of once-plentiful rivers and lakes? Or is Mars locked in an ice age that has frozen most of its water at the poles or beneath a layer of surface dust? Does water, even now, exist beneath the surface?

Martian water holds many clues to the planet's history. Assuming Martian life is dependent on water, as is life on earth, an understanding of the daily and seasonal appearance and disappearance of water is necessary to establish whether life could have existed on Mars.

Before Viking-1 lands on or about July 4, it will orbit the planet to pinpoint warm, wet places with thick soil layers. Viking-2 will arrive seven weeks later, well after the first spacecraft has had time to land and send back engineering data about the descent and arrival site. In this way, the trajectory of the second Viking could be changed to land elsewhere if desired.

Once the Vikings land on Mars—after years of work by thousands of scientists and engineers—a boom will be unfurled to dig up soil samples for incubation and analysis. Several experiments then will be conducted to detect the presence of living micro-organisms.

Comparing the earth

These are among 13 separate investigations of Martian conditions, including planetary structure, weather, chemistry, and biology that will be undertaken both in orbit and on the surface. We now have first-hand data on two bodies of the solar system—earth and the moon—and less-extensive but direct measurements of Venus, Mercury, and Jupiter. Knowing the makeup of Mars in detail will enable us to compare it with the moon, the other planets, and earth, yielding a far better insight into how planets evolve.

Mars has sand dunes, cloud formations leeward of some mountains, and similar earth-type phenomena. Martian weather may be a simple version of earth's. If so, the Viking weather station will help us learn how weather is formed on planets, including our own.

When you stop to think about it, you realize that biology is our only science, so far, without comparative reference. Until we find life on another planet—even microbes—we can have no comparative biology as we now have comparative geology, physics, chemistry, and the other sciences. If life does *not* exist on Mars, we at least will have a close-up comparison of a planet evolving in the absence of life, a new approach to understanding how the earth's teeming lifeforms have affected this planet.

But if life *does* exist on Mars—or on a Jovian moon, for instance—we will have much more than a new science. We will have proof at last of that elusive quest without human parallel: that life is not confined to this one planet alone.

. . . the fact that we perform our space feats openly on the world stage dramatizes how our nation has matured over those 200 years.

your job

The relationship between building a space capability—even searching for life on another planet—and improving life on earth is closer than is generally realized. Of all the areas of U.S. society needing improvement in 1976, inflation and unemployment are among the most crucial.

We certainly are a nation of workers. Despite a comparatively high rate of unemployment, 93.2-million Americans *are* employed. Spaced only a mile apart, we'd reach the sun! Of the total 214-million Americans, 43.5% are working. That's almost half of all of us, children and retirees included, who have jobs.

The sheer numbers make us realize the awesome magnitude of job creation in a free-enterprise system, the delicate interplay of capital investment and technology, the necessity for job enrichment, and the rightfulness of government transferring tax-bought knowledge back to the people.

No one in government would argue that premise. How effective the space program is in creating and upgrading jobs and in reducing the hidden tax of inflation is the question.

Productivity reduces inflation

Economists don't often agree. But they are unanimous in believing that increased productivity constitutes a potent long-term solution to inflation. The forces causing inflation are neutralized both by getting more out of each unit of labor and by expanding the supply of goods and services. Higher outlays for space research and development have been shown to result in lower rates of inflation.

An extensive study conducted last year by Chase Econometric Associates Inc., Bala Cynwyd, Pa., dramatically demonstrates the role of space technology in reducing inflation. Employing sophisticated models of the spreading effect of several hundred industrial projects, Chase found that high-technology endeavors, of which the space program is clearly the largest, result in significant rates of social return out of all proportion to their cost.

The study showed that a $1-billion annual increase in space research and development programs, if begun this year, would have the following results 10 years hence:

1. The gross national product, at bare minimum, would be $23-billion higher by 1985 (in today's dollars). That is an annual return on investment over the 10-year period of more than 40%.

2. The 1985 inflation rate would fall by a full 2%.

3. The unemployment rate would be reduced by some 400,000 jobs. In addition, the size of the labor force would rise by 1.1-million new jobs. (The difference is caused by the increase in demand reducing the amount of hidden unemployment as more workers join the labor force.)

The reason the Chase model projects the space payoff so high is that the research investment spreads to other industries as well. Achieving higher industrial output and lower inflation is inevitable, according to Chase, due to the growth of labor productivity.

Productivity growth means that less labor is needed per unit of output. As less labor is required, costs decline. As costs decline, prices decrease and consumers' real income rises, which then leads to greater purchases of goods and services and improved mass production which lowers unit costs still further. The size of the labor force then can increase through greater job opportunities spread across many industries, old and new.

These economic spinoffs don't occur immediately, however. They begin to become significant after about five years. Our growth in output per man hour actually has fallen behind that of other industrial nations due to a slowdown in the last 25 years of U.S. investment in new technology. A revitalized space investment is part of a larger emphasis on industrial growth that must be made if the U.S. is to retain its narrowing technological leadership.

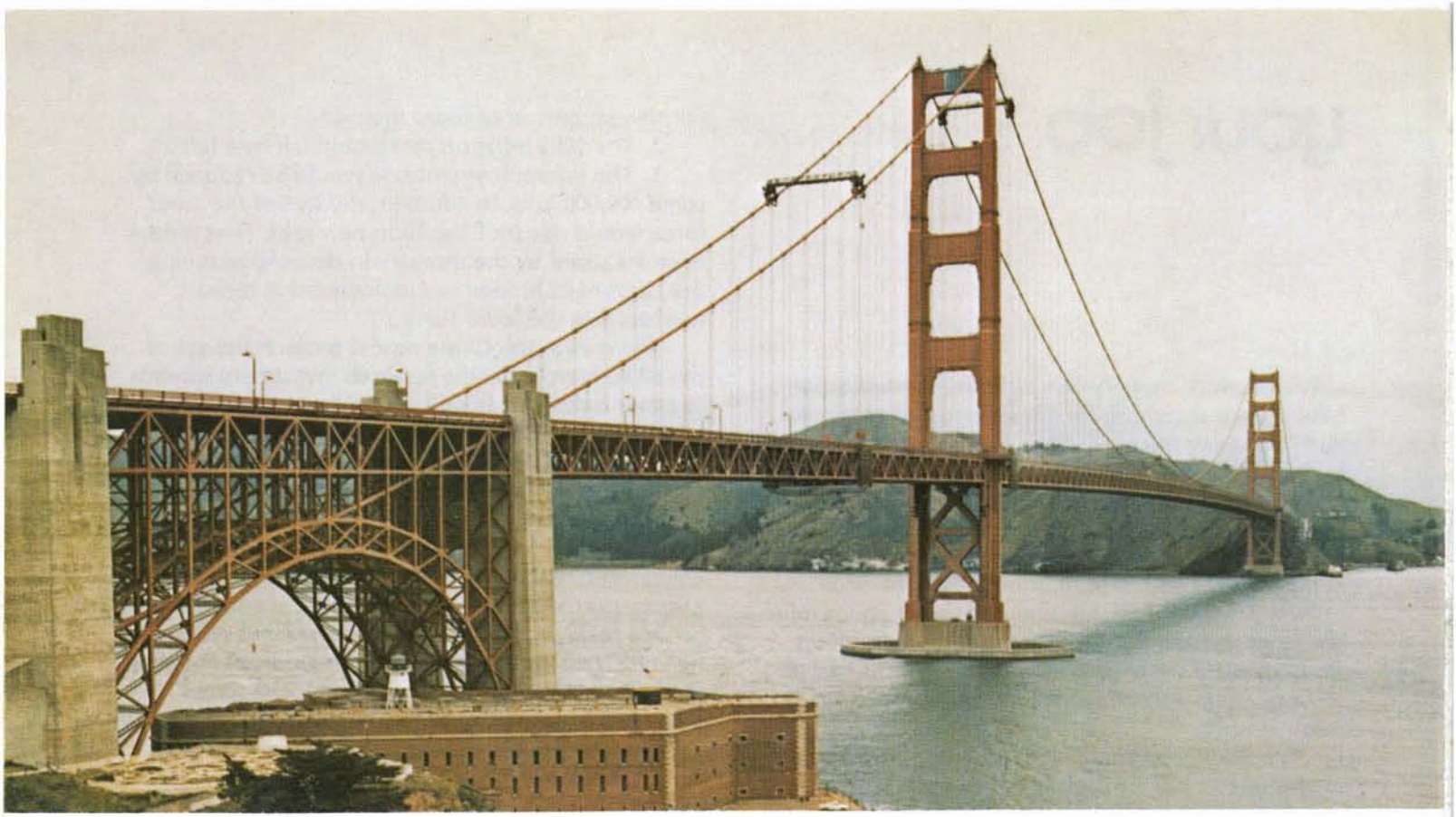
Space-spawned industries

Some 30,000 people in 47 states will be at work on the space shuttle by June—in addition to those employed directly by NASA. The number is expected to increase to a maximum of 50,000 sometime next year.

Yet direct jobs are only a small part of the job-making and inflation-reducing payoff of space research. Spending on space must be distinguished from investing in space. A society can spend on pyramids just to make jobs. But investing in space creates whole new industries.

The computer business is probably the greatest non-aerospace spinoff of space technology. Every major computer system in the world is made in America, but without the forcing function of NASA's stringent requirements, these computers would not be available today. U.S. exports of computers increased 1400% in the first decade of the space age.

Industry officials forecast a million computers operating by 1980, versus a current population of 175,000. That's a growth rate of 40% a year—about twice that of the past decade. Even more important, the growth of computers magnifies increased productivity throughout the world in all industries that use computers—and that means virtually all industries.



Painting the Golden Gate Bridge requires 42 painters at work for five years. New space coating now being tested on bridge is expected to take less time to apply and last considerably longer than conventional paint.

There are other space-related industries too. High space standards advanced the state of vacuum technology so far that processing of high-purity materials, coatings, and especially semiconductors now is done routinely in vacuum. The cryogenics, or ultralow-temperature, industry erupted as a direct result of liquid gases needed for rocket propulsion and life support in space. Today hospitals and steel mills are among dozens of beneficiaries throughout the nation that routinely store and use liquid oxygen, nitrogen, helium, and other frozen gases.

Even the pipeline business has benefited from new aerospace technology, combining two techniques in a novel way. One is the space method of winding glass thread to make lightweight, strong rocket casings. The method has been applied to manufacturing lighter-weight pipe, making it possible to utilize the emerging technology of laying entire pipelines by helicopter, especially in remote areas.

Last year, economists at Mathematica Inc., Princeton, N.J., isolated four mature examples of spinoffs and estimated their return to the economy. Benefits from these four areas were projected conservatively to add up to $7-billion by the early 1980s. These are not models, but actual thriving industries spun off from the space program:

1. *Integrated circuits.* Developed for satellites, communications, and other space uses, and now used in TV sets, automobiles, and hundreds of industrial and household products, the improved technology will return an estimated $5,090,000,000 from 1963 to 1982.

2. *Gas turbines.* Initially developed for jet-engine aircraft, but widely spun off to electric-power generation plants, these turbines will effect fuel-cost savings of an estimated $111,000,000 between 1969 and 1982.

3. *A structural-analysis computer program.* Developed originally to help design more efficient space vehicles, the NASA program today is used to design railroad tracks and cars, automobiles, bridges, skyscrapers, and many other structures. It is expected to return $701,000,000 in cost savings from 1971 to 1984. Use of the program yields about a 60% improvement in predicting the behavior of stressed parts and a two-thirds cut in calculation time.

4. *Insulation for cryogenic uses* (explained above). The probable estimate of benefits is $1,054,000,000 between 1960 and 1983.

While these industries were deliberately selected because they are large and because NASA's involvement was significant, remember that their $7-billion return represents *just four examples* of spinoff.

Of course it takes time for new developments to mature into new or expanded industries. Increases in industrial productivity that affect your job begin with isolated bits of technology. Some of these new space spinoffs that may have that potential are described next.

Better paint for bridges

An improved zinc-rich coating that protects against salt spray was devised by space researchers and then found to be an ideal paint for bridges. Tests on the Golden Gate are under way this year to determine the life of the paint on coastal bridges where salt corrosion is a major problem.

When you add up all the bridges over salt water, offshore drilling rigs, ships, utility pipelines, and other candidates for the improved corrosion-resistant paint, you have a huge, $2-billion, annual market.

Another example of increased productivity through space spinoff is a process for manufacturing metallic filters from spun fibers used in rockets. Today the filters are used in chemical processing, making photographic films, and in underwater filtering on offshore drilling rigs.

NASA's need for reliable ultrasonic devices to inspect welds on rocket casings has been spun off into a variety of devices. One is a group of unique rail cars that drive slowly over some 160,000 miles of track in the U.S., Australia, Europe, and Mexico checking old track welds for deterioration. The cars find improper welds not readily seen in X-rays, and save countless hours in the search.

The "clean rooms" devised for handling semiconductor and other miniature assemblies also have been spun off from the space program to the food-processing industry. Marked savings in previously rejected packaged foods have resulted.

Bigger plows and faster mail

You may have noticed that farmers pull bigger plows today. The reason is both because their tractors are more powerful and because their plows and other implements don't break as easily when hitting rocks in the field.

NASA fracture-toughness tests originally devised to check spacecraft structures helped bring about these improvements. Electric utilities and nuclear pressure-vessel manufacturers also use these tests now to inspect for flaws in an attempt to avoid devastating brittle fractures.

Even the Post Office is automating its parcel-sorting equipment as a result of a space spinoff. Techniques worked out for the automatic checkout and launching of spacecraft now help make it possible for a postal worker to key zip codes into a computer. The computer then controls the discharge of the parcels at very high speed. So far, the computers are at work in post offices in California, Illinois, New York, and North Carolina.

Stronger plows, more powerful tractors owe their improvements in part to NASA fracture-toughness tests originally devised to check spacecraft structures.

Computer-assisted banking operations, both to assist tellers and, in some cases, to do without them have been spun off from Apollo-guidance software and hardware.

Management by computer

Management techniques, basic to a nation's productivity, have been significantly advanced in the U.S. by the space input. Computer-based management systems borrowed from the space program help us plan and control thousands of actions required in complex industrial projects.

It is doubtful whether the mammoth nine-year man-to-moon project could have been coordinated effectively without the program evaluation and review technique. Originally devised by the Navy to facilitate construction of the Polaris submarine, the technique, as modified by NASA and offered to industry as a computer program, now is applicable to all kinds of large construction and other projects requiring complex scheduling. Before usage of the program became widespread in industry, scheduling could be agonizing.

"It's like childbirth! That's the best way I can describe what we go through to create project networks for proposals and programs," according to one contractor. Another: "I don't know which is worse—reproducing acres of network diagrams for everybody's mutual bewilderment, or spending countless hours specifying special diagrams for the draftsmen to draw up."

But then a company in California combined the NASA computer program with another to generate graphic output automatically. The result: no more pains of childbirth! The output provides automatic, precise, easy-to-read networks. Management can use the method to depict costs, manpower needs, and other information. It is an accurate and fast way of scheduling modifications in nationwide branch offices, modeling accounts receivable, and of planning other corporate activities.

One of the most complex computer systems in the world is the automatic checkout equipment devised for the manned missions to the moon. It was built to integrate the extensive Apollo spacecraft procedures from manufacture to launch.

The system has been spun off to retail-store and bank transaction systems, as well as to control electric power transmission grids, thereby reducing the likelihood of power blackouts. Those automatic machines you see in banks today that spit out money when you insert your credit card are examples of the spinoff. So are the computerized machines in car rental agencies and airline ticket offices.

It is doubtful whether the mammoth nine-year man-to-moon project could have been coordinated effectively without the program evaluation and review technique.

your health

NASA's role in major areas of human concern is nowhere more evident than in its myriad contributions to health. Space medicine together with innovations in remote acquisition, monitoring, and interpretation of physiological processes during flight have generated technology for improving both the quality and quantity of health care.

The problem even in this advanced country is staggering. Seven of 10 Americans visit their physicians at least once a year; one of 10 is hospitalized. The cost of the country's health services is some $83-billion, roughly 7.6% of the nation's gross national product.

Pacemakers that can be charged

Probably the best-known space spinoff to your health is the cardiac pacemaker, an outgrowth of miniaturized solid-state circuitry developed for spacecraft. When the natural heartbeat becomes irregular because of heart disease, the electronic pacemaker delivers small, regular electric shocks to pace the heart. About 30,000 pacemakers are implanted each year in the United States and a like amount in the rest of the world.

Until recently, pacemakers lasted only about 22 months, after which time their battery power is depleted, necessitating surgery to remove and implant a new device. Repeated surgery can be traumatic. It's also expensive, typically costing more than $2,000 for each operation.

A new pacemaker developed by industrial researchers with an assist from NASA is rechargeable through the skin by inductance. Once a week the patient simply puts on a charger vest for an hour to recharge his pacemaker. Since recharging can be done frequently, only one cell is required and the size of the pacemaker has been reduced to half the thickness. Now they weigh only 2 oz.

Another advantage of the new device is that it is immune to electrical interference such as microwave ovens or automobile ignitions that sometimes stop conventional pacemakers. The development is evolving. Current research is aimed at further reducing the size and increasing its reliability.

But even better pacemakers can not prevent cardiovascular disease, the number-one killer in the U.S. that accounts for more than a million deaths a year. Many of these deaths could be prevented if firemen and other rescue workers had better training and better technology that, in effect, would deliver the facilities of a hospital to the scene of the heart attack.

NASA now has spun off its Skylab telemetry to a "Telecare" emergency system. Telecare contains in one package all the instruments that a doctor or paramedic could reasonably want in a cardiopulmonary emergency. It contains a respiratory resuscitation system, a 15-minute oxygen supply derived from a chlorate candle that *releases* oxygen when burned (also a space development), an electrocardiogram display and telemetry system, a defibrillator for external heart stimulation, and a blood-pressure measuring system similar to that developed for Skylab that works even when there is high background noise.

Telecare units now are being used in ambulances in Houston, Cleveland, and other cities, as well as in a demonstration remote-care program in the 4,300-square mile Papago reservation in southwest Arizona where 10,000 Indians live.

The cardio-emergency alert

Telecare also is an important ingredient in a new NASA-assisted cardio-alert program in Cleveland. Here, firemen trained as paramedics telemeter a heart-attack victim's data to the Fairview General Hospital's Kemper coronary unit. Listen:

PM: (paramedic): *Kemper, This is Squad Two . . . We're at the victim's side. A 62-year old woman. We have no respirations yet.*

KU (Kemper coronary unit): *Did you institute CPR?*

PM: *Yes. We're starting right now.* (CPR is cardiopulmonary resuscitation, or artificial breathing and blood circulation.)

KU: *Is there a pulse?*

PM: *Negative.*

KU: *Continue CPR. Do you think someone can start an IV of 5% dextrose and water?*

PM: *Five percent. Okay.* (An IV, or intravenous infusion, must be set up as fast as possible. If the heart isn't pumping blood to fill the veins, they'll collapse, making it difficult to medicate the patient.)

KU: *Are you hooking the patient up to the monitor?*

PM: *We're beginning.*

KU: Is she responding at all?

PM: Wait a moment. No. No pulse.

KU: *Try a precordial thump* (a blow to the chest). *How long has she been unresponsive? Can you hook her up to the monitor yet?*

Within one minute, the paramedics begin transmitting the electrocardiogram, which is printed out and taped at the hospital. In the scene described, adapted from the Fairview General Hospital publication, the paramedic-trained firemen shock the heart electrically into a more normal pattern. They also administer drugs, have the hospital notify the patient's doctor and retrieve her records, and of course

rush her to the hospital.

She lives. So do almost all such victims in the area of the cardio-alert. The Cleveland program, in which 21 firemen have graduated as paramedics, is a pilot project that may be extended to communities elsewhere.

Electrodes for cardiograms

Another cardiac spinoff derives from biomedical electrodes that transmit electrical signals from astronauts' bodies. At the onset of manned spaceflight, it was discovered that existing electrodes were not acceptable since they must be comfortable over great lengths of time and extremely sensitive to pick up the heart's weak electrical signals. Since then, biomedical electrodes have been under intensive development all during the space program. They are used in electrocardiogram and other hospital instrumentation throughout the country, especially with patients requiring constant and long-term care.

NASA's developments of spacecraft transducers, or devices used to convert energy from one form to another, now have been transferred to detect arteriosclerosis, or hardening of the arteries. The usual test involves inserting a hollow needle into an artery and directly measuring the arterial pulse. It's time-consuming and painful.

The space spinoff determines the flexibility of arteries externally. The device uses a pressure-sensitive transistor that converts arterial pulses into electrical signals. When amplified they can be recorded on a standard electrocardiograph.

Sound waves instead of X-rays

A portable "echo-cardioscope" has been adapted for man on earth from monitoring heart functions of astronauts. It too replaces the need for inserting tubes in blood vessels (through which X-ray motion pictures are taken). The echo device forms images of internal organs using high-frequency sound—in somewhat the same way that underwater objects are detected from submarines using sonar.

Other ultrasonic imaging equipment also has been transferred from space use to avoid reliance on potentially harmful X-rays. A new system is capable of resolving body-tissue images that are comparable with the quality of those from X-rays. The first clinical trials are underway this year in detecting breast cancers.

But until ultrasonics replaces X-rays for that purpose, still another space development is helping physicians reduce the quantity of X-ray exposures. Typically, doctors take more than one picture to expose an X-ray film properly. Now, solar cells that convert sunlight to electricity on space satellites can make a single exposure suffice.

Since solar cells are sensitive to X-rays as well as light, a sensor made from such a cell is placed directly beneath the X-ray film and determines exactly when the film is exposed to optimum density. Not only was the X-ray hazard reduced significantly in a trial project at a Pasadena hospital, but the number of patient examinations was doubled. The sensors are expecially useful in breast radiography. Since the breast is transparent to X-rays, very low-energy X-rays must be used, requiring exacting exposures.

Space research has been transferred to cancer therapy too. White blood cells and bone marrow—often destroyed along with cancerous cells in leukemia treatment—now can be stored for future use, just as blood plasma is kept in blood banks.

Previous attempts to freeze disease-fighting blood cells and bone marrow either destroyed the cells by rupture when cooled too fast or by dehydration when too slow. A special circuit developed for precise temperature control of scientific instruments aboard the Mars-bound Vikings has been adapted to a new freezing unit using liquid nitrogen. An evaluation unit, which can freeze white blood cells in an hour, was delivered last year to the National Cancer Institute.

Remember the suits the lunar astronauts wore between splash down and their quarantine on the recovery ship? Designed to protect the environment from unknown microorganisms, similar suits now protect immune-deficient children and patients suffering from leukemia, burns, or other maladies where infection can kill. The suits make it possible for such patients to leave their isolation rooms for up to several hours.

Defrost-warning crystals packaged with food at time of freezing turn bright red on thawing and stay that way even if frozen again. Unique crystal is a spinoff from high-altitude battery research. The crystal tags could be packaged with frozen blood plasma too.

The food protectors

American health also is safeguarded by food-protection techniques transferred from the space program. For instance, "clean rooms," the sealed, slightly pressurized chambers originally used in the electronics industry to eliminate dust from tiny space components, now are being utilized by food processors.

NASA's experience in producing spacecraft food even has been adapted to meal packages that don't require refrigeration. The packaged food is meant for handicapped and elderly live-alones who often suffer from malnutrition.

And a frozen-food indicator will warn grocers if those frozen mushrooms just arrived have ever been thawed and refrozen. The unique tag turns bright red if the food, with which it is packaged, is ever defrosted.

It was discovered in the development of a battery system for operation in balloons at high-altitude temperature extremes. Almost by accident, frozen salt crystals used in the battery were found to turn red on thawing and stay that way even if refrozen. The crystals also can be frozen with blood plasma or other medical supplies to warn against inadvertent thawing during transport.

A whole new line of medical instruments has been spun off from an atmosphere analyzer aboard satellites.

Medicine by Mars probe

A whole new line of medical instruments that measures the ventilation of the lungs to help treat diseases such as emphysema has been spun off from an analyzer that detects the composition of the atmosphere from satellites.

This year, a modification of the device allows a single nurse to monitor up to 15 patients by watching a television screen. A "spinback" of the instrument will help determine whether life is present on Mars if the Vikings land successfully.

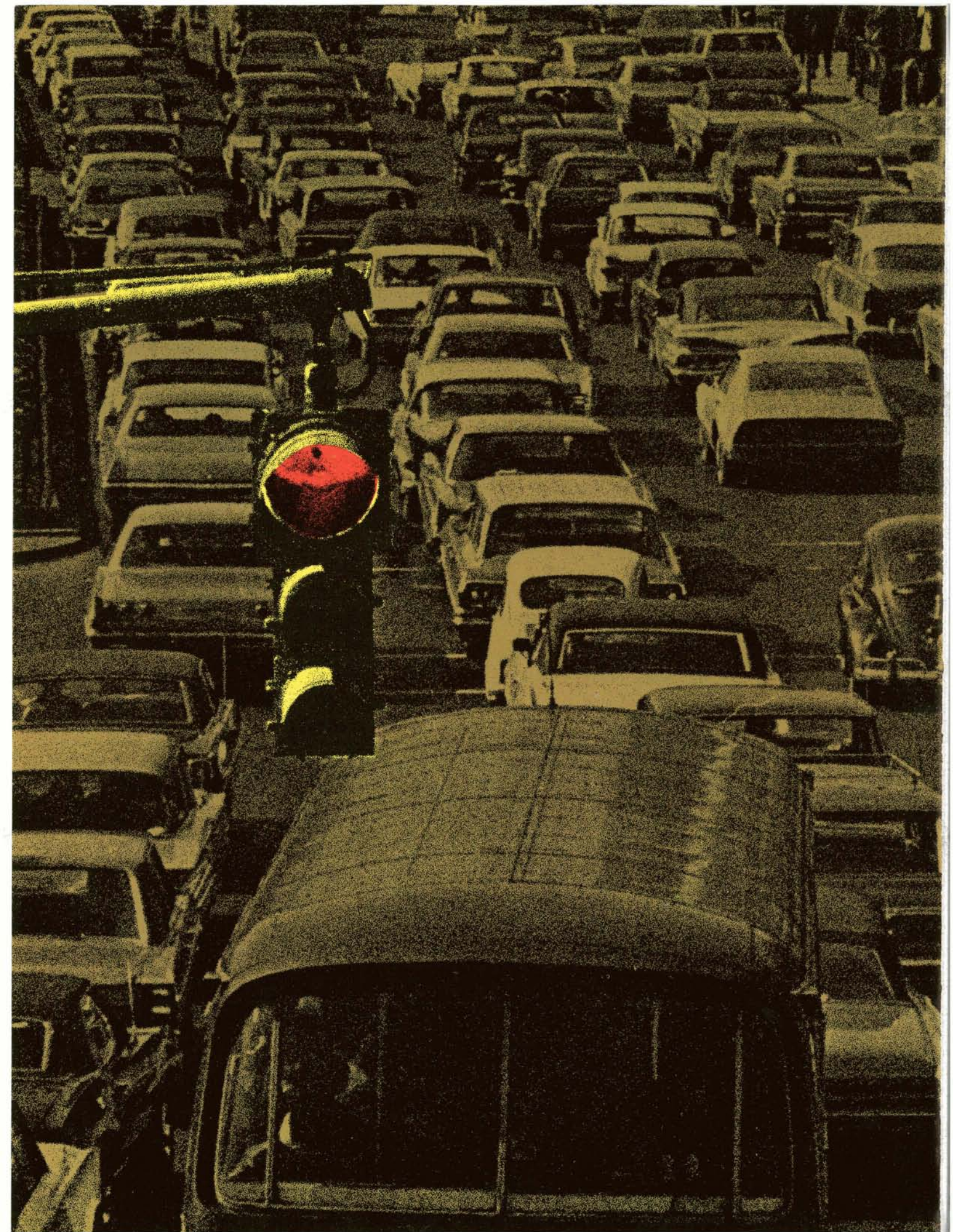
The Viking mission has contributed to the mundane problem of decontaminating hospital oxygen systems in another development. The unlikely relationship goes like this: technology developed to sterilize the Vikings utilizes a dry-heat technique ideal for sterilizing ventilators and other oxygen equipment.

The apparatus typically is contaminated from previous patient use. Chemical disinfectants remove most of the microorganisms. But the few that are left multiply rapidly in the humid oxygen. A NASA laboratory helped re-design one manufacturer's equipment using space-type plastics and new methods of sealing compartments.

Weighing babies in incubators

In other new developments, premature babies can be weighed inside their incubators as a result of a NASA-sponsored summer institute in biomedical engineering. A weight-alleviation device, enabling a stroke or other paralysis victim to re-learn muscular coordination, is being adapted from the suspension device that helped astronauts simulate the one-sixth gravity of the moon before the Apollo landings. Techniques developed for space telemetry have evolved into a complete motion-analysis laboratory in California to analyze the walking patterns of crippled children. An electro-optical instrument developed originally to measure the visual performance of pilots has been spun off to test your vision and print out the proper prescription for glasses automatically. And a "feeling meter" initially invented to determine whether prolonged weightlessness in space could cause neurological damage now helps neurologists assess sensory perception.

Measuring inequalities of lung ventilation helps diagnose and treat diseases such as emphysema. This extremely reliable, mobile device—adapted from a small mass spectrometer designed to analyze composition of earth's atmosphere from Explorer satellites—now measures composition of air exhaled from lungs.



your mobility

Your mobility has grown dramatically over the years. Distance in 1976, means little to Americans who annually fly more than 100-billion passenger miles and drive an average of 10,000 miles a year. To increase that mobility, highways and streets have been added at the rate of 200 miles a day during the past two decades.

But freedom of mobility has been costly in accidental deaths and injuries, particularly from automobile traffic. Some 45,000 fatalities and 4.8-million injuries occur each year. The economic loss due to highway accidents is approximately $19-billion.

NASA, in a sense, is primarily in the transportation field through its development of advanced aircraft and spacecraft. Much of its work in surmounting technological difficulties, though, is applicable to highway and railway traffic as well as to aircraft.

Auto traffic safety and efficiency

For instance, the Apollo programs to analyze trajectories and landing locations on the moon have contributed to the nation's first fully computerized automobile traffic-control system. The prototype system, uniquely named SAFER, for Systematic Aid to Flow on Existing Roadways, has been installed by an aerospace company in a nine-square-mile area in Los Angeles county, where it controls about 200,000 vehicles daily at 112 intersections.

In operation, information on existing traffic conditions is collected and fed to a computer, which then calculates the best traffic-light sequence to match the traffic flow. Motorists creeping ahead in rush-hour traffic find the system relieves congestion far better than the usual predetermined red-green light pattern. During tests, mobility was improved 15%, saving motorists a considerable amount in gas consumption and auto maintenance due to engine idling. Of course it also reduces auto-exhaust pollution for the same reason. These systems now are being installed in Baltimore, Md., and Overland Park, Kan., and are planned for other cities.

A different way to increase automotive efficiency—and save considerable amounts of fuel in the process—is to eliminate air friction on cars and, especially, on square-shaped trucks. Streamlining trucks obviously would improve their aerodynamics, but truck lines need "cubic" vehicles so they can be packed with square boxes.

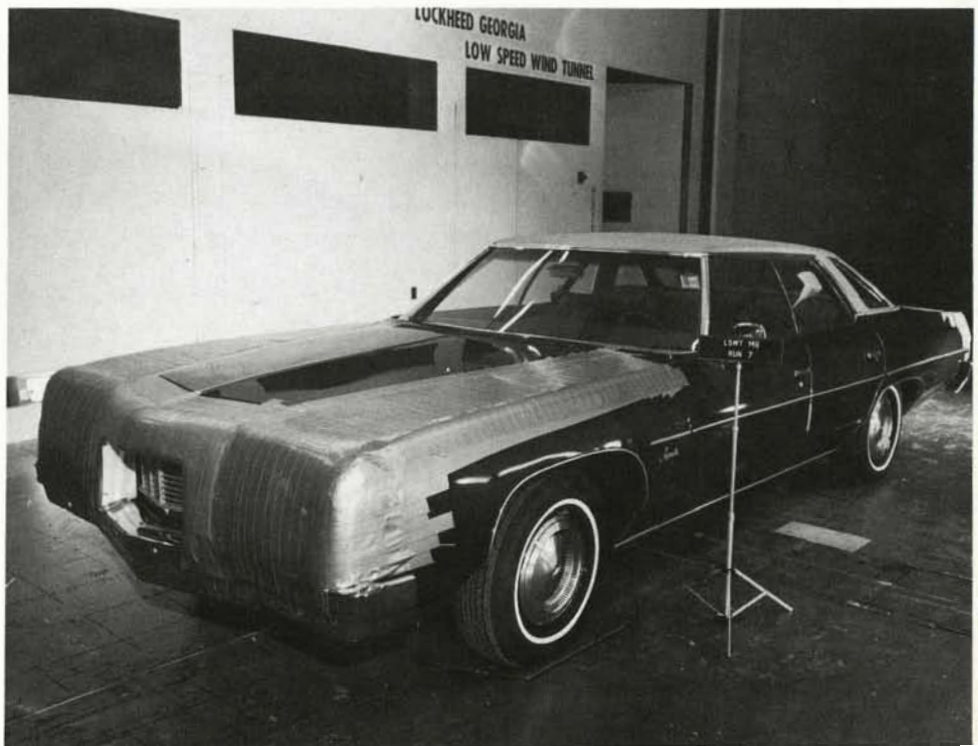
NASA engineers have found that air-drag reductions of 24% can be achieved simply by adding wind deflectors at the top of the truck between cab and trailer. In tests, the method has saved about 10% of fuel consumed.

On automobiles, adding a plate extending a few inches below the front bumper and a small spoiler on the back of the trunk results in about a 5% fuel savings.

Safer winter tires are another automotive transfer from space. If all goes as planned, the one-ton Viking lander will parachute to Mars this summer supported by just three straps of a remarkable new fiber. The fiber, five times stronger than steel, now is being used as the cords in the new tires.

The rubber of these tires, which do not use highway-destroying studs, is the same as that used on the tires of the "Rickshaw" used by astronauts Alan Shepard and Stuart Roosa to transport equipment on

Congestion like this is relieved significantly with "SAFER" system that calculates best traffic-light sequence to match automobile flow. Prototype system, transferred from computerized moon-landing equipment, is being tested in Los Angeles.



Auto body entering wind-tunnel test is modified to reduce aerodynamic resistance. NASA engineers find simple deflectors, other changes save 5% of fuel in cars, up to 24% in trucks.

the lunar surface. Conventional tires lose their pliability below freezing. The new ones provide traction even in the coldest weather. After all, they remained pliable on the moon in temperatures as low as 195 degrees below zero!

Smoother riding on highways and railways soon may occur through adaptations of gyro-stabilized spacecraft guidance systems. A new instrument is being devised to measure bumps, curves, and grades. Highways and railways thus can be shaped more precisely for better and safer riding, as well as making them easier to maintain.

Other new automobile improvements from space include better brakes lined with a new high-temperature space material; hybrid circuitry for more accurate digital clocks and radios that use 20% less electricity; and truly bright searchlights and flashlights for emergency use. The intense searchlight, which can operate from the cigaret-lighter receptacle of your car, was spun off from the xenon

Small moon tire (right) that remains pliable in extreme cold was spun off to all-winter radial (left) that grips ice without metal studs.

Grooves sawed into highways to reduce tire hydroplaning are adaptation of NASA runway research to eliminate airplane skidding.

arc lights developed for the space program to simulate the sun. The million candlepower searchlight is about 50 times brighter than your car's high-beam headlights, yet weighs only 7 lbs. A smaller unit in the shape of a flashlight produces 20,000 candlepower, or about nine times as much light as an ordinary two-cell flashlight.

Safer driving (and airplane landings) are resulting from aircraft runway research. NASA has conducted an extensive testing program on cutting grooves in runways to eliminate airplane skidding during rainy weather. Now sawed into highways, the grooves reduce tire hydroplaning, a phenomenon created by a thin layer of water on highways that causes tires to slip. New uses studied by NASA include pedestrian walks, playgrounds, sanitary concrete slabs in cattle ranches and dairy farms, loading docks, ramps, warehouse floors—anywhere that men, animals, or machines can slip on wet surfaces.

Driver aid to the handicapped

The lunar rover driven by Apollo astronauts on the moon also suggested a spinoff to enable severely handicapped people to drive an automobile. A quadriplegic impressed by the lunar rover's almost automatic controls was invited to try to drive the rover at Johnson Space Center. He did. He started, stopped, turned, backed, and even parked.

Thereafter, NASA and the Veterans Administration's Prosthetics Center began a long-range program to develop lunar rover-type controls for handicapped drivers.

Out of this work a design concept emerged that would integrate the control device of the lunar rover into a passenger vehicle. Field testing is proceeding now to determine whether the severely handicapped can drive such vehicles in traffic.

Mass—and individual—transit

Your mobility also may be extended through a variety of rapid-transit systems being explored now by aerospace companies seeking to utilize space-earned knowledge. Aerospace technologies in flight safety, reliability, and complex control designs are being adapted to mass-transportation systems. NASA contractors have built two high-speed gas-turbine powered trains for service between New York and Boston, and are designing a transit system for Columbia, Md., a "planned city."

A NASA program to develop a series of small, driverless electric vehicles is underway in Pasadena. Proximity sensors, optical filtering, and other space-developed methods are incorporated into a six-passenger experimental tram that automatically follows a thread-like cable on the roadway surface. The tram isn't supposed to replace urban rail or bus service, but rather will support these systems by providing inexpensive short-run feeder service to conventional stations.

The low-speed tram is started and stopped at will by the passengers themselves. Proximity sensors halt the car when anything comes in its path. It is steered by automatic circuits and a hydraulic servo system.

The first 'A' in NASA

In aircraft developments, NASA is providing the technical leadership for short-takeoff-and-landing aircraft, which ultimately offers a solution to the 300% growth in intercity air traffic expected 10 years hence. NASA's $100-million program, begun in 1971, will provide the technical base to build practical short-takeoff airplanes. Small airports then could be

Driverless electric tram, an outgrowth of several aerospace technologies, follows small cable on a roadway. Experimental vehicle may be forerunner of inexpensive feeder service to mass-transit systems. Proximity sensors stop the slow-moving car when approaching obstacles.

All weather inertial navigation system, "Carousel," an early transfer from Apollo spacecraft, now flies aboard some 500 jetliners. During flight, the instruments measure changes in airplane's position and speed, calculate new headings, and can be connected to autopilot to steer the plane.

Radar-reflecting cover of orange metallized polyester film aids searchers in marine rescues. Life raft can be spotted by radar 15 miles away. Improved raft is outgrowth of radar-reflective material devised to locate returning astronauts.

shoehorned into cities and surrounding suburbs, thereby making existing jet terminals adequate for some time to come.

Advanced airplane engines of the 1980s will utilize a significant breakthrough in ball-bearings designed by NASA. They will last 20 times longer than the highest-quality bearings now in use. Airplane-fuel consumption can be lowered at least 20% through the use of hydrogen-enrichment methods now under study at several NASA facilities. The research aims at improving general-aviation engines both to save fuel and reduce emissions. And helicopters will require less maintenance as a result of space-transferred high-speed carbon seals that last four times longer than conventional seals.

Internal navigation systems used by Apollo spacecraft have been spun off for commercial aircraft early in the space age. In more than 12-million hours in flight, the systems have proved to be 99.5% accurate. Today these navigation systems are flown in about 500 commercial aircraft. They are invulnerable to weather and are not dependent on radio, radar, or celestial navigation.

Rescue at sea

While all of these advances improve your mobility when you *plan* to go somewhere, one of the early successes of transferring space technology was the development of a life raft. The original life raft, utilizing a radar-reflective material, was designed by NASA in 1959 to assure that astronauts could be found if their returning spacecrafts were off course.

After reading about the radar-reflective idea in a 1964 *NASA Tech Brief*, several companies attempted to design a commercial version. But it wasn't until a scientist named Robert Perchard acquired an exclusive license from NASA and developed an improved raft that it entered widespread use. Perchard had a personal reason. His son, a Coast Guard pilot, had crashed in Alaskan seas. Conventional radar searching had failed to locate his life raft until he had died of exposure.

Perchard's new design incorporated a radar-reflective canopy colored speckled orange for easier sighting. He made dozens of other improvements too, in both rafts and life preservers. A man floating with a life preserver utilizing the radar-reflective material can be sighted from an altitude of 6,000 feet. Today the rafts and life preservers are carried by the world's navies, merchant marines, and pleasure aircraft and boats.

Last year, an airplane manufacturer began another phase in the evolution of this spinoff, the development of a life raft that can be deployed quickly from a downed helicopter. Most ditched helicopters sink immediately, rolling inverted, with water rushing in through cockpit windows.

The evolution of the radar-reflective life raft is repeated in kind with most spinoffs. Technology often progresses by the centimeter. But it never ends.

your home

Your home is a prime beneficiary of space technology. New building materials, better use of existing fuels as well as solar energy, fire-prevention techniques and tools, and a variety of household products all have been spun off from our national investment in space.

Builders and manufacturers of homes and housing equipment constantly strive for new methods and materials to survive in the highly competitive marketplace. Probably the most significant opportunity for change in houses over the next few decades will be in energy management. Our homes consume about 20% of the energy used in the United States each year—an amount almost equal to all imported crude oil.

Why not *show* builders, manufacturers, and homeowners how space spinoffs relate to home improvements? A dramatic way to do that would be to construct an actual house utilizing as many of the new developments as possible.

Planning for such a house has been under way for some time, and NASA will build a demonstration house during this bicentennial year at its Langley Research Center near Hampton, Va.

The Energy Conservation House being built at NASA near Hampton, Va. utilizes solar collectors, waste-water recycler, solid-state appliance controls, and many other space spinoffs. Demonstration house will be open to public this bicentennial year.

Now: the 'Tech House'

The demonstration house is called TECH, standing for The Energy Conservation House. Unlike past "houses of tomorrow," Tech House emphasizes cost effectiveness. It is not only a compilation of space spinoffs. Rather, Tech House integrates technical developments expected to be commercially available by 1981.

The 1,500-sq-ft building contains a living room, kitchen-dining room, three bedrooms, two bathrooms, laundry, garage, and an outdoor living area. Tech House will be tested by being occupied by a family for at least a year. Afterwards, it will be opened to the public.

NASA established some stringent criteria for inclusion of new developments in the house. For instance, initial costs of improvements must be repayable to a buyer through energy or other savings effected by the improvements themselves over the life of an assumed 20-year mortgage.

Tech House maximizes energy savings. Heating is provided by solar collectors and a nighttime radiator system using a heat pump. The house even partially reclaims waste water. Wall, roof, floor, and window sections, as well as home appliances, were studied to determine which components provide the greatest net savings.

Many of the energy-reduction advantages of Tech House are made simply through good design. For instance, the long axis of the rectangular house is oriented east-west with large south-facing glass areas. The garage is positioned to protect the house from the north wind. Two interior fireplaces, added for aesthetic reasons, are provided with glass doors to reduce heat loss through chimney flues. Doors between sleeping and living areas furnish better zone-temperature control.

Even the landscaping is designed in accordance with a new concept called "solarchitecture" that

contributes to the house's energy conservation.

While good design can go far in making improvements, space spinoffs are the essence of Tech House. Space materials are being used as part of "thermal shutters" to reduce heat loss through windows. Space-developed fire-retardant materials for curtains and carpets also are used, as are superinsulation, solid-state appliance controls, and low-noise flow valves for air-supply ducts. An integrated burglar-alarm system is independent of the house's electrical system.

Wires, flat and thin

NASA's flat electrical wire originally designed for spacecraft also is being incorporated into Tech House through special baseboards. Both baseboard flat wires for homes and under-the-carpet wires for offices now are being tested.

Substantial savings are expected to result because of reduced installation time.

Another housing development to which space technology has contributed is the unique geodesic dome originally designed by noted architect R. Buckminister Fuller. NASA supplied a grant to Fuller and his co-workers to develop the domes into future space structures. Today, larger geodesic domes are enclosing living areas, swimming pools, tennis courts, greenhouses, and commercial work areas. Nine of these structures can be seen at the Kennedy Space Center where they are to house the U.S. Bicentennial Science & Technology Exposition.

Some of the wall panels made for prefab houses also are a space spinoff. They resulted from high-performance plastics developed for rocket casings and liquid-hydrogen containers, and now save more than 15% in the cost of conventional prefab panels.

Better firefighting equipment

Should your home ever burn, firemen might use axes to provide ventilation. But axes are slow. Now small amounts of a special explosive can literally cut a hole instead of blasting a part of the structure apart as with ordinary explosives. The unique cutting charge was derived from the explosive used to separate stages of the Gemini launch vehicle.

Firemen now are being equipped with lightweight air tanks pressurized about twice as high as previous tanks. The new tanks, harnesses, regulators, and face masks with a wider field of view all were based on spacesuit technology. Firefighters also will have better short-range radios based on a NASA patent for weather-balloon communications.

Firemen's lightweight air tanks with double the previous pressure, better tank harnesses and regulators, and wider-view face masks are spinoffs from spacesuits.

Safer natural gas and solar heat

Not only building materials, but better fuel-handling, less waste, and new sources of power, are being derived from space practices. For instance, after the 1973 disaster on Staten Island that killed 40 workers repairing a liquid natural-gas storage tank, New York City requested NASA's help. The space agency has been at the forefront of handling liquid gases used as rocket fuels. NASA engineers have completed a prototype risk-management technique for use by the New York Fire Department in reviewing construction of liquefied natural gas tanks and equipment.

When gas or other fuel is burned in homes, much of it often is wasted through insufficient insulation. Such waste has been discovered selectively—and homeowners in several communities invited to see the results—by use of an aerial survey technique developed with NASA support. A thermal infrared scanner was flown over rooftops in Nebraska and South Dakota last year by a midwestern utility company. Temperatures of the roofs of buildings were recorded as "thermograms," in which warm roofs appear in light tones and cool roofs in dark ones.

Even the waste heat escaping through chimneys can be reclaimed. Heat-pipe technology devised for cooling electronic systems aboard spacecraft has been transferred to commercial equipment. The heat pipes extend into a chimney flue and redirect the otherwise wasted heat back into the building. Manufacturers of these highly efficient heat-transfer devices have found they increase heating efficiency in homes by about 10%.

NASA also is experimenting with solar collectors for heating homes. About half of the total heat demand of several multi-dwelling homes in Greenbelt, Md., is expected to be furnished by solar collectors installed this year on their roofs.

Private homeowners also have adapted NASA solar technology for their own use. One installed a corrugated thermal absorber he read about in a NASA publication to heat his swimming pool, estimating a utility savings of $400 annually.

A NASA scientist has determined that "black chrome," once used for plating cameras and decorating objects, is about 20% more efficient than commercially available coatings for solar collectors. While today's coatings make it possible for collectors to heat water to about 200 degrees, black chrome can raise it to well above the boiling point. The higher heat makes air conditioners significantly more efficient.

Products for your home

In addition to new building materials and fire-safety techniques, space research has contributed to the development of many products used in your home. For instance, the life of electric-motor brushes in vacuum cleaners, electric shavers, cameras, and many other products has been extended substantially with new space lubricants. These thin-fluid or dry lubricants were developed first for bearings and motors that had to work in the vacuum of space aboard orbiting satellite observatories.

Quartz-crystal clocks and watches that have an accuracy of a minute a year also came from space technology. They were developed for the Apollo moon missions, in which accurate timing was critical.

And, for the home hobbyist, a small 7-lb welding torch has been spun off from the space-developed chlorate candles that uniquely generate oxygen while burning.

Heat-pipe technology devised for cooling spacecraft electronic systems has been transferred to commercial equipment. Manufacturers have found about a 10% increase in home heating efficiency.

your environment

The population and technological explosions that have occurred so drastically since the nation began 200 years ago have modified your environment in the extreme. You live mostly in a world of metal and concrete instead of forests and streams. Made to go five miles an hour, you go five hundred. Built to eat when hungry, now you're governed by the clock.

Of themselves, these changes are neither bad nor good. It is what we make of them, how successful we are in adapting our environment to our goals—and in adapting ourselves to our environment—that we create better or worse conditions for human life. The realization that our environment is threatened, that our natural resources are finite need not be cause for despair. Conversely, they teach us an appreciation of human ecology, the interdependence between man and his surroundings.

Spinoffs from space technology are helping to improve that ecology. They locate and protect our natural resources, warn of storms and fires, detect and improve the quality of the air and water, and even contribute to our recreational pursuits.

The water and food watch

Among the myriad purposes of our Landsats, or land-surveying satellites for locating earth resources, is the monitoring of fresh-water supplies. Hydrologists analyzing Landsat data have found that man currently extracts fresh water from only about a hundredth of one per cent of the total global supply.

Satellites are promoting better utilization by observing large areas on a repetitive basis. For example, satellite pictures of snow accumulation and possible locations of subsurface water supplies in relation to cities, irrigated areas, and industrial developments make future planning more accurate and economical.

There is 20 times as much underground water in the United States as in lakes and rivers. Florida alone has more subterranean fresh water than exists in the Great Lakes!

Satellite water-volume measurements in Florida now calculate how much water is present in previously unmeasurable places such as swamps, and help decide whether to release water from one area to another. The satellites measure rainfall over remote areas. They determine the size and number of thousands of temporary small lakes in the southwest U.S. They immediately spot new water bodies, such as Lake Anna Reservoir in Virginia. They accurately map wetlands and drainage patterns in inland states. Even glacier ice—containing nearly 80% of the world's fresh water—is monitored by satellites for possible future use.

Crop identification now is performed routinely by satellite, utilizing NASA's computer-processing capabilities to make much more accurate forecasts of harvests. Precise estimates become more and more vital as the world's food demand rises.

By necessity, the satellite food watch also becomes a watch for the conditions in which destructive insects breed. Among the most damaging of agricultural insects is the screwworm. A satellite-sensing mission now is underway to eradicate screwworms in Mexico, as has been largely done in this country.

The screwworm is a grub that destroys cattle, poultry, and wildlife in warm regions. Eggs laid in open sores and navels of new-born animals hatch and grow to a length of a half-inch by eating living flesh.

At one time screwworms infested the U.S. from Florida to California and as far north as Nebraska. They have been kept in check in the last two decades by dropping billions of sterile flies to mate with females in the infested regions, thereby eliminating offspring. A 300-mile buffer zone along the Mexican border has helped protect the U.S.—although a reinfestation in parts of Texas in 1972 caused $10-million damage to livestock.

The two-country cooperative effort began last year in a 50- by 100-mile area in central Mexico. It is the forerunner of a much larger program to eradicate the insect throughout all Mexico, maintaining a new buffer zone across the narrow isthmus near the Mexican-Guatemalan border.

Without satellites, 260 additional weather communications links would have to be constructed to yield accurate environmental data. Continuous, detailed reports on soil temperature, moisture, and vegetation coverage are required to determine the insect's breeding patterns so sterile male flies can be distributed effectively.

Similar technology may help extend the sterile-fly technique to other insects, such as the tsetse fly in Africa. The disease-carrying tsetse is so great a danger that thousands of square miles of Africa today are unfit for human or animal habitation.

Forest fires and floods

Among the most dramatic applications of space technology to your environment is the improved ability to detect possible disasters such as forest fires, tornados, and floods. Forest rangers say that knowing where fires may occur and how they might act is almost as important as quenching them.

NASA sensors originally developed to detect fires on airplanes and spacecraft have been teamed with a


NASA

Fire-index monitor, adapted from instrumentation developed to detect the characteristics of spacecraft cabin atmospheres, checks forest for flammability, tells where a fire might be most likely to occur.

satellite relay station and computers to provide a fire-index monitor for forests. The sensors check air temperature, relative humidity, and the flammability of forest-floor litter, in an experimental program in California.

The measurements are converted and beamed to satellites to avoid interference by mountains. There they are coordinated with area-wide photographs. The combined data then are beamed to a NASA facility in northern California where they are processed by computer and sent to the forest ranger stations.

The data measurements are consistent and accurate—so much so they are being used now by the weather service in Sacramento for long-range regional forecasts. Data now are collected throughout the year instead of just during the "fire season," which improves forecasting. Integration of a fully automatic data-processing system now underway will serve as a prototype for a network of 23 automatic unmanned remote stations scheduled for mid-1977.

Another kind of space technology has been in use for more than a year by the U.S. Forest Service to help with its huge job of surveying our vast forest resources. It is a "pole of light" that enables surveyors to take a bearing on a point they can't see.

The surveying tool, a spinoff of laser technology developed for space communications, is carried into the woods and erected over an otherwise-unseen marker. It sends a narrow beam of light vertically into the sky. The beam thus literally becomes a pole of light that can be used as a target for one or more receivers placed at great distances from the laser. The technique eliminates the need for machetes or bulldozers to carve a straight sighting path through jungles or forests.

The weather watchers

Forest protection is a vital but small part of the earth-watch by satellite and other space technologies. A larger part of it is weather forecasting. The 36-hour predictions of today are as accurate as the 12-hour forecasts issued 10 years ago—correct 82% of the time.

Even better forecasts should ensue as a result of the three meteorological satellites now in fixed orbits 22,300 miles above the equator. Number one in the series, launched in 1974, provided the first almost-continuous day-night coverage of a major hurricane and later was moved in time to observe last spring's tornado season in the midwestern and eastern U.S. The last of the three satellites was launched last fall.

NASA is working not only to observe and investigate tornado phenomena, but also to develop tornado-resistant building designs. Similarly, the space agency's computer technology and satellite pictures are mapping areas flooded by the Mississippi River, helping states assess damage and plan disaster relief.

After the 1973 Mississippi flood, which resulted in extensive damage and loss of life, Mississippi and Louisiana officials received special training by NASA in remote-image analysis. In coming years some 20,000 communities will need detailed surveys not only to control floods but to determine what insurance rates should be set for various flood areas. NASA is helping with the mammoth task, utilizing its technologies in surveying, hydraulic analysis, mapmaking, computer software, and digitization procedures.

Another vital resource—urban land—is no less a candidate for ecological study by space technology. Techniques developed for analyzing data from the moon and planets will help suggest better uses for specific areas of land later this year in Los Angeles and Tacoma, Wash. Experimental programs begun there incorporate maps, satellite photos, and other land data into routine city and county census records. Urban planners can query their data bases and display numerical values for each of their city's blocks and streets on a TV screen.

The system is being developed in such a way that it can be used in some 200 large U.S. cities that use computerized census files. These cities then will be able to make more intelligent rezoning and other urban-planning decisions.

The freon threat

Space techniques also contribute to controlling air pollution over cities and in the upper atmosphere. NASA recently developed an extremely sensitive spectrometer to determine whether gases released from aerosol spray cans are disrupting the earth's protective ozone layer. Flying the instrument at various levels in and above the atmosphere, scientists found hydrogen chloride—produced by the breakdown of aerosol gas molecules in the stratosphere—is distributed in a layer starting at nine miles and reaching a maximum concentration of almost one part per billion at about 12 miles.

The results don't necessarily implicate the use of freons, since hydrogen chloride is released naturally from the oceans and volcanoes. But the level is relatively high now and must be monitored to detect any future buildup.

Freon itself doesn't harm the ozone layer, but when it reaches an altitude of about 25 miles, the sun's ultraviolet rays trigger the release of chlorine from freon. The chlorine breaks down the ozone. Millions of tons of freon are produced annually, but it takes about 10 years for freon to drift up to the level where it dissociates. Thus measurements at all levels of the upper atmosphere are needed. The high-

altitude research also is important in determining the pollution effect of supersonic jet airplanes flying in the stratosphere. Later this year the Orbiting Astronomical Observatory-3 will be used to add to the body of information gathered from aircraft and sounding rockets.

Similar instruments are being used by NASA to measure air pollutants emitted from airports, coal-fired power stations, city incinerators, and automobiles.

In one spinoff, a NASA instrument developed to detect effluent produced by solid-rocket fuel is being used to measure harmful gases released from burning waste oil in the Gulf of Mexico.

In another, computer programs devised to perform thermodynamic analyses of rocket combustion have been transferred to predict where oxides of nitrogen will be formed in municipal combustion chambers. For instance, the Los Angeles water and power department had spent $6.5-million constructing a new plant when a building permit was denied because of anticipated emissions of nitrogen oxides. Use of the NASA programs reduced the emissions sufficiently to comply with the new law. The additional pollution-control equipment will cost $2-million compared to the total plant cost of $68-million.

Not only are ideas and products being spun off. So is used equipment. One space contractor has adapted the facilities it built to test the lunar-module rocket engines into a facility for removing sulfur from coal economically. The company's plant south of Los Angeles includes test stands, fabrication shops, computerized monitoring equipment, and a complete chemical laboratory. A half-ton per hour pilot plant is being built there to treat the coal. It will occupy the lunar-module engine test stand.

One space contractor has adapted the facilities it built to test the lunar-module rocket engines into a facility for removing sulfur from coal economically.

But because high-sulfur coal will have to be burned for some time, NASA also is working to measure smoke-stack emissions. A program to detect sulfur-dioxide effluents at a distance is under way. Ultraviolet video tubes and telephoto lenses measure the otherwise-invisible emissions. The television technique was spun off from its first purpose—to identify hydrogen leakage and prevent fires in tanks where space rocket fuel is stored.

Cleaner sewage: accidental and otherwise

Accidental inventions, proof of theories, or interesting items of information often are found while looking for something else. Horace Walpole's fairy-tale about Ceylon, "The Three Princes of Serendip" (as Ceylon used to be called), whose heroes made such discoveries routinely, injected the word "serendipity" into our language. Serendippers, or finders of things unsought, also operate in the realm of space technology, at least once in awhile.

One significant example is the million-gallon-a-day sewage treatment process that originated when a NASA chemical engineer was testing materials in search of a lightweight rocket-engine insulator. He built a pyrolysis unit for manufacturing activated carbon. As a result, he later discovered that sewage solids made an excellent raw material that proved to be a good agent for further sewage treatment!

The work led to the construction of a new kind of sewage plant. Expected to begin operating later this year at Huntington Beach, south of Los Angeles, the plant converts solid sewage to activated carbon. The carbon then treats incoming wastewater.

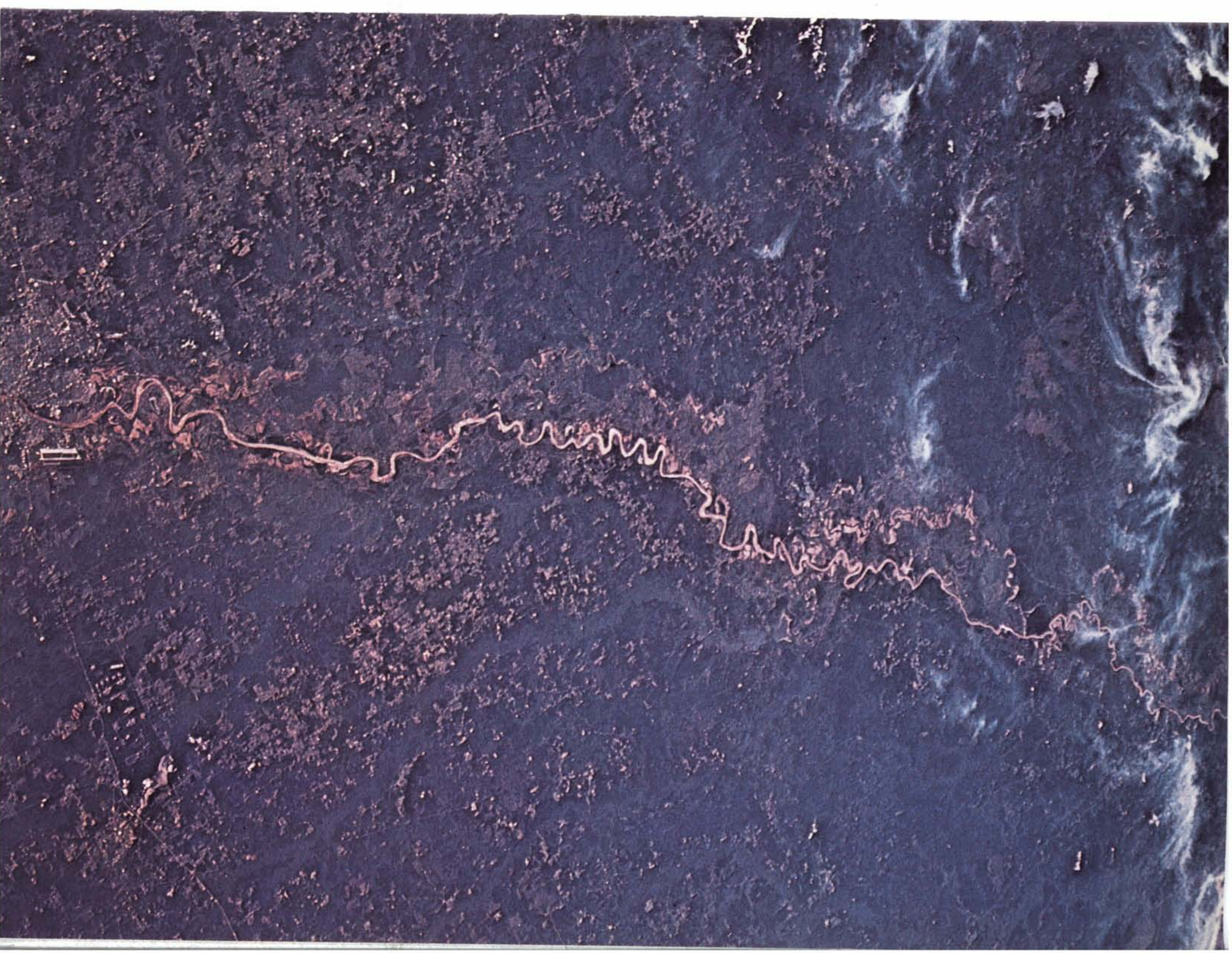
This sewage plant—which incidentally is a large-scale pilot operation for even bigger ones to come—not only makes activated carbon out of the solids by high-temperature heating, but recycles the newly made carbon back with new sewage solids, where it is reactivated. A small amount of ash is all that remains at the end of the process. Contrast that to most municipal sewage plants in the U.S. today, which discharge about 40% of their solid wastes into the nation's rivers and offshore waters. The new NASA innovation is a solid breakthrough in more ways than one!

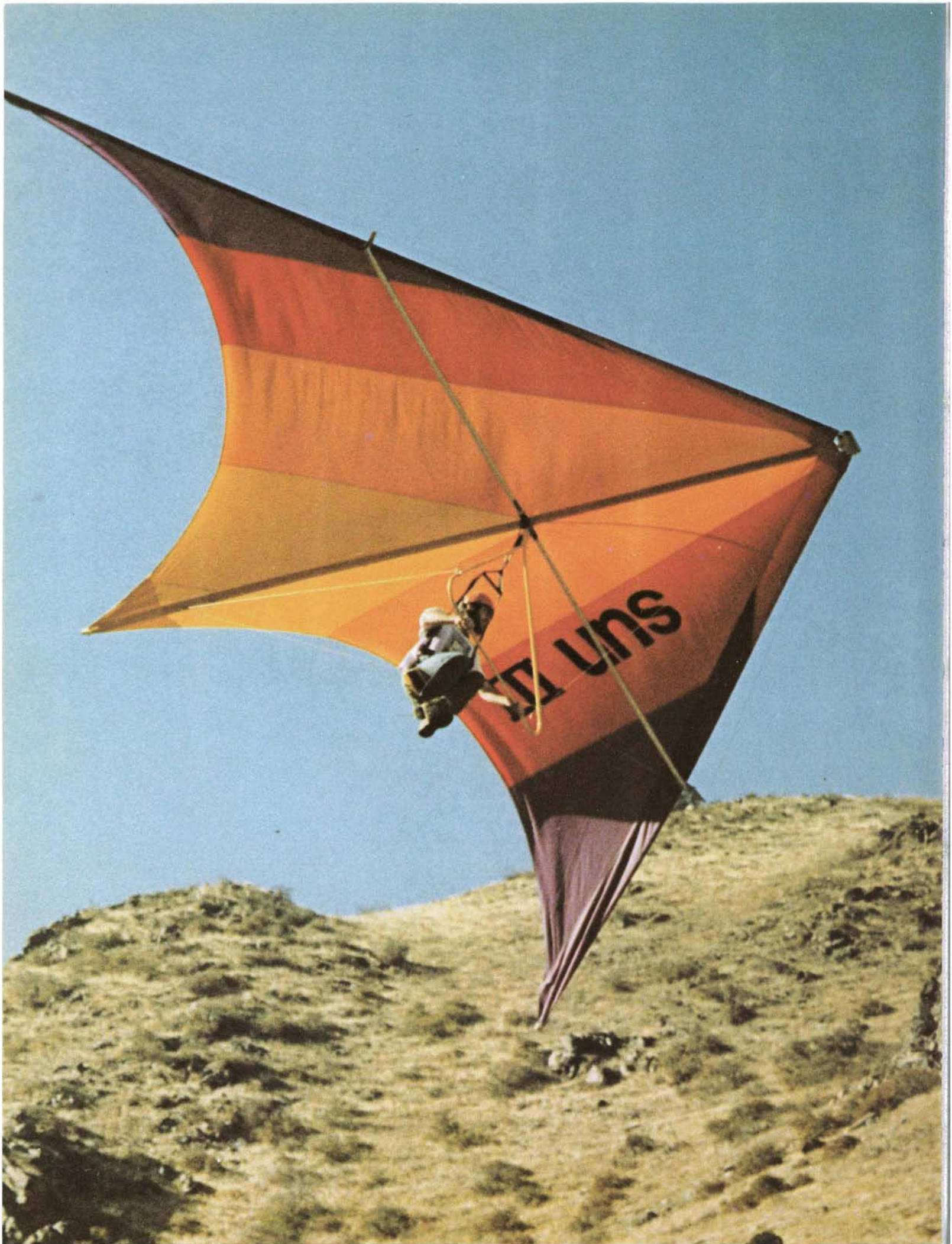
In another kind of water pollution, hot water discharged from power plants into rivers, lakes, and oceans often is suspected of increasing algae growth, which depletes dissolved oxygen in the water and kills fish. On the other hand, clean hot water from power plants has been shown to promote fish growth.

Obviously, better tracking of hot water streams, or "plumes," is needed to foster a better understanding of the effect of heated water on marine life and to decide where to locate future power plants.

NASA's work with sonar systems and advanced electronics to find space payloads landing in water will be spun off this year to tracking underwater thermal plumes. A miniature sonic transmitter will be modified to determine both temperature and depth. The device thus will become a wireless "bathyther-

The Red River Valley in Louisiana between Shreveport and Natchitoches is seen from space. Straight light marks in foreground are Barksale Air Force Base near Shreveport.

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mograph," or instrument to measure the temperature of various water depths.

The unmodified sonar beacons also might be used to track wastes dumped in our oceans. For instance, garbage from nearly a *tenth of the U.S. population* now is barged and dumped in an area within about 25 miles of New York Harbor. Sludge is formed, but effluent from it drifts along the bottom, creating a potential health hazard. The NASA sonar beacons allowed to drift just above the seabed could monitor the direction and spread of the sludge to determine whether or where to allow future dumpings.

Predicting the 'red tide'

A space-assisted attempt to identify the onset of "red tide" also will get under way this year. The red tide consists of ocean-borne algae that leave tons of dead fish rotting on beaches. In Florida alone, a red-tide invasion has cost as much as $20-million in lost tourist business in a single season. The algae also concentrate a poison in shellfish.

NASA is working on an early-warning system that will include aircraft flying at various altitudes, on-site sampling of oceanic waters from research ships, and a scanner to be flown on the Nimbus-G pollution-sensing satellite scheduled for launch in 1978. The scanner is a spinoff from Apollo use where it enabled astronauts to determine prevalent chemicals in ocean landing areas. The space agency also is developing a submersible instrument to measure water clarity and an underwater meter to determine how daylight scatters in water—both as part of the warning system.

Environment for recreation

Your environment is—and should remain—of recreational quality. Space spinoffs not only are serving to improve and protect the land, air, and water, but have resulted directly in recreational devices. New products for outdoor sports, concerts, and even a cross between a movie and an amusement-park ride are among current items.

For instance, the aluminized plastic devised originally to keep cryogenic fluids cold now has spun off into extremely lightweight sportsman's blankets and jackets, sleeping bags, and ski parkas. Spacesuit technology has resulted in electrically heated gloves and skiboots that are rechargeable. Composite materials used in many space structures have been adapted for lighter, more efficient golf clubs and casting rods. An anti-fog compound formulated to keep spacecraft windows clear during launch now is used on diving masks, ski goggles, and snowmobile windshields.

NASA's Rogallo wing first used to recover space payloads now are sweeping the country as hang gliders.

Even those hang gliders colorfully winging their way along beaches and sand dunes are a spinoff from space.

A new silicone plastic foam that takes the shape of impressed objects but returns to its original shape even after a 90% compression has been transferred from better airplane seats to the liners of football and other sports helmets. Used as a gymnasium pad, the foam material is said to absorb all the energy of an adult falling 10 feet.

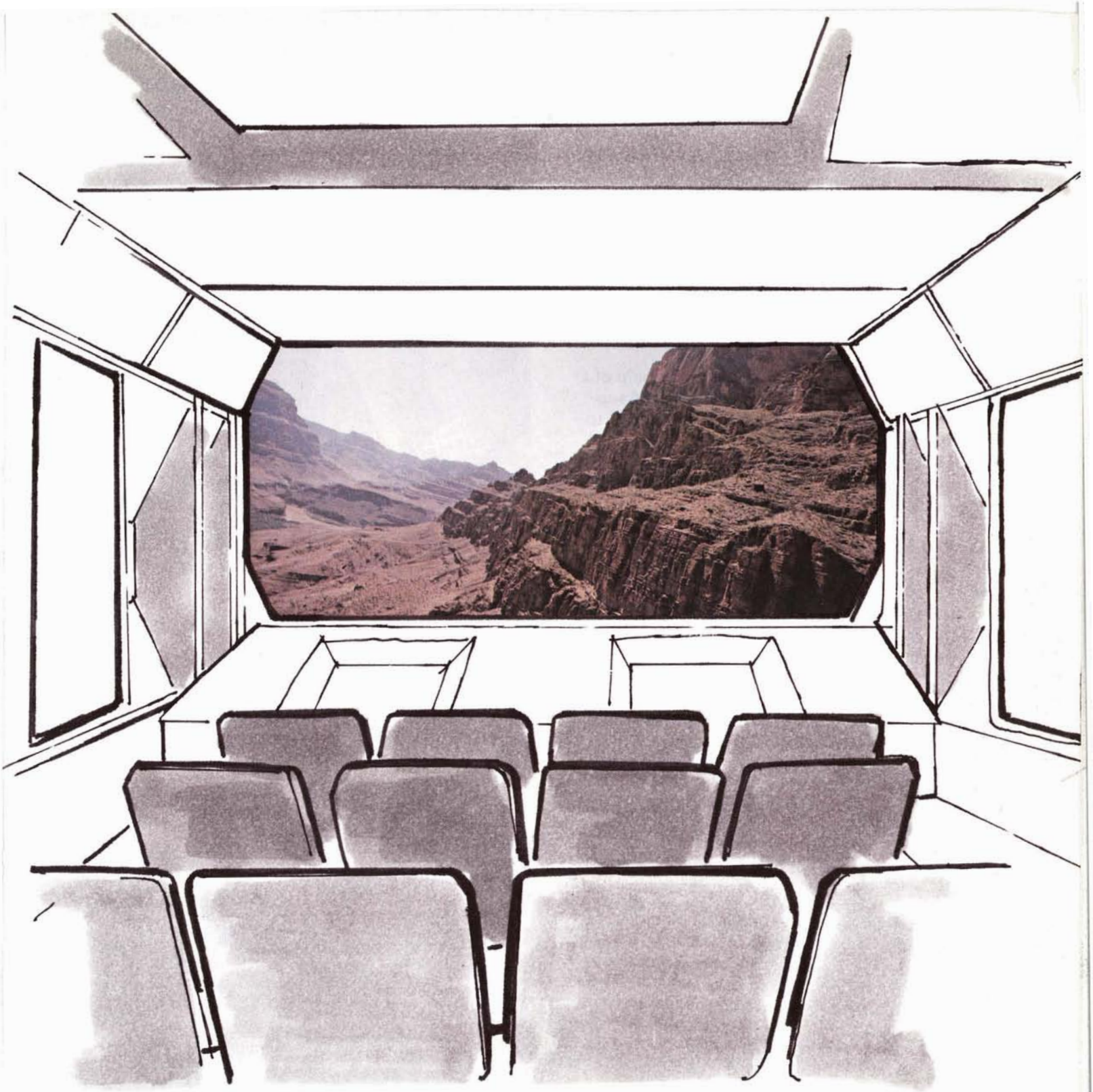
Even those hang gliders colorfully winging their way along beaches and sand dunes are a spinoff from space. They were designed first to recover spacecraft.

Safer pleasure boats have resulted from a material devised to protect fuel tanks on spacecraft and airplanes. The material, applied as either a coating or a tape, protects fuel hoses for inboard motorboats. In case of fire, the coating swells to as much as 200 times its original thickness and releases gases and water that help quench the fire.

Outdoor concerts now can utilize collapsable, reusable 100-ft towers to hold spotlights and speakers. The lightweight towers are a spinoff from the large radio telescope antennas used aboard orbiting satellite observatories.

And your indoor recreational environment has undergone a beautiful change in a performing arts hall in Akron that uses movable ceilings to accommodate audiences as small as 900 or as large as 3,000.

Reusable tower arrives on scene in collapsed form, then is extended 100 ft or more. A transfer from satellite antenna tower holds spotlights and speakers for outdoor concerts, among other uses.



Showride—a cross between a movie and an amusement-park ride—combines features of each in 12-person "moving" cabin. Development emerged from technical information provided by a NASA industrial applications center.

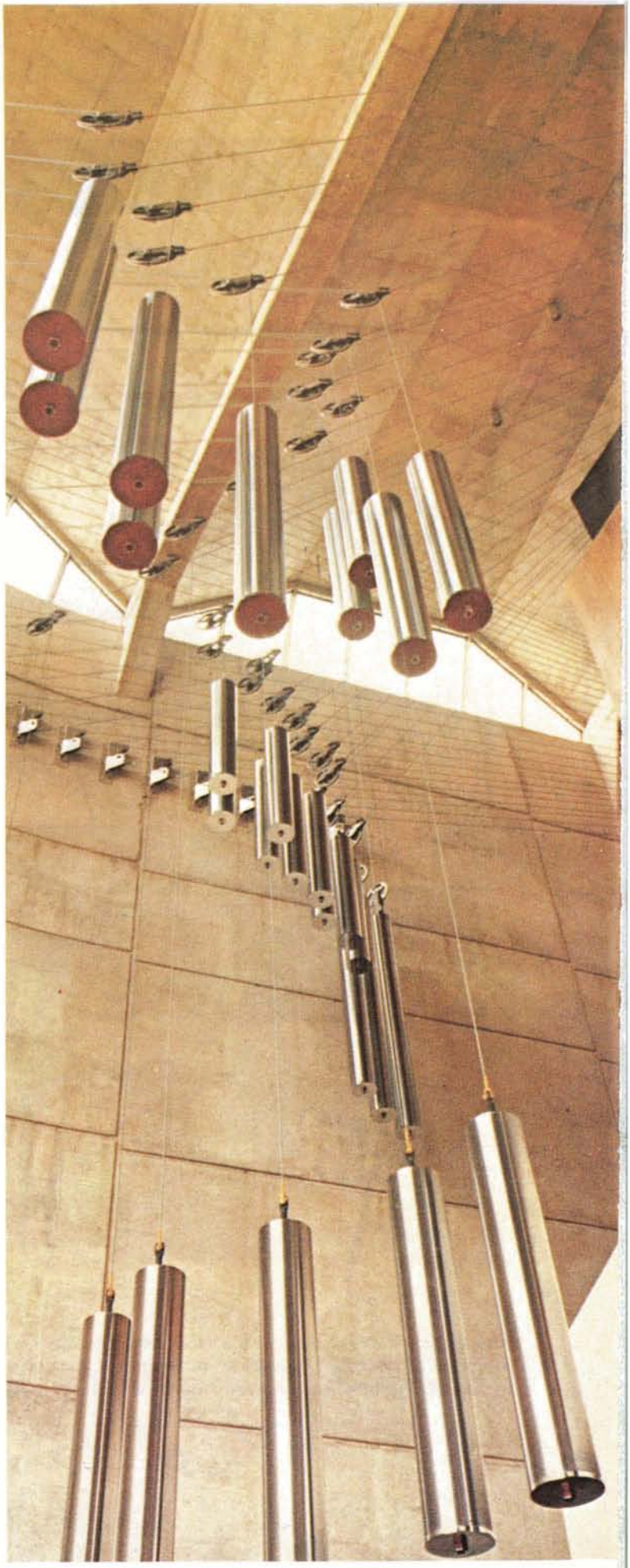
With population pressures increasing, new recreational pursuits both indoors and outdoors doubtless will emerge.

One of the most attractive theater-concert halls in the world, the building employs a computer-controlled acoustic ceiling for sound-tuning the various activities conducted inside.

The movable ceiling functions with the help of a simple tool devised to equalize tensions in 150 supporting cables. The tool originally was developed to measure and adjust the cables of the elevators used at Cape Kennedy for lifting heavy spacecraft.

Finally, a new recreational device billed as a "total sensory experience" resulted from information furnished by a NASA industrial applications center. The entertainment product, called "Showride," consists of a 12-person cabin that can simulate any kind of room, a wide movie screen, and a four-track audio system. The cabin is moved smoothly or suddenly in synchronization with the motion picture.

Your world in a box is fun—for amusement parks. With population pressures increasing and with Americans expected to work fewer hours as our next century unfolds, new recreational pursuits both inside and outdoors doubtless will emerge. In any event, a cleaner, less-cluttered world will be essential to your recreational and mental well being. Space technology will continue to contribute to improving your environment.



Combination theater-concert hall in Akron uses movable ceilings to change seating capacity and alter acoustics. Ceiling is adjusted with cable-tension tool developed by NASA for elevators to left spacecraft.

your future

One observation can be made of all the developments so far related: we live in an age of great change, of cultural revolution, and fortunately so. As Emerson asked, "If there is any period one would desire to be born in, is it not the Age of Revolution, when the old and the new stand side by side and admit of being compared?"

Compare them. The Wright brothers made the first successful powered flight in 1903, within the lifetimes of many people alive today. Sixty-six years later we landed men on the moon. Now we fly unmanned ships a half-billion miles to Jupiter.

The first 200 years of our nation may well prove to have been the hardest. When you realize how far we have come in understanding the universe and in using it to improve our lives in such a brief time span, you realize how much further we can go in the next 200—further, perhaps, in human relations as well as in technology. The two fields are closer than previously realized.

For instance, who would have thought just a few years ago that the Soviet Union in 1976 would be planning a ground station to receive data from our Landsat earth-resource satellites? Or that U.S. experiments would be flown on board a Soviet spacecraft? These are just two examples of hundreds of areas of recent cooperative programs in space between the U.S. and *most of the other nations of the earth.*

In a sense, *all* of the case histories of space benefits related in this report—and literally thousands more—will affect our lives to an increasing extent in the future. So will trips to the planets and, ultimately, to other solar systems. But what of the near term? How will spinoff affect your life in the next few years?

The coming age of solar power

Chief among these relatively near-future space benefits are energy developments, and chief among those is the direct reduction of sunlight to electricity. While the national debate proceeds to determine which sources of power shall have priority, the fact that solar-power conversion works *now* means that it will play a role as an energy source. Only the extent of solar-energy usage is undecided today.

NASA has gone to great lengths—literally into space!—to improve the performance of light-to-electricity, or "photovoltaic," cells. These devices, so far quite expensive for large energy outputs, are used routinely to power equipment aboard spacecraft. While they work on the surface of the earth too, they are more effective in space where they are free of clouds and nighttime conditions.

An exciting idea is to build large power satellites in orbit. There the cells would be more than three times as effective as the same cells placed on earth. Their energy would be beamed in the form of microwaves to large antennas positioned anywhere on earth.

A more efficient photovoltaic cell is being perfected at NASA's Jet Propulsion Laboratory. The cell is made from a compound called gallium arsenide with an extremely thin, nearly transparent gold film on its surface. In addition to greater efficiency, the solar cell resists radiation better than former cells, making it suitable for long life either on earth or in space.

While more standard research proceeds on increasing photocell efficiencies, NASA also is investigating other theoretical approaches to converting sunlight to electricity. One recent study funded by the space agency at a university seeks to determine the theoretical feasibility of a solar-conversion technique patterned after insect antennas.

Light received by our eyes is converted to electrical impulses by the retina. Insects communicate not only by receiving light rays, in the infrared as well as the visible spectrum, but they do so selectively—that is, by actually tuning their antennas to the proper frequency. Learning how they do this could prove valuable in developing lightwave energy-conversion devices of the future.

Related to the development of solar energy is the age-old windmill. Like photocells, wind generators

Hundreds of cooperative space programs are underway between the U.S. and most of the other nations of the earth.

are a clean-energy replacement for fossil or nuclear power. They can be used in areas where winds are abundant and steady.

NASA has spun off its expertise in aerodynamics, generators, and computer technology to design a modern 100-kilowatt windmill under sponsorship of the Energy Research & Development Administration. It was built late last year at the NASA Plum Brook test area near Sandusky, O. Electricity produced is sufficient to power 25 single-family houses. It is supplied through existing utility lines. The experimental system consists of a 125-ft rotor blade, a large tower, and transmission equipment.

In future models, NASA plans to utilize tiny semiconductor computers developed for spacecraft

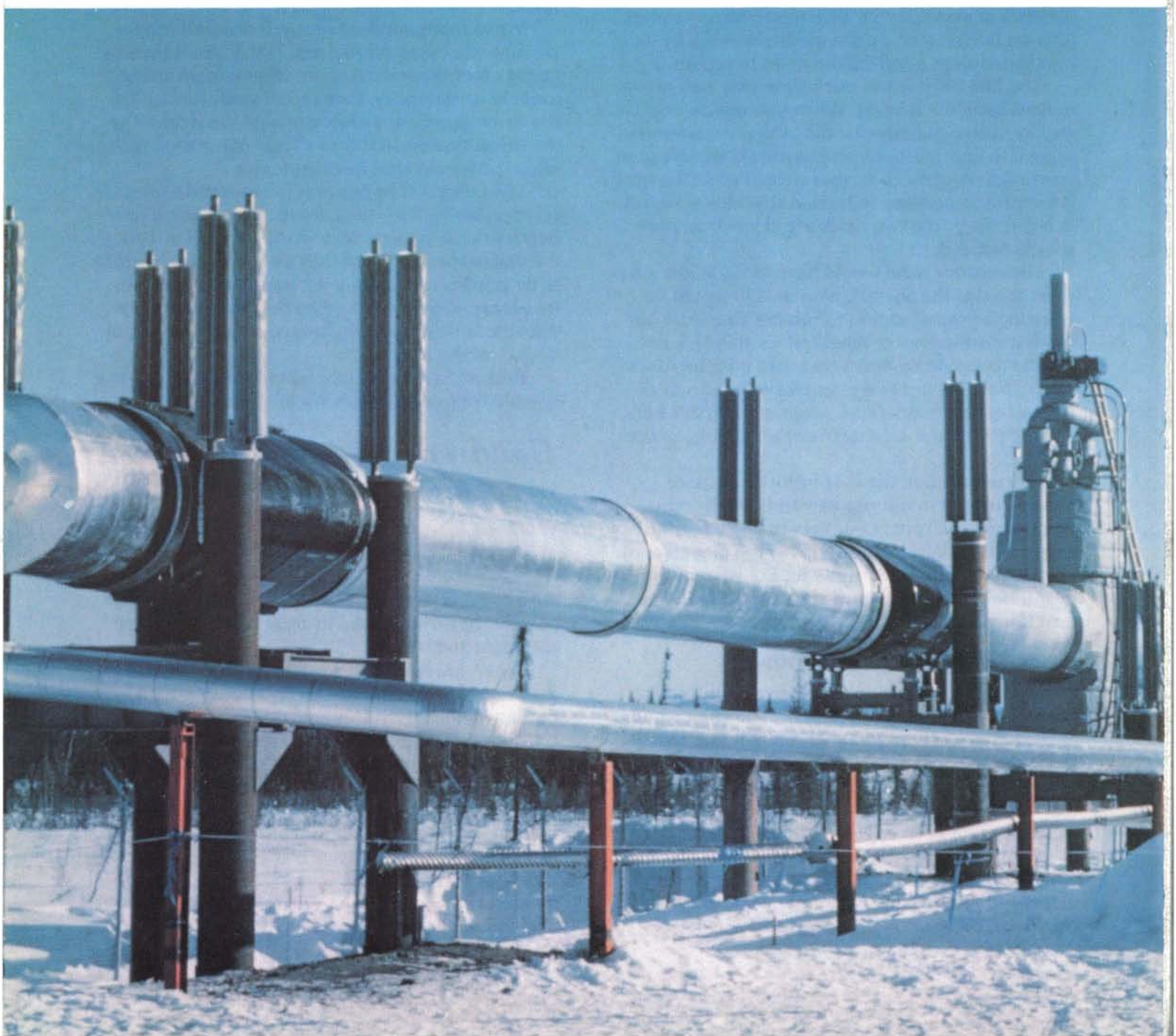
to adjust the blades automatically in response to wind changes. Such tests must precede development of truly big wind machines capable of producing millions of watts. If the output of the new NASA windmill could be increased tenfold by more efficient designs and larger rotors, about a half-million windmills—according to one estimate—could generate all the electrical energy now consumed in the United States.

In addition to supplementing conventional utility systems, windmills are ideal for remote locations. The main problem here is storing power during comparative calms. Thus NASA is studying the storage of wind energy by containing it in flywheels, by compressing air to drive air turbines, by separating water into oxygen and hydrogen, and by improving battery systems.

Coal, oil, and minerals from space

Conventional energy improvements also are being spun off from space technology. NASA and the U.S. Department of the Interior are working together to develop improved coal and coal-mining methods to be demonstrated in the mid-1980s. The coal research will draw on aerospace technology in such fields as automation, remote control, and combustion.

And when the oil finally begins to flow southward from Alaska's rich new fields, space technology will be largely responsible. A revolutionary heat pipe developed to cool electronic equipment on spacecraft has been transferred to the arctic environment where it is being used to keep the ground frozen along the 800-mile pipeline from the North Slope to the southern port of Valdez. The permafrost must be



kept frozen along the entire route to avoid frost-heaving, which can tear apart a pipeline and spew oil over the landscape.

The exploration for even newer supplies of petroleum will proceed more efficiently by using a variety of remote-sensing satellites and space-instrument spinoffs.

One of the latter is a neutron-monitoring device developed to analyze chemicals on the moon. Now it is helping locate oil and other needed minerals on earth by bombarding search areas with neutrons. (The bombardment is of such low intensity that there is no residual activity after detection.)

The instrument, together with a data-acquisition system, can indicate what geographical areas show the most promise. Detailed core samples then can be taken in these locations to reveal oil, coal, or ore deposits.

Another instrument, initially devised to investigate small changes in the atomic composition of spacecraft metals that could cause structural failure, has been adapted into a gravity-meter. The density of hydrocarbon-bearing rock produces gravity anomalies slightly different from other soil. Thus the super-sensitive gravity-meter may be able to reveal mineral and oil deposits from the air.

Our near-future Alaskan oil supply will begin its journey in a pipeline across the state, passing over permafrost part of the way. Heat pipes that cool electronic equipment in spacecraft now keep the permafrost frozen. The vertical heat pipes, shown on either side of the pipeline, contain ammonia that evaporates as it soaks up heat from the ground. Heat pipes prevent frost-heaving that could tear pipelines apart.

Diagnosing defects before birth

Sometimes the link between space technology and private use is anything but obvious. For example, the computer-image processing systems now used routinely by the space agency to enhance satellite photos have been adapted for genetics research. Geneticists are beginning to use the technique to identify missing chromosomes for diagnosing inherited diseases before birth. Such analyses could help reduce severe human afflictions such as mongolism in the near future.

NASA's new automated procedure starts with blood samples to produce microscope slides containing cells with visible chromosomes. The slides are searched by a computer-controlled microscope that finds the cells and feeds their images into the computer. There the individual chromosomes are isolated, measured, grouped by type, and arranged in the standard geneticist's format.

Diagnosing genetic errors by inserting a small needle probe into the abdominal wall of the mother also can be done now. The probe carries light through tiny fiber-optic tubes to the interior of the uterus, and returns an image to a television camera. The light source is a scaled-down version of the huge xenon arcs used in space simulators. It is ideal for this work because of its high brightness and concentrated beam. Research is proceeding currently to reduce the size of the optical system without loss of image quality.

Of less profound importance, another advance of personal interest soon may be available due to a space technique for coating lenses. If you've ever been bothered by glasses that slip off your nose or have dropped a pair, you may have considered plastic lenses that are lightweight and don't shatter. The trouble, of course, is that they scratch easily. The scratches scatter the light, reducing light transmission. The new space method results in an antireflection coating that reduces scattering, and could be used to coat plastic eyeglasses and many other lenses.

In designing unmanned spacecraft to explore the planets, NASA has gained a unique capability now being transferred to the planning of health-care needs. A computer model that integrates demographic, health, and other data already is being used experimentally in Los Angeles. The data can project rational requirements for hospital beds and medical specialists.

Among spinoffs in other areas that will affect your near-term future should be included the coming era of automated banking and ticketing described under "Your Job" in the context of increasing productivity. Tellerless banking machines, already in the lobbies of many banks and other buildings for use after closing, will coincide with the expected explosion of credit transactions in the near future. Ultimately, over the long term, currency could become obsolete.

Many of the other products and techniques reported in this publication will come into use in the near future, since all of them are current or ongoing projects. Automobiles with better gas mileage and less air drag, architectural improvements such as geodesic domes and the Tech House, better use of urban land as a result of marrying computerized demographic data with maps, longer weather forecasts, fewer forest fires, new recreational pursuits—all of these spinoffs soon will begin to affect your future. Perhaps later some of the products you use routinely even will be manufactured in the null gravity and vacuum of space itself—the ultimate spinoff.

Our irreversible commitment

Ours is a progressively technical civilization. Our national commitment to technology for improving our lives is irreversible; thus, technical goals must be questioned carefully more than ever before. Understanding this technical world is a challenge for all of us, not just for scientists and engineers.

In addition to formalized education, several nonprofit organizations exist today to fill the educational void that exists between specific areas of technology and the public. In the space field, for instance, there are the American Institute of Aeronautics & Astronautics, the American Astronautical Society, and the National Aeronautic Association. These are primarily organizations for aerospace technologies or educators.

A new organization was launched last summer for laymen, called the National Space Institute. Among its current projects is the awarding of a "Space Product" seal of approval to manufacturers of the kind of spinoffs described here—thereby enabling consumers to identify a product derived from space technology. The purpose of the institute is to offer a forum for the discussion of national space goals.

It is important that the public have a voice in the direction of civilization's vast new frontier. It is important that people from all walks of life partake in both the realities of space today and the dreams of tomorrow. Dreams of a better life built America, and they will build the frontier of space.

There are whole new worlds out there, and whole new worlds of thoughts. Where have we come from? Where are we going? The answers lie in the dark reaches beyond this planet.

Or in the brightness of another sun.

How do all these aerospace spinoffs work? And how do industry and NASA make them happen?

Technology Twice Used

industrial productivity

How do all these aerospace spinoffs work? And which industrial companies and NASA centers are making them happen?

The technology underlying many of the current spinoffs in the first section and other ongoing programs are described here in more technical detail under categories in Construction, Transportation, Energy, Industrial Productivity, Safety, Medical Instrumentation, Medical Systems, Pollution Control, Natural Resources, and Recreation. These stories reflect the direction of NASA's Technology Utilization Office. They are examples of NASA's continuing efforts at the beginning of 1976 to spin off technology from the space program to industrial and commercial usage, for the benefit of all Americans.

Programing for design

Structures under stress are designed much more rapidly—allowing for remarkable increases in productivity—since NASTRAN (for NASA Structural Analysis) has become available. The versatile computer program, written originally to help design more efficient space vehicles, finds additional applications each year.

Use of the program has been estimated to result in a 60% improvement in predicting the behavior of stressed components and a two-thirds cut in calculation time.

Because it can be used to analyze both dynamic and static behavior of elastic structures under a wide range of loading conditions—with more than 65,000 degrees of freedom—the program is adaptable for structures of any size, shape, or purpose.

For example, the automotive industry uses the program to design front suspension systems and steering linkages. Railroad tracks and cars are designed with NASTRAN. It's also used in designing bridges, power plants, skyscrapers, aircraft, and—round robin—now the space shuttle.

A recent use of NASTRAN has enabled Pullman-Standard Inc. to simulate the dynamic behavior of rugged railroad cars for bulk commodity transport.

By far the most widely used computer program to emerge from the space program, NASTRAN helps analyze the behavior of elastic structures of any size, shape, or purpose, such as the hopper car below. This one program alone has been estimated to return $701-million in cost savings from 1971 to 1984.

Faster finances

The automatic checkout equipment for the Apollo spacecraft is one of the most complex computer systems in the world. Used to integrate the extensive Apollo checkout procedures from manufacture to launch, it has spawned major advances in computer systems technology.

These advances have been applied by TRW Inc. to retail-store and bank-transaction systems, as well as to control systems for electric power-transmission grids—reducing the chance of power blackouts such as the one in 1968.

The store and bank credit system has caused significant improvements in speed and accuracy of transactions, credit authorizations, and inventory control. To date, TRW has installed some 60 retail computer systems for 40 of the nation's largest retail chains. More than 50,000 point-of-sale terminals are connected to these systems.

Commercial banks in the U.S. have remained at about 14,000 since 1946, but bank branches today have doubled that number. Some 40-billion checks will be written each year by 1980. The banking explosion requires tellerless bank facilities and an automated clearinghouse for interbank exchange of paperless entries.

NASA's Apollo guidance software has been adapted by TRW both for tellerless banking terminals and for faster teller transactions, in which almost all normal human errors are eliminated.

A similar computerized service, called "Validata," now is used nationwide by airlines, airline ticket offices, car rental agencies, and hotels. A central computer contains 10-million credit records. TRW subscribers use small terminals at ticket counters or cash registers to make credit inquiries when their customers submit credit cards, checks, airline tickets, and other noncash payments. The Validata system has 1,000 subscriber terminals in 151 localities throughout the country.

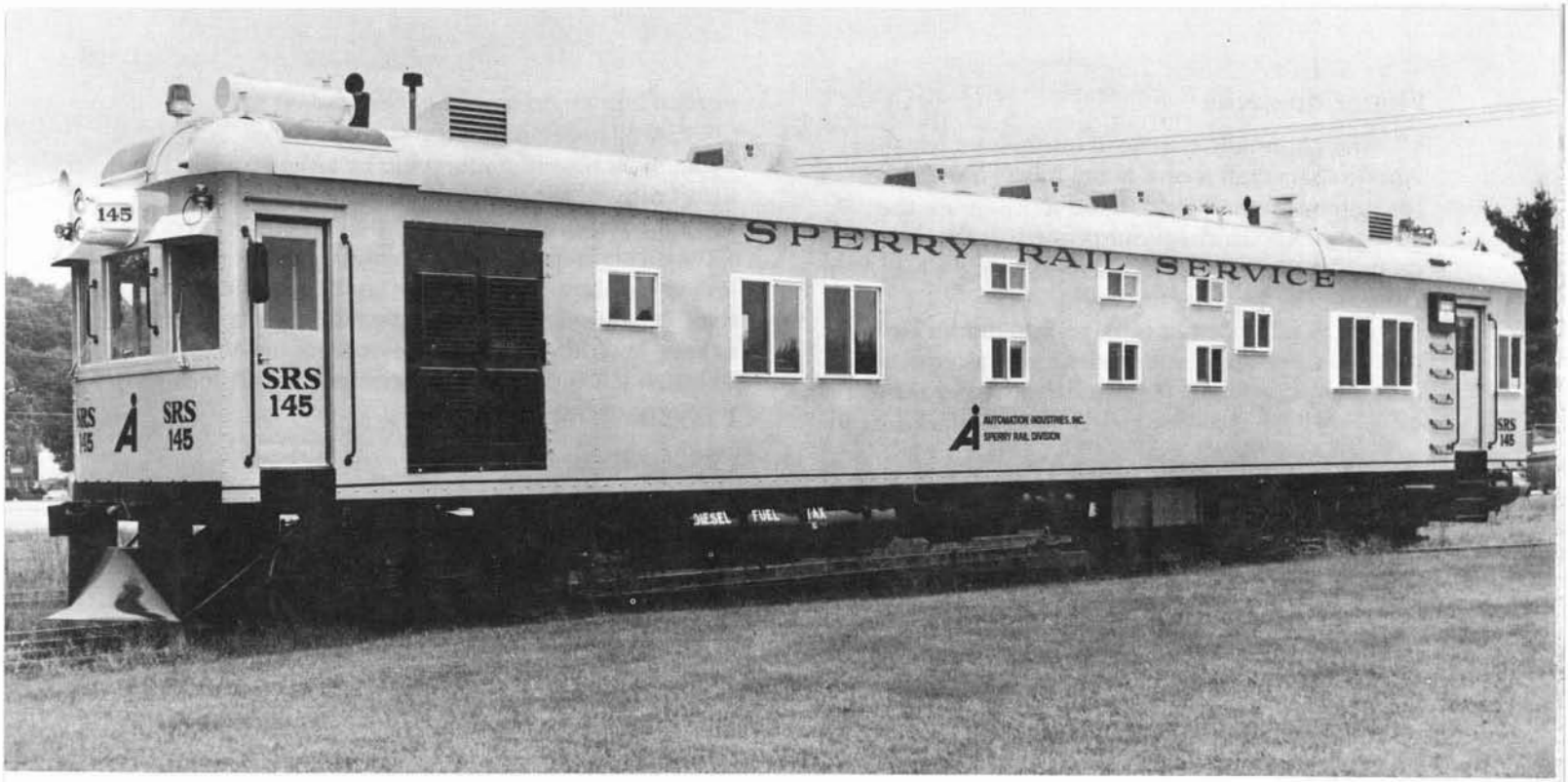
Drying thermoplastics

Taking an organized, thorough look at existing technology before beginning research has helped many companies save significant time and money. Retrospective searches to do that, as well as other forms of technical assistance offered to industry routinely by the NASA Industrial Application Centers.

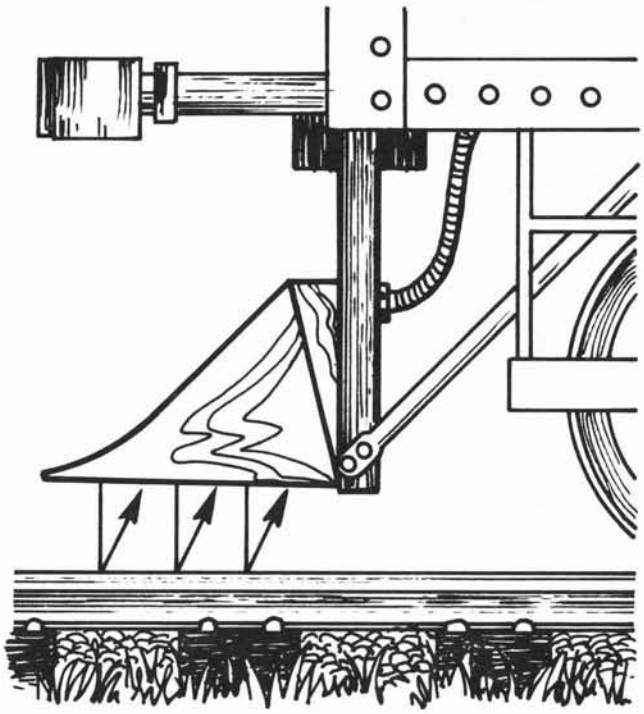
The recent experience of Conair Inc., Franklin, Pa., is typical. Conair employs 90 people to produce machinery for the plastics industry. In searching for an improved method of removing water from polyester-type resins without damaging the materials, the company turned to the NASA center at the University of Pittsburgh.

The center searched the NASA and other computerized files for microwave drying of thermoplastics. About 300 relevant citations were retrieved—eight of which were identified as being directly applicable to the problem. The company estimates it saved a minimum of a full year in compiling research results assembled by the information center.

Automatic checkout equipment devised for manned landings on the moon has been spun off to speed bank transactions, car rentals, airline ticketing, and other business functions.



"Delta manipulator" is mounted beneath instrumented railroad car above to inspect track welds. The instrument uses two or more transducers that transmit ultrasonic energy into the track at an angle that produces shear-waves (right). The sound propagates in the track until it strikes an interface which differs in acoustic impedance from the parent material, interrupting the propagation pattern of the sound beam. The interface may be an inclusion, crack, or absence of weld penetration.



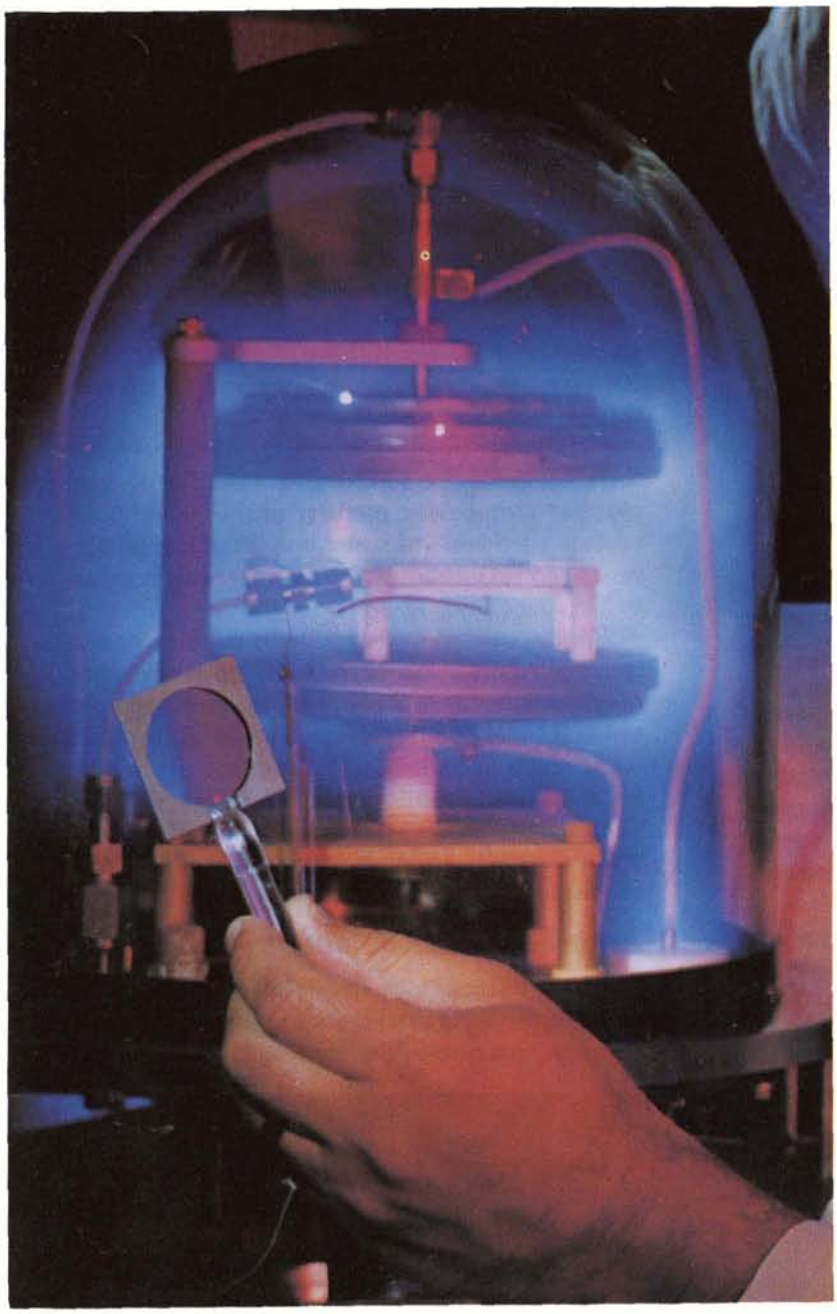
Ultrasonic inspection

A Connecticut company, Automation Industries Inc., has had more than $2-million in contracts to produce innovative equipment for the Apollo program and has successfully spun off many times that amount in sales.

When the Marshall Space Flight Center sought a fast, nondestructive way to inspect butt welds in aluminum alloys for spacecraft, the company developed a reliable ultrasonic device using multiple transducers. Called a "delta manipulator," it can detect lack of weld penetrations not readily seen in radiographs.

That was only the beginning. Automation Industries soon adapted the ultrasonic equipment to a unique rail inspection device that saves countless man hours. The device is contained in self-propelled railroad cars produced and operated by the company to check old track welds for deterioration.

The company operates 28 of the cars on U.S. rails and several in Australia, Europe, and Mexico. The cars move along at about 7 mph, inspecting 160,000 miles of track annually for 100 different railroads.



Plasma polymerization technique originally developed by NASA to coat infrared lenses is being inspected by a company scientiest in a potentially significant "knowledge spinoff." The company expects to utilize the technique for coating plastic lenses of film projectors and other optical equipment.

Coating plastic lenses

Often, NASA scientists cooperate directly with industrial researchers. Bell & Howell Co., at its own expense, arranged to have one of its technologists spend several months working with an Ames Research Center scientist to learn the NASA technique of plasma polymerization.

Plastic lenses can be injection molded at a tenth the cost of making glass lenses. Plastic can be easily formed into aspherical surfaces. Compound lenses can be made from plastics of different refractive indexes. Plastic lenses are lighter than glass and can't shatter.

The bad news is that they scratch easily. The scratches scatter the light, thus reducing light transmission.

NASA-Ames had developed the plasma-polymerization technique for coating infrared lenses made of salt. Salt crystals are used because they are transparent to infrared light. But, since just a slight amount of moisture fogs the salt surface, the plastic coating process was developed to increase the salt lens's resistance to moisture, at only a few cents per coating.

medical instrumentation

Heart sonar images

The latest in a variety of cardiac instruments that have been spun off from space technology—such as the pacemaker and biomedical electrodes— an echo-cardioscope now has emerged.

NASA-Ames engineers developed the instrument to monitor cardiac functions of astronauts in flight. It forms images of internal structures using high-frequency sound—in much the same way that submarines detect underwater objects with sonar. The instrument is compact, lightweight and portable, and dc-powered for safety.

The new technique could replace catheterization, a difficult procedure in which plastic tubes are threaded through blood vessels until they reach the heart. In that technique, a dye is injected into the tube, or catheter, and X-ray motion pictures are taken. Obviously the method is cumbersome and even risky.

Stanford University cardiologists validated the image quality and ease of operation of the ultrasonic device while working with a test group of 100 patients, including 40 infants. Results were excellent.

Twenty of the infants were acutely ill, housed in incubators and monitored with a variety of electrical equipment. These babies are particularly susceptible to electric-shock hazards and repeated doses of X-rays. The battery-powered ultrasonic device, being isolated from its electrical environment, has an inherent safety advantage.

Sick babies were among a test group of 100 patients whose cardiac functions were determined by ultrasonics instead of X-rays. The safer instrumentation was derived from that used to monitor heart functions of astronauts in space.

Biomedical conferences

Frequently in science, one highly specialized discipline is unaware of relevant advances made in other areas. In an attempt to familiarize researchers in a variety of disciplines with medical problems and needs, NASA has sponsored conferences that bring together university scientists, practicing physicians, and manufacturers of medical instruments.

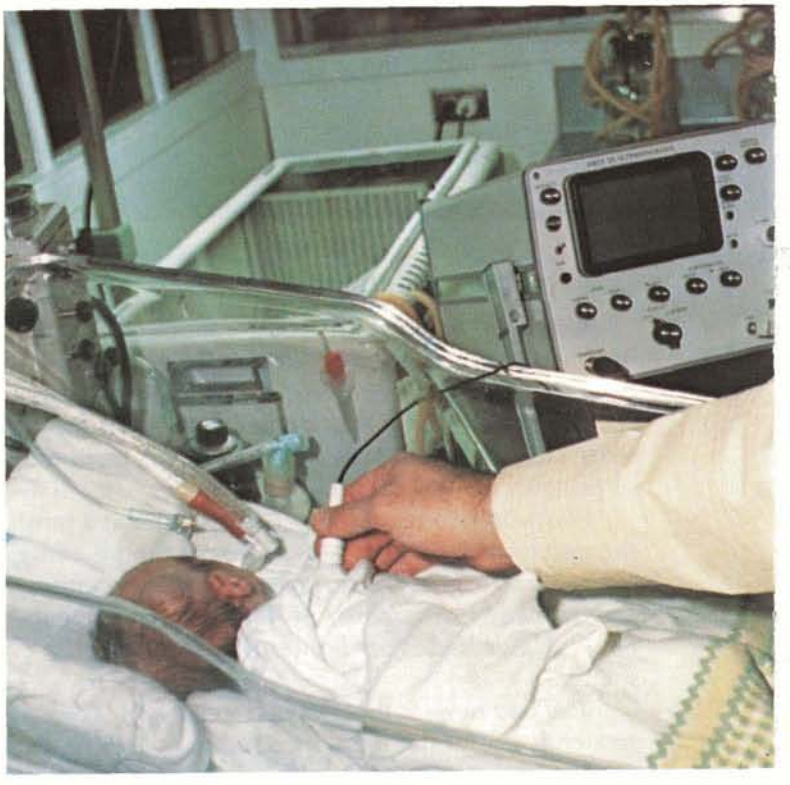
The first International Conference on Biomedical Electrodes Technology, held in 1973 at Stanford University, was one of these. Another, last July, was held on Cardiovascular Imaging and Image Processing.

The heart-imaging conference related NASA technology developed for processing satellite photographs to improving pictures of the heart. X-ray motion pictures and sonar images of the beating heart can be enhanced by computer techniques just as are space photographs.

Both conferences were held by the NASA Biomedical Application Team at Stanford University Medical School. As a result of the electrode conference, several companies have adapted the space technology to make a soft, flexible, surface electrode for long-term monitoring of heart patients. In Vivo Metric Systems Co., Redwood Valley, Calif., already has produced cardiac electrodes based on NASA technology.

Arteriosclerosis detection

Early detection of arteriosclerosis, or hardening of the arteries, is extremely important since, among diseases, it is one of the leading killers in the U.S.



The usual test involves inserting a hollow needle into an artery and directly measuring the arterial pulse. It's time-consuming and painful. External instruments have been made, but they are bulky, insensitive, costly, or imprecise.

NASA-Goddard's work with transducers used on spacecraft was applied to the problem. The result: an arterial pulse-wave transducer that can determine the flexibility of arteries externally. The device employs a pressure-sensitive transistor that converts arterial pulses into electrical signals. These are amplified and recorded on a standard electrocardiogram machine. The whole examination takes only a few minutes.

The transducer uses a fluid-filled cavity sealed by a soft membrane placed next to the patient's skin. The transducer is simple, inexpensive, small, and highly sensitive.

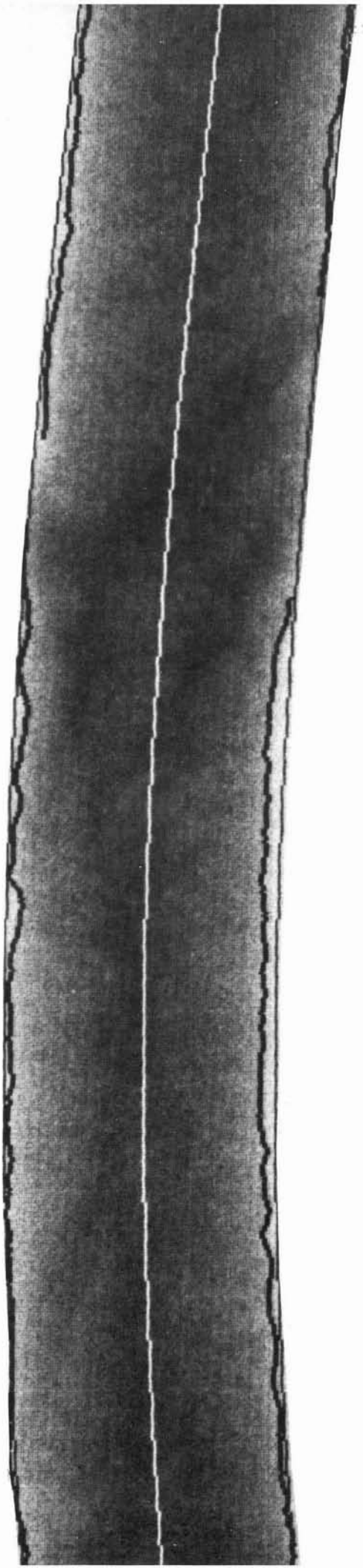
The Veterans Administration Hospital in Washington, D.C., which cooperated with Goddard in adapting the device for arteriosclerosis detection, is in the midst of a three-year evaluation. The hospital is using the instrument to record responses of the heart and arteries to drugs given to lower blood pressure.

In a related development, NASA-JPL's computer technology for clarifying televised pictures from space has been applied to the detection of a specific type of aerteriosclerosis.

Research is underway in collaboration with the University of Southern California, funded by grants from the National Institutes of Health. About 100 heart patients undergoing exercise and weight-loss therapy are having their arteries measured each year to determine whether they are becoming occluded or more flexible.

The computer scans X-ray film of the blood vessels, tracks the edges of the vessels' shadows, estimates the location of the original or pre-diseased vessel wall, and then derives a measurement of the roughness or irregularity of the existing vessel edges.

The work began in 1971 on the laboratory's computer used for space pictures. It was expanded last year, utilizing a stand-alone computer image-processing system to perform the analyses. The instrumentation will be expanded again in 1976 to analyze the coronary arteries and the blood vessels of the retina.



Computer image-processing techniques originally developed by NASA to enhance spaeecraft pictures have been applied to biomedical imaging problems. A digital-enhanced image of a femoral artery is shown. The computer-detected edges are shown along with an estimate of the location of pre-artherosclerosis vessel wall. The difference between the two (taken in the root-mean-square sense) represents the relative amount of disease in the blood vessel.

Unskilled technician tests patient's eyes in seconds using automatic instrument spun off from NASA research. Device prints prescription for glasses, also checks for cataracts and glaucoma.

Lunar gravity simulator for training astronauts has been adapted to rehabilitation efforts. Man uses the weight-alleviation device to re-learn muscular coordination following a stroke.

Vision test in seconds

You can have your eyes tested in seconds, and by a relatively unskilled operator, with an electro-optical instrument transferred from NASA-Ames research. The device automatically measures the refractive error of the eye and prints out the proper prescription for glasses. The unit also detects cataracts.

Stanford Research Institute developed the original instrument under grant from NASA to measure the visual performance of pilots. It was a servo-controlled infrared optometer—or instrument that measures the eye's focus. In a classic case of "people transfer," Acuity Systems Inc., Reston, Va., employed Dr. Tom N. Cornsweet who had worked at SRI on the optometer. Cornsweet developed the Acuity instrument, called "auto-refractor."

The device contains three subsystems. One presents the visual target to the patient. A second performs automatic alignment. The third measures the refractive error, or defect in the eye that prevents exact focusing. The instrument deflects infrared light rays entering the eye until they meet at the retina. Then it measures the amount of deflection necessary.

A special-purpose computer provides a readout, or prescription, in three values: sphere error that measures farsightedness and nearsightedness, cylindrical error, and cylindrical axis. The last two measure the degree of astigmatism. All this takes 4 seconds.

Among the advantages of the machine, large numbers of people—such as in schools and factories—can be tested quickly without a physician's attention.

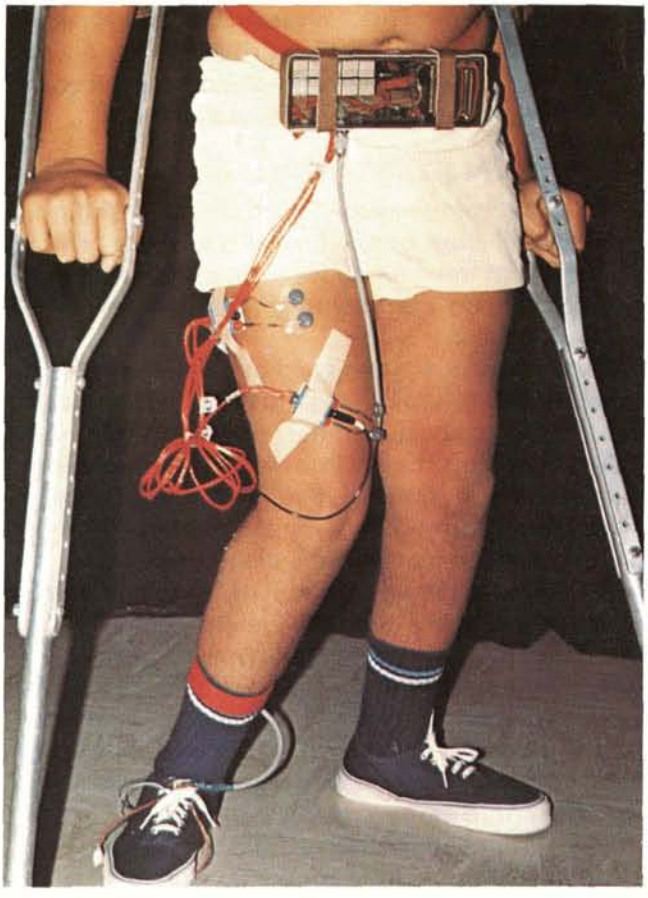
Some 400 instruments have been sold throughout the world. Last year, the company expanded by introducing an automatic lens meter to measure the strength of corrective lenses.

Offsetting gravity

The only condition of space that cannot be simulated on earth is weightlessness. Attempts to approximate it have led astronauts underwater and into harnesses that suspend all or a portion of their weight.

One such suspension device built at Langley Research Center to approximate the one-sixth gravity of the moon now is being transferred to rehabilitation work. Such a weight-alleviation device could enable a person to walk and re-learn muscular coordination following a stroke. Hospitals could use it to lift handicapped patients.

The NASA Biomedical Application Team at the Research Triangle Institute in North Carolina is working with the Coastal Center, Ladson, S.C., to adapt the device for physically and mentally incapacitated children.



Walking pattern of crippled child is measured and recorded without the inhibiting tangle of wires through a spinoff of space telemetry. Step-sensors in soles of shoes and miniature radio transmitters send signals to receiver without wires.

Gait analysis laboratory

A complete motion-analysis laboratory has evolved out of analyzing the walking patterns of crippled children at the Stanford Children's Hospital, Pala Alto, Calif. The technology used in the laboratory was spun off from techniques developed for space telemetry.

Ames Research Center adapted biotelemetry to monitor the awkward, jerky gait of cerebral-palsied children, thereby eliminating the previously necessary long bundle of wires leading to recording equipment. Children often were inhibited by the tangle of wires and electrodes attached to their bodies, thus distorting the readings. Biotelemetry—or radio transmission such as that used to monitor astronauts' bodily functions in space—eliminates the need for wires from patient to recorder.

In order for corrective therapy to be effective, precise knowledge of how each muscle group contributes to the child's walking problem is required. The Stanford hospital now collects the data by placing tiny electrical sensors over the muscle groups of a child's legs and inserting step-sensing switches in the soles of his shoes. Miniature radio transmitters then send signals to a receiver for continuous recording of his abnormal walking pattern.

The system has proved useful in evaluating benefits that might be produced by muscle- and tendon-lengthening operations. It also helps determine whether medications may improve a patient's mobility by decreasing muscle spasms.

The work has helped the Stanford Children's Hospital to become a regional center offering motion analyses of patients referred from northern and central California.

Nearby NASA engineers at Ames are working to apply space-electronics miniaturization techniques to reduce the size and weight of the telemetry system further. They also are striving to increase the signal bandwidth so analyses can be performed faster and more accurately using a mini-computer.

Breast cancer detection

While ultrasonic imaging is under development at NASA to replace X-rays in many applications, commercial development and widespread usage will take several years at best. Meanwhile, Jet Propulsion Laboratory scientists have come up with another technique to decrease exposure to harmful X-rays, especially in mammography, or breast radiography.

Typically, physicians make more than one exposure to arrive at an X-ray film of acceptable density. Now the same solar cells used to convert sunlight into electricity on space satellites can make a single exposure suffice.

The cells are sensitive not only to light, but to X-rays as well. Very low-energy X-rays are used in mammography since the breast contains no bone and is transparent to X-rays. When several small solar cells are connected electrically so their output is additive, they can sense extremely small amounts of X-ray energy. Placing a fluorescent material in contact with their surface increases sensitivity even further.

When the solar cell sensor is positioned directly beneath the X-ray film, it can determine exactly when the film has received sufficient radiation and has been exposed to optimum density. At that point, associated electronic equipment sends a signal to cut off the X-ray source.

The NASA laboratory recently tried this control system at the Huntington Memorial Hospital in Pasadena—with overwhelming success. The reduction of mammography to single exposures not only reduced the X-ray hazard significantly, but doubled the number of patient examinations handled by one machine. Through a Technology Utilization Office applications engineering project, NASA now is attempting to transfer this technology to the X-ray industry. The attempt is to modify existing equipment to take advantage of the solar sensors.

medical systems

Projecting health needs

NASA's Jet Propulsion Laboratory has developed a computer model for planning future health-care needs in the Los Angeles area. The model integrates demographic, health, and other data to provide rational projections of hospital-bed and physician-specialty requirements.

In designing unmanned spacecraft to explore the planets, the laboratory has gained a unique capability in systems design, operations management, telemetry, and computerized data handling now being applied to health care and other domestic problems.

The NASA computer model provides improved projections when compared with existing models. California is evaluating the NASA Los Angeles model for possible use throughout the state.

Respiratory distress

Some 20,000 babies succumb to respiratory distress in the U.S. each year, a condition in which the lungs progressively lose their ability to oxygenate the blood.

Both positive- and negative-pressure techniques have been used—the first to force air into the lungs, the second to keep the infant's lungs expanded. Negative pressure around the chest helps a baby expand his lungs and maintain the proper volume of air. If doctors can keep the infant alive for four days by either method, the missing substance in the lungs will usually form in sufficient quantity to permit normal, unassisted breathing.

The University of Miami School of Medicine was among the first to use the negative-pressure technique, and improvised a chamber to cover an infant's upper abdomen, arms, and throat. But a serious problem was encountered: the waist seal leaked excessively and both neck and waist seals caused inflammation and swelling skin.

NASA's Research Triangle Institute Biomedical Application Team was asked to assist. The team enlisted Marshall and Johnson engineers to adapt the lower-body negative-pressure system seals used during the Skylab missions. In the weightless and relatively confined conditions aboard Skylab, blood circulation of the legs is restricted. So the astronauts periodically would put their legs into the chamber up to their waist. The slight negative pressure in the chamber increases circulation.

The Skylab chamber and its leakproof seals were adapted for medical use with seals that not only don't leak but are adaptable to a considerable difference in infant size. Further design refinements are necessary and are expected to be completed this year.

Biological isolation garment

A spinoff of the astronaut's biological isolation garment will allow hospital patients who are highly vulnerable to infection to leave their sterile habitats for several hours, carrying their germ-free environment with them.

The garment was designed originally to be worn by astronauts returning to earth until their arrival in a quarantine facility aboard the recovery ship. It was meant to protect the environment against unknown microorganisms from the moon—an unnecessary precaution, it turned out, but one that may become important when men visit the planets.

A prototype isolation garment has been tested in hospitals and by the National Cancer Institute with favorable results. It is a coverall-type suit with attached mittens and slippers, all made out of a penetration-resistant fabric. The fabric prevents penetration of particles greater than 0.3 microns. A separate hood with a transparent face mask is attached to the suit. The entire garment is easily sterilized.

Air is supplied through a diffuser at the top of the head. A flexible tube conducts purified air to the headpiece from a filter-blower system powered by rechargeable batteries. Positive pressure is maintained to prevent unfiltered air from entering the suit.

The garment is an adjunct to patient isolation rooms, becoming an extension of the protected environment. The garments thus can be used in any of some 200 hospitals where isolation rooms are installed to treat leukemia, radiation injuries, burns, respiratory diseases, organ-transplantation patients, and immune-deficient children. Environmental infection can be a serious problem in these cases. For instance, it is responsible for nearly 70% of all deaths in acute leukemia.

While no commercial versions of the garment are yet available, several manufacturers have shown interest in licensing the NASA patent.

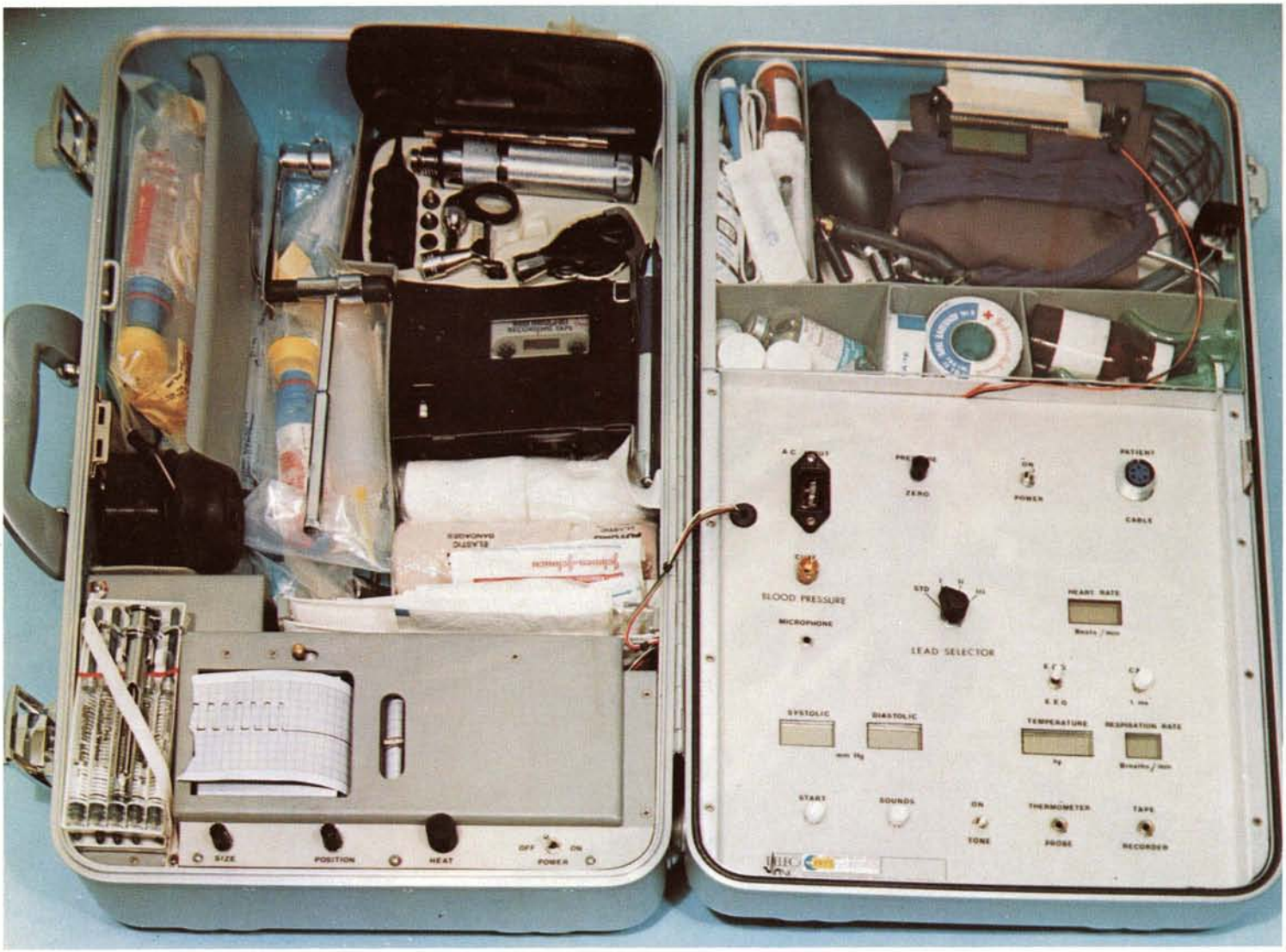
Storing blood cells

White blood cells and bone marrow now can be stored for future use by leukemia patients as a result of Goddard and Jet Propulsion Laboratory expertise in electronics and cryogenics—the science of extremely low temperatures.

Drugs and radiation used to destroy cancerous cells during leukemia treatment eventually also destroy bone marrow which produces disease-fighting white blood cells. Previous attempts to develop an adequate freezing system either destroyed the cells by rupture when cooled too quickly or by dehydration when cooled too slowly.

Immune-deficient child leaves hospital sterile room for up to four hours carrying germ-free environment with her in a modification of the astronaut's isolation garment. The garment was developed originally to be worn between spacecraft landings and quarantine as a precaution against carrying unknown microorganisms from the moon. The spinoff is intended for children with aplastic anemia, leukemia, or other disorders requiring a sterile environment.

White blood cell- and bone-marrow bank can be established using freezing unit that emerged from NASA electronics and cryogenics research. Freezing system monitors temperature of the cells themselves and the system maintains a consistent freezing rate. Ability to freeze, store, and thaw white cells and bone marrow without damage is important in leukemia treatment.



Engineers at JPL proposed a solution to the blood-cell freezing problem first identified by the Research Triangle Institute Biomedical Application Team during discussions with the National Cancer Institute. JPL's solution utilized a special electronic circuit developed for precise temperature control of scientific instrumentation now on its way to Mars on board the Viking spacecraft. JPL then turned the idea over to the Goddard engineers for implementation, since the Goddard Center was geographically more convenient to the National Cancer Institute.

The freezing unit monitors the temperature of the cells themselves. A thermocouple placed against a polyethelene container relays temperature signals to an electronics system, which in turn controls small heaters located outside of the container. The heaters allow liquid nitrogen to circulate at a constant temperature and maintain a consistent freezing rate.

Freezing white blood cells is important in leukemia work. There are more than 80 types of white cells, making patient-donor matching difficult. Storage life of unfrozen white blood cells is only a few hours.

The Goddard freezer, which was delivered last year to the cancer institute, can freeze up to 220 ml of white blood cells in one hour. Animal bone marrow also is being frozen by the unit for transplant research. Results so far are encouraging.

Better physician's 'black bags'

There's a limit to what a physician can carry in his "black bag." But NASA-Johnson is extending that limit dramatically by transferring technology accrued through monitoring of astronauts' vital signs.

The development is evolving now in preparation for providing diagnosis and treatment of space-shuttle crew and passengers. Of course it can be adapted to aircraft, shipboard, and physician emergency calls too.

The portable medical-status system contains an electronic vital signs monitor, a cassette machine for recording electrocardiograms and electroencephalograms, equipment for minor surgery, as well as conventional diagnostic instruments such as the stethoscope, and drugs.

The big job was to make it all portable. Liquid-

Portable medical status system—a highly advanced physician's "black bag"—weighs less than 30 lbs, yet contains equipment for monitoring and recording vital signs, electrocardiograms, and electroencephalograms. "Black bag" is outgrowth of astronaut-monitoring technology.

crystal displays are used to present 15 digits of data simultaneously for long periods of time without excessive use of battery power. A single printed-circuit card contains all the circuitry required to measure and display vital signs such as heart and respiration rate, temperature, and blood pressure.

So far the unit measures 7 x 22 x 14 inches and weighs less than 30 lbs. It will be field-tested this year, even as efforts continue to reduce the size further.

construction

Flat wire

Flat conductor electrical cable, originally designed for spacecraft by the Marshall Space Flight Center has been installed for the first time in a housing project. Six apartments in Yonkers, N.Y. have had the wiring installed. Because it is very thin, the wire can be mounted on the surfaces of walls and floors instead of inside of them. Installation costs are reduced significantly due to single installation time.

Both an undercarpet and a baseboard system are being developed after five years of test installations. A solar test house at Marshall and the NASA Tech House at Langley both will utilize the method. Various companies and government agencies, such as the N.Y. State Urban Development Corp., Amp Inc., and Western Electric Corp. are working with NASA on this project. The Technology & Economics Inc. applications team coordinated the project under direction of NASA's Technology Utilization Office.

Currently the process of commercializing flat wire is centered around gaining approval of the National Electrical Code. The code, which is rewritten every three years, with the next edition in 1978, is a privately developed body of regulations that serves as a model for most of the nation's local building codes. Acceptance, therefore, is a prerequisite to using a new electrification method in mass construction.

Flat, very thin wires originally designed for spacecraft soon may go under carpets in offices resulting in savings over conventional wiring.

In order to have the flat wire accepted in the code's 1978 edition, NASA and interested companies have commissioned fact-finding studies at Underwriter's Laboratories to provide necessary technical data.

The flat wire and some of the other developments reported above will be demonstrated in the "Tech House" to be constructed this year by NASA at its Langley Research Center near Hampton, Va. Both the Department of Housing & Urban Development and the National Association of Home Builders have served as advisors in planning Tech House. It is described in Section one of this report under "Your Home."

Tool for movable ceiling

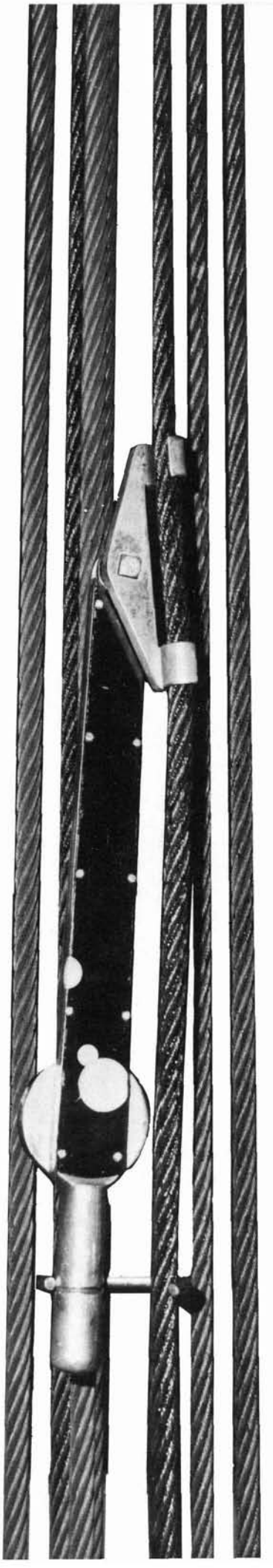
The University of Akron's performing arts hall is a cultural and architectural triumph. It was constructed to accommodate concerts, opera, ballet, and theater productions. These may be cultural relatives, but they are architectural opposites, because the main hall has to shrink and expand to accommodate audiences as large as 3,000 and as small as 900.

Movable ceilings were required not only to alter the size of the main hall, but also to regulate the volume and manipulate the acoustics.

The movable ceiling, the most modern in the U.S., contains overhead hexagons that can be lowered in clusters to exclude either 600 seats or an additional 1,500 seats.

Once the hall has been sound-tuned, the various positions of this ingenious ceiling and related acoustic curtains may be called into play immediately by pushing buttons on a control console that has been programed previously. With the touch of a finger before an event, a technician may condition the hall for chamber music, symphony, or theater.

A simple, inexpensive tool devised in the space program was used to equalize tensions in the 150 cables of the ceiling. The tool was developed sometime before by the Bendix Corp., under contract to NASA's Kennedy Space Center, to adjust the relative tension in elevator and crane cables. The 425-ft mobile launch tower contains two elevators for lifting spacecraft. The crane in the vehicle assembly



Inexpensive tool to equalize tensions in cables of movable concert-hall ceiling was developed first for elevator and crane cables used to lift heavy space vehicles at Kennedy Space Center.

building and other hoists at Kennedy also utilize load-bearing cables.

Previous commercially available cable tools weigh 16 lbs. The Bendix tool weighs only 2 lbs and costs a tenth as much. It consists of a short plate that can be attached to the cable, a torque wrench to twist the plate while it is attached to the cable, and a hook to hold the wrench at a uniform distance from the cable. Cable tensions in a suspension system are compared with this tool so that equalizing adjustments can be made.

Izenour Associates Inc., New Haven, Conn., further adapted the NASA tool into a multi-cable version for use in the Akron hall movable ceiling.

In a related if more prosaic application, the elevator division of Dover Corp., Memphis, uses similar NASA-spawned cable-tension tools to measure and adjust the tension on elevator cables in office and other buildings during installation and inspections. The tool saves about 20% of adjustment time and increases cable and pulley life.

New space paint is applied to girder of Golden Gate Bridge to test its resistance to salt spray and weathering. The inorganic paint requires only one coat and is expected to last twice as long as conventional paints.

'Rigidized' metal panels

Not all of NASA's industrial assistance includes direct technology funding or even transfers of aerospace research. Sometimes the catalyst is more subtle. NASA maintains six industrial applications centers at universities throughout the country which have computerized access to about three-quarters of a million space-related reports as well as 10 times that many reports and articles from private sources.

Typical of the several companies served annually, the Plasteel Products Corp. in Washington County, Pa. approached one of these NASA information centers to search for ideas on "rigidized" metal sheeting. Thinner-gage metal with the strength of heavier sheeting can be obtained through cold bending, stamping, dimpling, or embossing—referred to as "rigidizing."

The NASA Industrial Applications Center at the University of Pittsburgh came up with 36 reports relevant to Plasteel's needs. On the basis of this search, the company purchased an embossing machine with which it hopes to provide thiner-gage metal panels where permitted by building codes.

Space paint

An improved inorganic paint may help protect coastal bridges, which are subject to extreme corrosion from seawater spray.

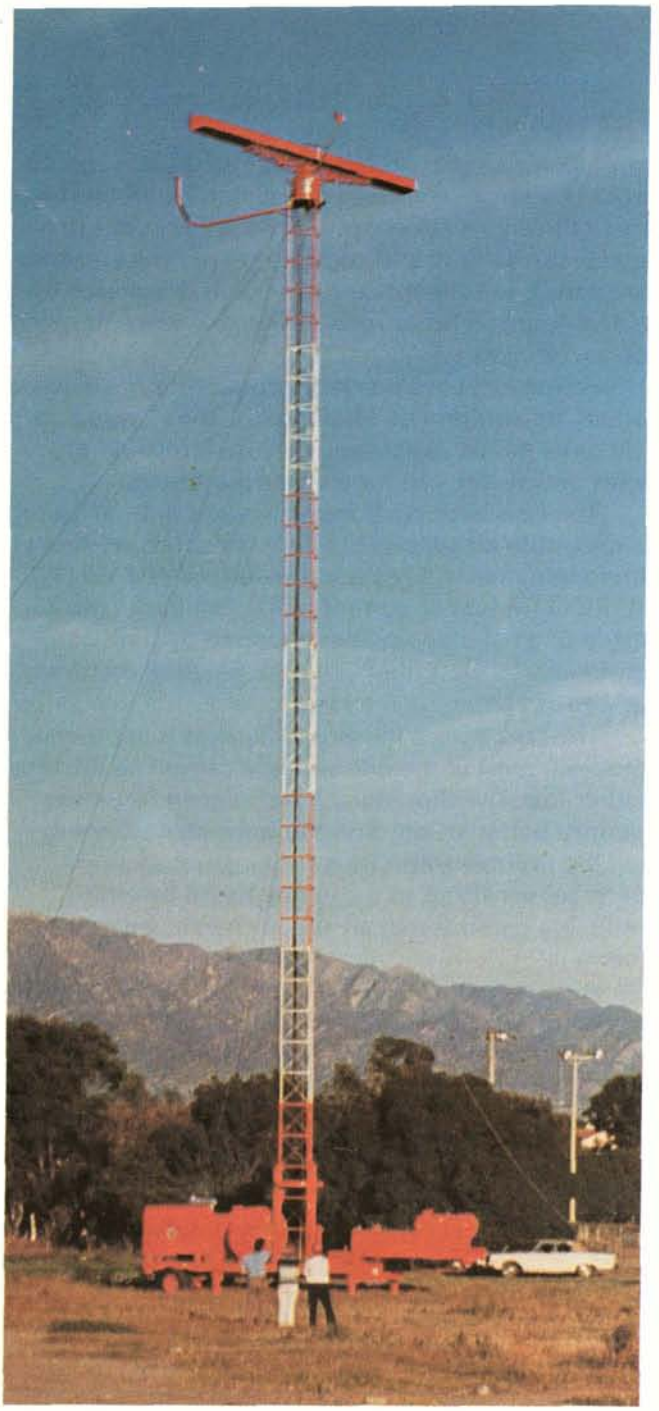
Zinc-rich coatings with both organic and inorganic binders have been tried in the past. But organic paints don't last as long and require a finish coat, while inorganics normally are harder to apply but require only one coat.

The unique inorganic zinc-dust coating was developed at NASA's Goddard Space Flight Center. In preparation, potassium silicate is formulated into a thin, water-base binder that sprays easily, adheres readily, and can be heavily loaded with zinc particles to provide uniform coverage in a single coat.

One gallon of the paint covers 375 square feet, compared with the usual coverage for inorganic paints of about 200 square feet per gallon. In addition, the life of the paint may be doubled leading to significant cost and savings.

The Golden Gate Bridge Authority now is testing the space paint on a girder of the famous bridge.

Stanford Research Institute, a NASA Technology Applications Team, has measured an annual market in excess of $2-billion in painting highway bridges, utility pipelines, nuclear reactors, and railcar hoppers. Other suitable markets include offshore drilling facilities, railroad bridges, and ships. Patent licenses may be obtained from NASA.



Collapsible towers

About a decade ago, NASA needed a means of orbiting a large radio telescope antenna. Astro Research Corp., Santa Barbara, worked on the problem and came up with a new type of structure that was strong, lightweight, folded into a small storage space, and could be erected by rotation.

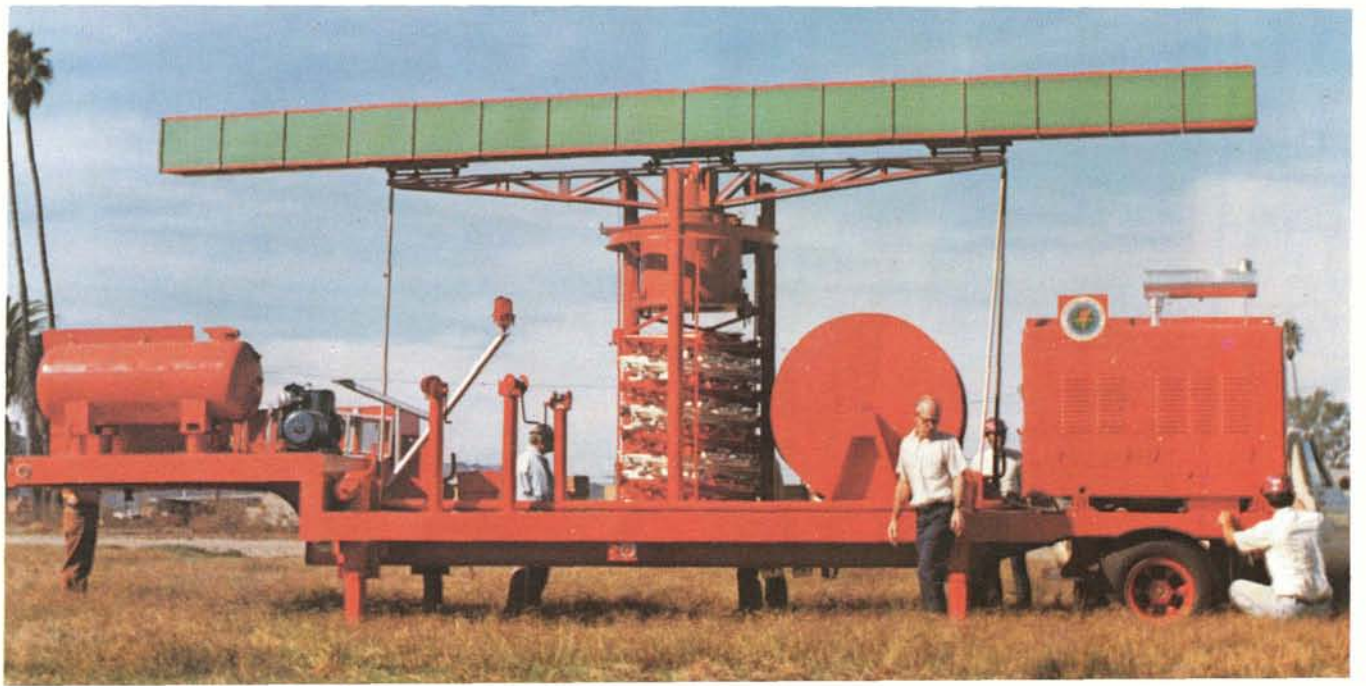
Later the firm adapted the technology to commercial use. Today, the "Astromast" tower consists of tubular aluminum alloy and stainless steel members that deploy into small three-sided bays. Each of these are made rigid by six diagonal cables. All joints are flexible to permit folding and unfolding.

The tower packs into a container only 5% of its height. It can be erected without tools and, of course, is reusable. The collapsible column has won a "Design of the Year" award from *Machine Design*. Depending on the accessories ordered, a 100-foot tower costs from $4,000 to $15,000.

The columns are used to hold stage lights and speakers for outdoor concerts, as antenna towers for radio communications by oil pipeline and forest-fire crews, and as a transportable site-survey system for permanent radar beacons. The Federal Aviation Administration is using the towers in this last application. Each site now can be tested for interference with an actual radar system prior to permanent construction.

Variations of the "Astromast" being considered include portable emergency bridges and commercial scaffolding.

A spinoff from a space satellite antenna, this lightweight versatile tower arrives on the scene in condensed package, below. To "unpack" the tower, you simply rotate each three-sided bay into its vertical open position and lock a diagonal cable latch until it is fully extended (left).



safety

Fireman's air tanks

Lighter-weight firefighter's air tanks now can be bought after several years of developing and testing them through a NASA-sponsored applications program. The air tank and complete breathing system are based on concepts and hardware developed by NASA-Johnson for astronauts in extravehicular space or on the moon.

Astronauts have no choice about whether to wear breathing equipment. Firemen do. Their avoidance of conventional apparatus, because it restricts mobility and vision, can have disastrous results.

The new back pack system weighs only 20 lbs for a 30-minute air supply—13 lbs less than conventional firefighting tanks. They are pressurized at 4,500 psi, about twice that of current tanks. The back tank is made of an aluminum liner wrapped by resin-impregnated glass fibers, thus eliminating corrosion as well as lightening the load.

The tank's pack frame and harness is improved, too, with most of the unit's weight carried on the hips rather than the shoulders. A redesigned face mask permits better vision. And the warning device—to tell the fireman when he is running out of air—has been personalized so it can't be heard by others, reducing confusion in an already hectic environment.

A survey conducted by Public Technology Inc., a non-profit technology-transfer organization that works with state and local governments, confirmed that fire departments would buy such a system. Trials in Houston, Los Angeles, and New York fire departments last year helped refine the apparatus.

As a result, A-T-O Inc.'s Scott Aviation division has begun producing the breathing equipment, called "Air Pak 4.5." The apparatus was received enthusiastically when its commercial availability was announced at the fall 1975 International Association of Fire Chiefs meeting in Las Vegas. Other companies expressing interest in commercializing the NASA system were briefed at an industry workshop last November at Johnson Space Center.

Structural Composites Industries Inc. now is offering similar fiberglass-lined cylinders commercially. In a spinoff of a spinoff, The Boeing Co. may use the lighter tanks on 747s to energize emergency-escape shutes. And Martin-Marietta Corp., Denver, a NASA contractor that developed the aluminum cylinder, is using them to pressurize Navy life rafts.

Firefighters' radios

Good short-range radio communications are essential during a fire to coordinate hose lines, rescue victims, and otherwise increase efficienty. A useful firefighting tool is a new lower-cost, more rugged, short-range two-way radio now being developed.

In 1973, Public Technology Inc. defined user requirements and searched NASA technology to devise the new radio. The effort uncovered a NASA patent on an inductorless electronic circuit developed at Goddard for weather balloon communications.

The unconventional circuit replaced inductances and coils in radio circuits with combinations of transistors and other low-cost components. This substitution promises reduced circuit size and cost, enhanced electrical performance, made the radio more durable, and improved maintainability by incorporating modular construction.

Twenty-five firefighters' radios are being built and field testing is planned for this year. Fire departments in Cincinnati, Houston, New York, Providence, Long Beach, Calif., and Fairfax Co., Va. now are testing the radios in actual fires.

Astronauts' lightweight airtanks, helmets, and two-way radios have been spun off to provide firefighters better mobility, vision, and communications.

Explosive entrances

When firemen need to get into a burning building, or chop a hole to provide ventilation, axes can be devastatingly slow. Explosive Technology Inc. manufactures a linear explosive charge based on its device first developed to separate stages of the Gemini launch vehicle.

Small amounts of explosives—10 or 15 grains per foot—make possible highly controlled explosions for spacecraft as well as emergency activities.

Using the shaped charges, called "Jetaxe," firefighters can cut a 2- x 3-ft ventilation hole or create a three-sided opening in a steel door. Another application is cutting emergency holes in airplanes and trains through which surviving passengers can escape after a crash.

The company also makes a 7,000-grain-per-ft explosive called "Jetcord" for controlled demolition of unsafe buildings or bridges. In contrast to other explosives, Jetcord does not demolish a structure, but cuts it precisely. The detonation cuts through thick steel girders or other materials more cleanly than can be achieved with torches or saws.

Jetcord won an IR 100 award as one of the 100 most significant new products of 1973.

Controlled explosives developed to separate manned upper stages of space rockets in case of mishap have been adapted to cutting emergency exits and demolishing unsafe buildings and bridges. In this series of photographs, Controlled Demolition Inc. employs the versatile explosives—which cut instead of simply blast—to take down the American Industrial Bldg. in Hartford, Conn. The "Jetcord" explosive cuts steel girders as precisely as saws or torches.

Safer liquid natural gas

After the disaster on Staten Island in 1973 in which 40 people were killed while repairing a liquid natural-gas storage tank, the New York City fire commissioner requested NASA's help in drawing up a comprehensive plan to cover the design, construction, and operation of liquid natural-gas facilities.

The gas-safety program is especially important for New York City as demand for imported liquid natural gas increases and new storage and handling facilities are required. Transforming natural gas into a liquid reduces its volume by a factor of 600 to one, making it desirable to transport and store the fuel in the liquid state.

But hazards include transportation, loading, storage, and the effect of the supercooled liquid on materials. When liquid, the fuel's temperature is minus 256 F. NASA has had extensive experience—and an impressive safely record—in handling similar, highly volatile liquid rocket fuels. The expertise could be transferred almost directly.

Two programs on behalf of New York now are underway. The first transfers the comprehensive risk-management techniques and safety procedures developed for the Apollo and Skylab programs at the Kennedy Space Center. As adapted for the New York Fire Department, the techniques and procedures take the form of an instruction document that includes:

—Determining liquid-gas risks through engineering analyses and tests.

—Controlling these risks by setting up redundant fail-safe techniques.

—Establishing criteria calling for decisions that eliminate or accept certain risks.

The second program, conducted by NASA's Lewis Research Center, called for preparing a liquid-gas safety manual, the first of its kind. The program extends other Lewis-prepared compilations, such as a hydrogen safety manual.

In order to extend the New York programs to other cities, NASA sponsored a two-day risk-management workshop at Kennedy last fall for government and industry officials.

Ambulance handbook

Firefighting and hazards prevention isn't the only safety technology to which space programs have contributed. A checklist devised for the Skylab inflight medical support system has been transferred for public emergencies. The checklist illustrates a procedure for diagnosis, treatment, and stabilization of a wide variety of emergencies.

Paramedics assigned to the Houston Fire Department now are using the checklist adapted from a NASA-Johnson handbook. The handbook instructs paramedics in the use and care of a portable ambulance module. The module is a self-contained cardiac diagnostic, therapeutic, and communications system placed in ambulances or used in rural areas.

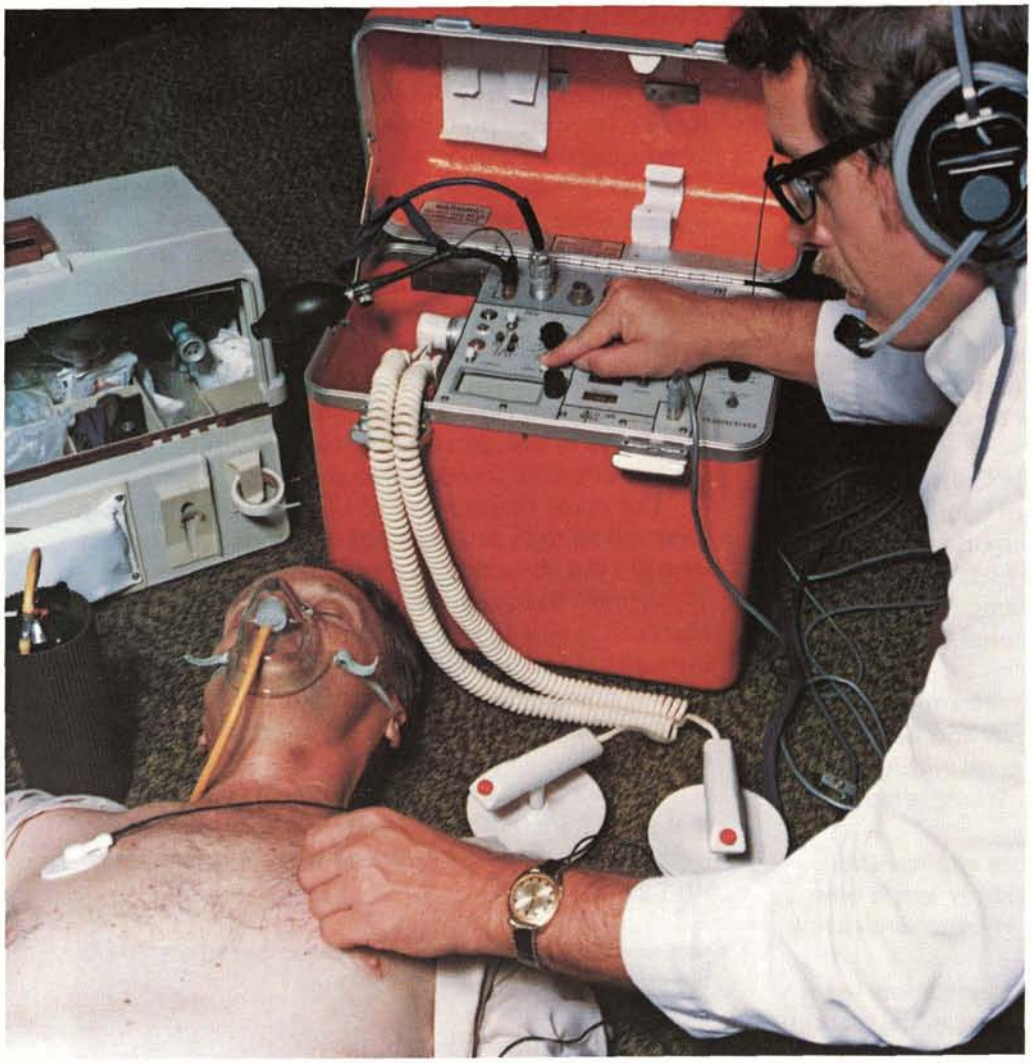
Organized in Skylab checklist format, the handbook presents a comprehensive, ordered description of the emergency medical equipment and its use in treating victims.

Water-powered tools

Cutting through bulkheads aboard ship during rescue operations is dangerous with acetylene torches or electrical tools. Explosions or short circuits from these methods often add to a disaster instead of reducing it.

Aramco Ltd., a minority firm in New Orleans is planning to produce a tool that uses water under

Water-powered saw cuts through concrete and steel plate, reducing danger of explosion or electric shock in rescue and other operations. Spinoff, Inc. is adapting the device using spacecraft turbo-pump technology.



Ambulance handbook derived from Skylab inflight medical system now is used by paramedics in Houston along with a portable ambulance module, also a space spinoff. The module, shown here in a street lifesaving situation, is a self-contained cardiac diagnostic and communications system.

pressure as its source of power instead of electricity or fuel. The device originally was created by Rockwell International's Rocketdyne division as an underwater tool for divers. It was a direct spinoff of the turbo-pump technology Rocketdyne developed as a major contractor for space missions. After signing a licensing agreement with Rocketdyne, Aramco last year established Space Spin-Offs Inc. in New Orleans to manufacture the hydrotool.

In a prototype unit, an efficient water-powered turbine drives an 8-in.-diameter grinding disk at 6,600 rpm. The exhaust water cools the disk and workpiece, quenching any sparks produced by the butting head. At maximum power the tool easily cuts through quarter-inch steel plate.

Coupled to a municipal water supply or other source producing 100 to 150 psi at a flow of about 100 gallons a minute, the water turbine becomes a safer tool for other uses too. For instance, adapter heads for chain saws, impact wrenches, heavy-duty drills, and power hack saws can be fitted to the hydrotool.

Lead-poison detection

Electro-optical expertise gained in NASA contracts helped Whittaker Corp.'s Space Sciences division to develop an instrument to mass-screen for lead poisoning.

The device is a portable and highly sensitive fluorometer that detects protoporphyrin in whole blood. Free corpuscular porphyrins occur as a very early effect of lead ingestion. The instrument also detects lead in urine, used to confirm the blood tests. The test is inexpensive and can be applied by relatively unskilled personnel.

While lead poisoning may not appear to be a large problem, the fact is that at least 400,000 U.S. children are poisoned by lead every year—some 200 resulting in death. Eating old, chipped, lead-based paint accounts for much of the problem, especially in ghettos among babies and small children. In areas where industrial wastes, mining, and lead smelters are prevalent, mass screening also is desirable.

A similar Whittaker fluorometry device called "drug screen" can measure morphine and quinine in urine much faster and cheaper than other methods.

transportation

Better brakes

A novel composite developed through Ames Research Center's continuing studies on high-temperature space materials may be useful for better brake linings.

Ames worked with the Bendix Corp., which fabricated several combinations of composite materials and evaluated the results. The one selected increases wear rates and lowers costs. It exhibits a constant coefficient of fiction at temperatures as high as 650 F, a region where conventional brake linings fade markedly.

A series of full-scale dynamometer tests was completed last year. This year Ames and Bendix will supply brake drums and disks aligned with the new material to the National Highway Transportation Administration for road testing.

The Stanford Research Institute applications team has performed a marketing study and is now seeking organizations interested in commercializing this technology.

Stanford Research Institute's Application Team believes that bus brakes offer the best initial market entry. Wearing of the linings and drums in heavy vehicles is significantly improved and noise is reduced. Other suitable markets include brakes for trucks and industrial equipment such as overhead cranes and hoists. Afterwards, the brake linings could find successful application in passenger cars.

Composite brake linings, pliable winter tires, and a technique to build smoother highways are among space spinoffs to transportation.

Studless winter tires

Even better brakes won't help when your tires slip. Remember the "Rickshaw," the mobile equipment transporter pulled on the moon by Alan Shepard during the Apollo 14 mission? Its tires, developed by Goodyear Tire & Rubber Co. for Johnson Space Center, remained pliable at minus 195 F.

Goodyear then used the flexible rubber in a winter radial tire for automobiles. Conventional tires lose their pliability below freezing. The hard rubber begins to bounce, losing surface traction. Steel-studded tires were introduced to increase traction on slick pavement. However, several states have banned studded tires because they destroy road surfaces and are less effective than studless tires on dry surfaces.

The cords of the new tire also are a space spinoff. They utilize the same material developed by DuPont to make the shroud lines for the Viking lander.

When Viking reaches the gravitational pull of Mars this July, a large parachute is to be deployed in the rarified Martian atmosphere to allow the payload to drift gently to the surface. Just three straps of the new fiber will support the brunt of the 2,300-lb weight.

The fiber has a chain-like molecular structure that gives it incredible strength in proportion to its weight. On a pound-for-pound basis, it is five times stronger than steel.

Material developed as parachute shrouds to soft-land the Vikings through the tenuous Martian atmosphere has been adapted to new radial tire by Goodyear being tested here. Five times stronger than steel, the material is expected to increase treadlife by 10,000 additional miles.

Highway profiling

Ride quality on highways (and railways) may be improved by Marshall Space Flight Center's adaptations of gyro-stabilized spacecraft guidance and control systems.

The Marshall work indicates that currently used instruments for profiling roadways may be enhanced by the addition of a stable three-axis platform-type inertial reference. The platform system can measure banks, bumps, curves, grades, elevations, speeds, and distances, and even can measure the distribution of roadway undulations. Appropriate computer programs then can be written to answer future questions concerning the roadbed.

Such a roadway measuring system can make a significant contribution to the safety and maintainability of roadways. Marshall now has selected a vehicle to carry the instrument and is in the process of devising a test program for a prototype to be built soon.

Bearing-failure detection

Technology derived by NASA for monitoring control gyros in the Skylab program is directly applicable to the problems of fault detection of railroad wheel bearings. The railroad industry currently is changing over from journal bearings to roller bearings for greater safety.

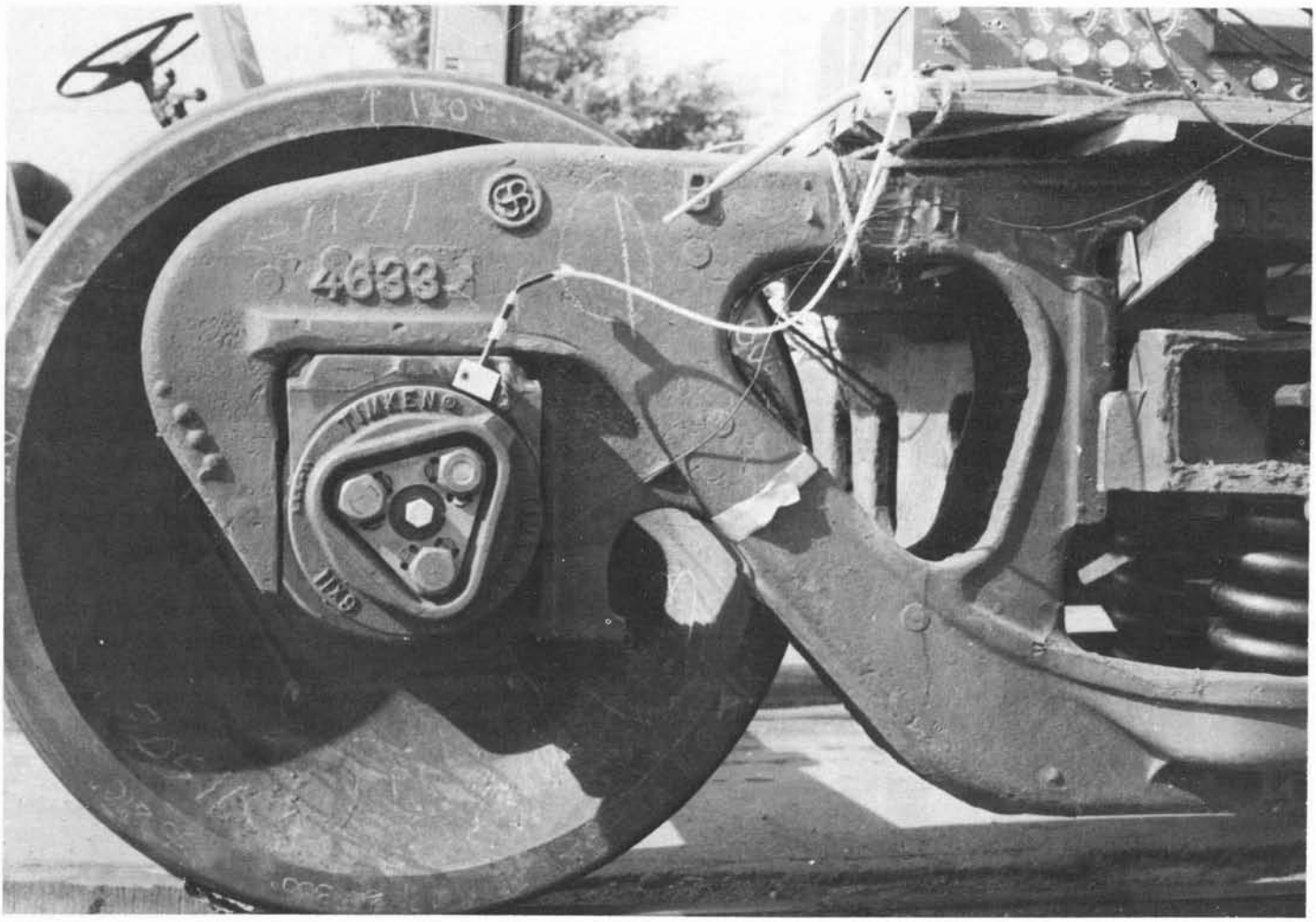
About half of some 2-million railcars in the country now are equipped with roller bearings and all will be by 1980. Many of the 500 annual derailments in the U.S., costing more than $10-million, are caused by bearing failures.

Roller bearings don't have a long temperature rise prior to failure, as do the older journal bearings, so fast detection becomes more important.

Marshall scientists have developed a detection concept based on the fact that bearing defects themselves excite the resonant frequency of the rolling elements of the bearing as they impact the defect. By detecting the resonant frequency and subsequently analyzing the character of this signal, bearing defects may be detected and identified as to source.

Shaker Research Corp., Latham, N.Y., now is developing a commercial version of this device under a cost-shared contract with NASA.

A test vehicle measures the resonant frequency of railroad roller bearings to identify the source of bearing defects. A spinoff from instrumentation devised to monitor control gyros, the bearing-fault detector will help eliminate this cause of derailments.



Heat pipes for Alaskan oil

Oil from Alaska's rich North Slope fields will be transported with the help of a truly revolutionary heat-pipe device developed through the space program. It is being used to keep the ground frozen along the 798-mile pipeline, saving hundreds of millions of dollars and protecting the tundra environment.

While heat-pipe principles have been known since World War II, it wasn't until spacecraft were built that heat pipes were developed for cooling onboard electronic packages. Satellites use them routinely. So did Skylab.

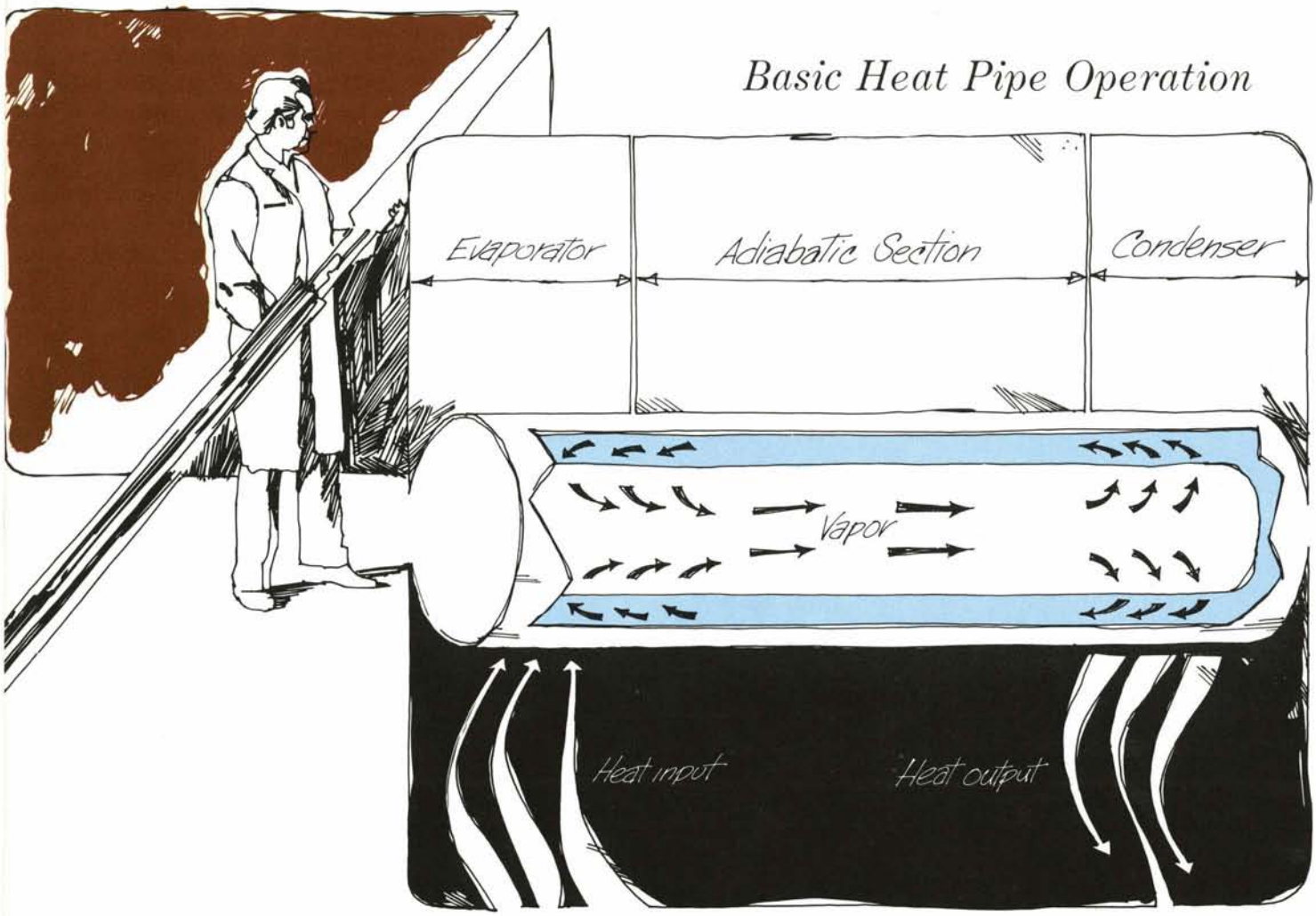
A major construction problem in the arctic is posed by the seasonal freeze-thaw cycle of the permafrost soil. Frost-heaving, which can raise structural piling by as much as 18 inches in one year, is followed by uneven settling during the summer thaw. The enormous forces involved literally can tear a pipeline apart, spewing hot oil over the countryside.

Protecting the tundra environment by keeping the permafrost frozen obviously was a significant consideration in passing of the pipeline bill in Congress.

The heat pipe was adapted to the Alaskan permafrost problem by McDonnell Douglas Corp. It is a sealed tube containing anhydrous ammonia, which has a boiling point of 25 F. The ammonia evaporates as it soaks up heat from the 30-degree permafrost. The heated gas rises to the top of the pipe and dissipates the heat through a fin-type radiator.

Having condensed back to a liquid, the anhydrous ammonia returns to the bottom of the pipe and the cycle repeats itself continuously, never allowing heat above 25 F to penetrate the permafrost. Thus heat pipes are totally automatic. They sense and respond to climatic conditions with no moving parts, require no external power, and never need adjustment or servicing.

The heat pipes are between 2 and 3 inches in diameter and 31 to 66 feet long, varying with the terrain. McDonnell Douglas-Tulsa is constructing



them for Alyeska Pipeline Service Co., the consortium responsible for construction and operation of the entire line.

McDonnell is building 112,000 of the heat pipes and radiators, an assembly it aptly calls a "cryo-anchor."

NASA's role in the Alaskan development did not end with initial research into reliable heat pipes for cooling spacecraft components. When Alyeska first became interested in heat pipes as a solution to the tundra problem, the Marshall Space Flight Center turned over the results of NASA research and channeled the consortium to NASA heat-pipe contractor companies.

Alyeska personnel also participated in a heat-pipe technology short course conducted by the NASA Industrial Applications Center at the University of New Mexico. And, as Alyeska's permafrost program neared completion, a technical review team at Goddard reviewed the heat-pipe application and suggested design improvements.

By developing the basic heat-pipe technology for space missions—and subsequently making that technology available to industry—NASA freed Alyeska from more costly, and longer-term, solutions. Thus, space research contributed directly to developing the North Slope energy resource.

Reclaiming waste heat

The heat pipe is probably the most efficient heat-transfer device known today. It can transport roughly 500 times the heat flux of the best solid conductors with a temperature drop of less than 3 degrees per foot.

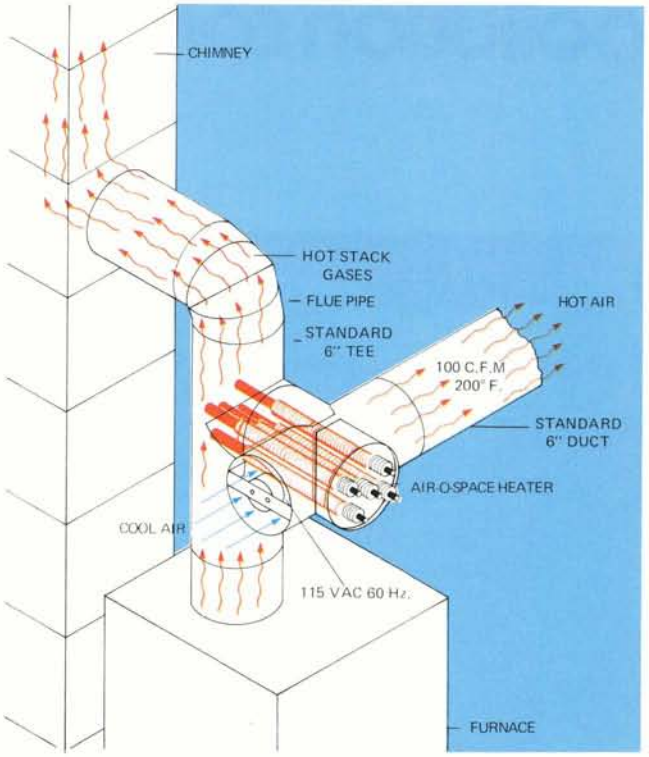
These facts led to the formation of Isothermics Inc., Augusta, N.J., to manufacture heat-pipe products. The equipment reclaims heat from chimney flue gases in home and industrial heating systems.

The heat pipes extend into the flue, pick up a portion of the heat and redirect it to the area to be heated. In home use a small fan draws surrounding air typically from the basement and forces it over the finned heat pipe. This heats the air, which then can be channeled for use in other areas.

A similar device uses the waste heat from industrial processes. It derives heat from the exhaust of a boiler or drier and returns it to the process or to a space heater.

These heaters are simple and inexpensive to install, requiring little modification other than additional ductwork to the existing system. In either home or industrial use, the only expense entailed in operating the heater is a small amount of electricity to power the fan. No additional fuel is required since the heat normally wasted is simply reused.

Isothermics has found that heat-pipe equipment increases efficiency in homes by about 10% and even more in industrial processes where waste-heat temperatures are higher. The heat-recovery devices



"Air-O-Space" heater based on spacecraft heat pipes requires no fuel other than electricity to run the fan. Installed in a chimney flue, heat pipes transfer the heat from waste hot gases (but not the gases themselves) to fresh air blown across the other end of the pipes.

actually pay for themselves in a few years.

The company is a subscriber to NASA's Industrial Applications Center at the University of New Mexico, where its employees attend symposiums on heat-pipe technology.

Another company, Kin-Tek Laboratories Inc., Texas City, has adapted NASA heat-pipe ideas and data to produce an instrument to calibrate gas analyzers used for air-pollution monitoring.

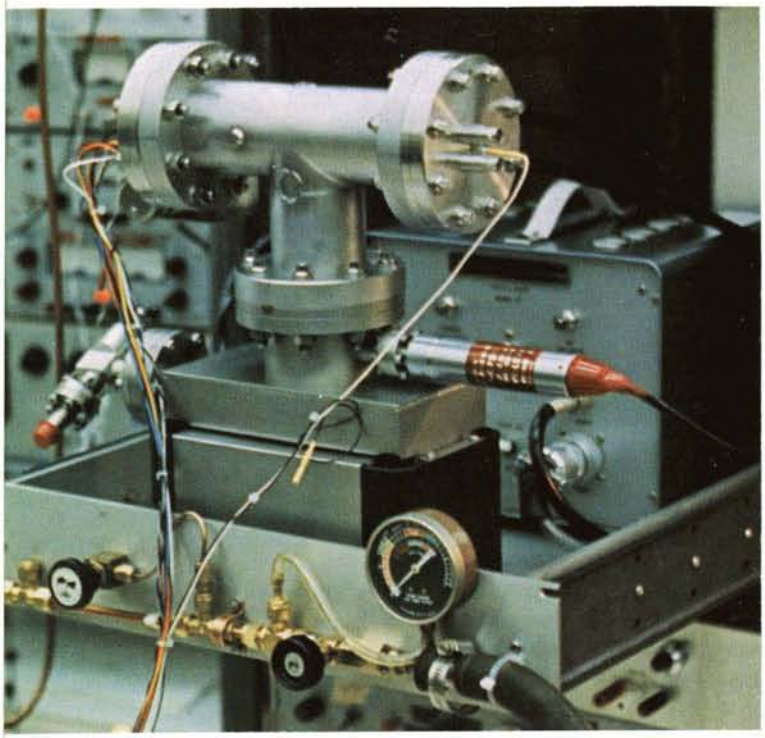
Flatplate solar energy collector

The avenues of technology transfer are illimitable. D. W. Barlow, a small truck-body fabricator in Florida became a producer of flatplate solar collectors after having an inexpensive literature search performed for him by a NASA information center.

The NASA Industrial Applications Center at the Research Triangle, N.C., searched its extensive technical literature files—containing both NASA and non-NASA reports—and provided Barlow with abstracts of 314 papers. Of these he requested 15 full-length articles.

His total cost: $100. Yet it was sufficient to launch him into a new venture, O.E.M. Products Inc. His flatplate collector design incorporates a new black paint developed by Dow-Corning Corp., but not yet commercially available.

pollution control



Small mass spectrometer is being developed to monitor hydrocarbons in the air aboard aircraft and ships. It also could be used to warn against respiration problems of patients under anesthesia.

Trace-gas monitoring

Space technology is contributing to air-pollution control primarily through improved detectors and analysis methods. In one program at NASA-Langley, a miniaturized mass spectrometer is under development to monitor vinyl chloride and other hydrocarbon contaminants in an airborne laboratory.

The portable system, using a 2-in. quadrupole and hyperbolic rods, will include a microprocessor for real-time data acquisition. Supported by the Environmental Protection Agency and the Air Force's School of Aviation Medicine, NASA is directing the development, which is expected to be ready for testing next July.

The miniaturized mass spectrometer can be used to protect personnel in naval and medical operations, as well as aboard aircraft. For instance, an advanced warning of respiration problems of patients under anesthesia can make surgery safer. The EPA is interested in the instrument for monitoring vinyl chloride and other hydrocarbon contaminants in the air.

Small-particle pollutants

Fly ash and urban aerosols seem to have a high concentration of toxic elements in very small particles. These submicron-size particles are too small to be filtered by ordinary methods and so can enter the human bloodstream easily when inhaled.

NASA's Langley Research Center is cooperating with the Environmental Protection Agency to measure the particle sizes of all elements in aerosols from airports, coal-fired power stations, municipal waste incinerators, and other combustion aerosol sources. If toxic elements are found among these small-size aerosols in harmful quantities, means will have to be improvised for reducing them. The problem is especially important because of the anticipated increase in the number of coal-fueled electric power plants in the next decade.

Langley intends to sample the air using its proton-induced X-ray emission technique initially developed to determine aerosols in jet-engine exhaust.

The Langley proton technique is important because no other rapid, nondestructive method now exists for measuring trace-element compositions of massive amounts of air. The method also can analyze human tissues and hair samples to determine exposure to the toxic elements.

The NASA work is expected to provide the major input to the EPA's new National Environmental Specimen Bank. Because the proton technique is nondestructive, specimens can be kept in the bank to help determine when new pollutants emerge, as well as to follow trends of known pollutants.

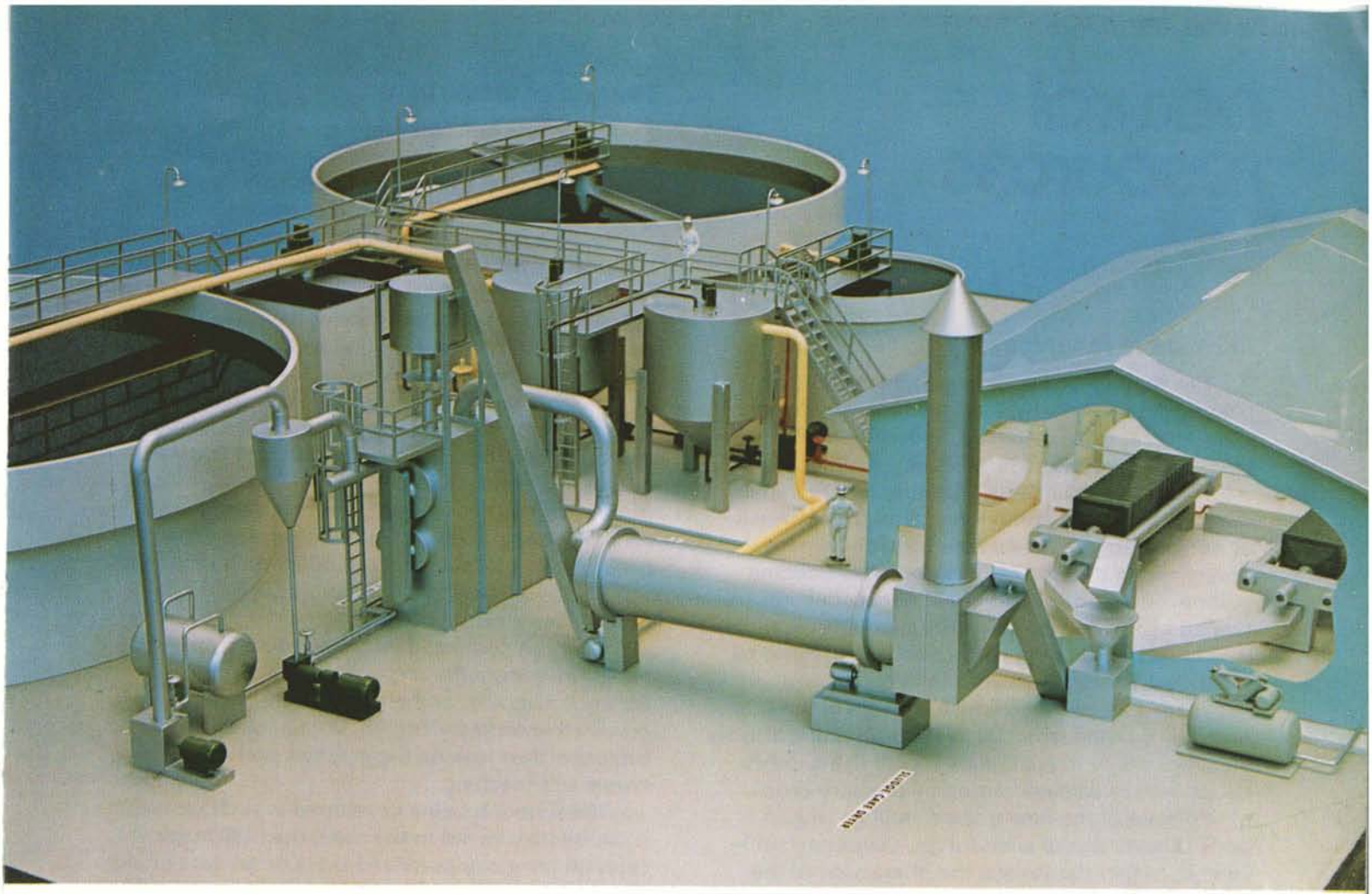
Carbon-monoxide detector

Another technical approach to pollution detection, which was used aboard Skylab, is nondispersive infrared spectroscopy. The principle was utilized to develop a carbon-monoxide detector for the Skylab cabin.

Previous nondispersive analyzers could not selectively distinguish between water vapor and carbon monoxide, thus necessitating water removal by another device before measurement. These analyzers also were susceptible to vibrations and other problems. The new instrument, which stimulates fluorescence in two carbon-monoxide isotopes in two sealed cells, eliminates these problems and increases sensitivity to a tenth of a part per million.

A company later reorganized into Andros Inc., Berkeley, Calif., developed the instrument under contract with Ames Research Center. Now produced and sold by Beckman Instruments Inc., Anaheim, Calif., the instrument is in use by state and federal agencies.

For example, the EPA flew it in a helicopter to determine the carbon-monoxide profile of the Los Angeles basin. No other carbon-monoxide analyzer could be used in this fashion.



Million-gallon-a-day sewage-treatment plant in Huntington Beach, Calif., converts solid sewage to activated carbon, which then treats incoming wastewater. The plant is scaled up 100 times from mobile unit NASA installed a year ago; another 100-fold scale-up will be required if technique is employed for widespread urban sewage treatment. the unique sewage plant is a serendipitous outgrowth of a need to manufacture activated carbon for rocket-engine insulation.

Sewage treatment

That space research can be utilized for much cleaner, cheaper sewage treatment probably is the ultimate in technology transfer. Yet a million-gallon-a-day municipal pilot plant will begin operating this year using a remarkable Jet Propulsion Laboratory-developed carbon-conversion process.

The new sewage plant, to be built at Huntington Beach between Los Angeles and San Diego, converts solid sewage to activated carbon. The carbon then treats incoming wastewater.

Activated carbon originally was sought as a lightweight rocket engine insulator. Sewage solids made an excellent raw material for the insulation material. And the resultant product proved to be a good agent for further sewage treatment.

Most municipal sewage plants in the U.S. today provide only primary treatment. That means about 40% of solids in raw sewage are discharged into the nation's rivers and offshore waters. Tens of billions of dollars would have to be spent to upgrade existing facilities with secondary-treatment installations to comply with new environmental laws. The significance of the new method is underscored when you realize that even secondary treatment fails to eliminate solid wastes.

The NASA system of making activated carbon out of the solids by high-temperature heating is an engineering breakthrough. The newly made carbon is recycled back with new sewage solids and reactivated, virtually closing the loop. Eventually a comparatively small amount of ash is extracted from the process. It is the only residue. And—like the squeal of the pig—the space-transferred system even uses the gases generated from the sewage as a source of power.

The California million-gallon plant is 100 times larger than a mobile unit the NASA laboratory installed there a year ago. If the technique is adopted for widespread urban waste-treatment, another 100-fold scale-up will be required.

The process already exceeds new Environmental Protection Agency standards for ocean discharges. It also reduces capital costs by 25% compared with conventional secondary-treatment plants.

natural resources

Tornado mechanics

The Nimbus and other weather satellites are helping determine why and how tornadoes form, their structure and dynamics, and—ultimately—how they can be prevented or artifically dissipated.

NASA-Marshall also is planning a cooperative research program later this year with the University of Arkansas to investigate how tornado damage occurs and to develop tornado-resistant building designs. The hardware and field-data collection are funded by the Technology Utilization Office, while data reduction is being performed by the National Oceanic & Atmospheric Administration.

Tornadoes cause extensive damage in the U.S., primarily by wind from 200 to 700 mph acting directly on structures or in combination with flying debris—as opposed to damage caused by pressure drops.

Purpose of the new research will be to gain better knowledge of wind forces, conditions sufficient to trigger the storms, the interaction of the wind with all parts of a building, and the way a structure collapses in high winds. Aerial photographic reconnaissance of the storm track in progress is needed, along with additional wind-tunnel and analytical modeling work.

The use of urban land

Suggesting how our finite American land can be used most effectively, especially in metropolitan areas, is one of the more important contributions space technology has to offer the nation.

Techniques developed for analyzing scientific information from the lunar and planetary missions now are being applied to land-resource management in and around cities. Two systems have been formalized by NASA's Jet Propulsion Laboratory and are being applied in the Los Angeles region.

The first, called the "land-use management information system," incorporates maps, aerial photos and other land data into routine city and county census records.

To achieve this merger of information, the JPL system uses a graphics terminal to display city-street networks. Urban planners can query their data bases and display numerical values for each of the city blocks shown on a TV screen.

They can command information for study-area selection, geographical specifications, street-network mapping, and other data. Instructions are provided in ordinary English, instead of computer language, thus making the graphics portion of the system self-teaching.

The system is being developed in such a way that it can be transferred to the more than 200 major U.S. cities utilizing computerized U.S. Census Bureau files of street networks and block-by-block demographic statistics of street networks and block-level census statistics.

The second system, "multiple-input land use," combines satellite imagery with other data sources. Its developers now are concentrating on the precise registration of two-dimensional pictures and the interfacing of this information with existing data files.

The first demonstration of the system will be applied in Los Angeles early this year. Multispectral analysis of data from Landsat images will assist the city in making basic rezoning decisions.

JPL also is working to bring the land-use management information systems to Tacoma, Wash. Essentially a city street map in computer-readable form, the system will help planners in traffic-accident analysis, mapping, and land-record integration.

Landsat photograph of Los Angeles enhanced by computer techniques results in urbanized and agricultural land being sharply differentiated from natural areas. Ocean portion of photo shows coastal sediment transport patterns, sewage outfall, and plumes associated with oil seepages. Extreme contrast reveals haze pattern along the Malibu and Santa Monica coast and south of the Channel Islands. The image to the right has been of use to California Coastal Zone Conservation Commission in its drafting of an overall coastal plan.

Beach erosion

Even beach erosion, a problem afflicting lake- and ocean-front communities throughout the world, can be abated through remote-sensing techniques.

As an example, some two miles of beach at Cape Canaveral that had been eroded by construction of a port and jetties was recently restored. Such work in harbors of many cities often disrupts the normal flow of sand for many miles along coasts.

An instrumented NASA airplane flew over the Canaveral coast approximately every three months providing color infrared photography. The pictures provided a measurable evaluation of the erosion before, during, and after project completion. It enabled the beach restorers to pinpoint areas of critical concern and shoreline instability so they could plan interim corrections.

Brevard County Fla. residents now enjoy a 400-ft wide public beach in an area in imminent danger of destructive erosion just a year previously. Before (left) and after (right) aerial photos show how more than two miles of beach were rebuilt with 2.7 million cubic yards of sand, helping abate the erosion problem caused by construction of jetties at Port Canaveral in the early 1960s. NASA volunteered its remote-sensing technology and instrumented aircraft to provide low-altitude color infrared photography about every three months since 1972. Photo at right also shows Trident submarine basin built between April 1974 and January 1975 when these two views were taken.

The photos also highlighted sand dunes that had been altered by construction and showed how they contributed to the beach erosion. Such encroachments of the dunes now have been restricted by local laws.

The restoration project is one of many examples of how aerospace technology can help solve community problems.

Exploring with gravity

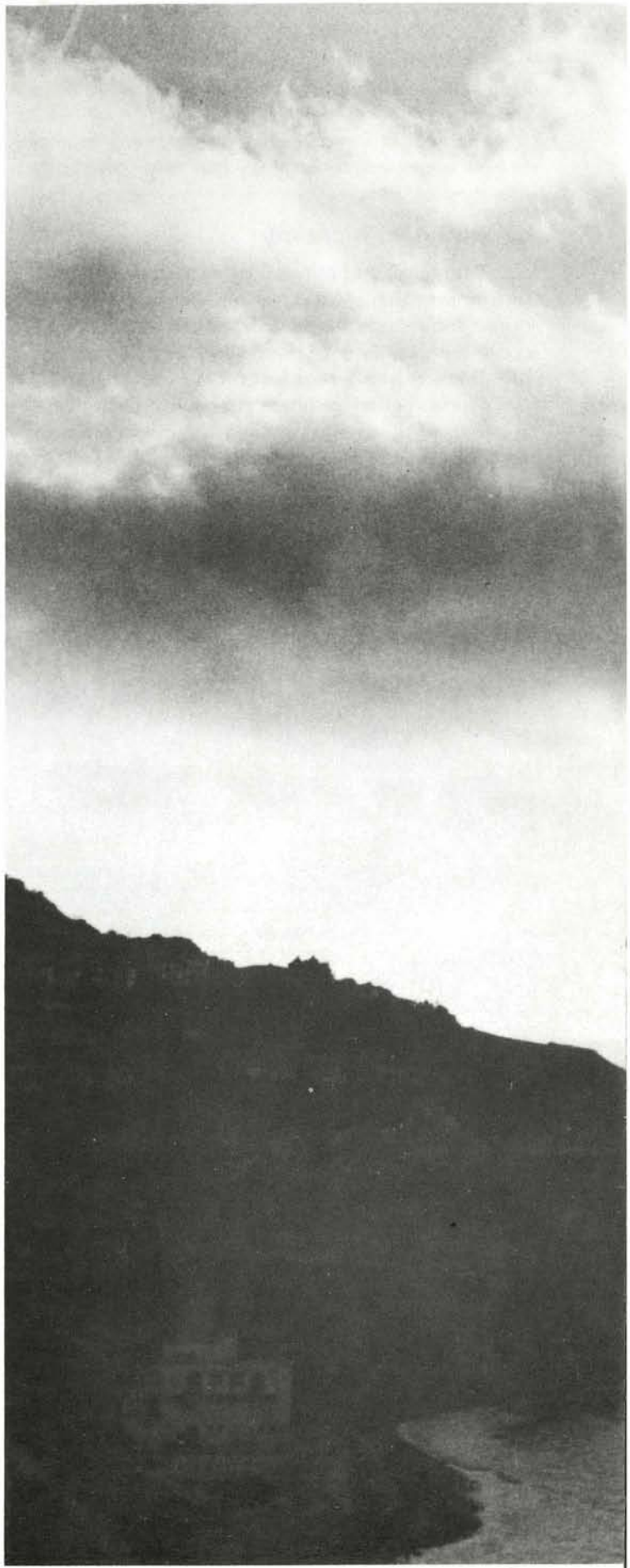
Among oil and mineral prospecting tools are instruments that measure anomalies in the gravitational and related fields. The instruments work because the density of hydrocarbon-bearing rock or ore deposits is different from that of normal soil.

Modern gravity meters actually can achieve an accuracy of up to one part in a 100-million, but only on the earth's surface using a complicated system of springs and levers that require extreme dismensional stability and tedious data interpretation.

Sponsored by the Technology Utilization Office, the Langley Research Center last year undertook a six-month feasibility study to adapt a sensitive resonance fluorescence spectrometer as a gravitometer. The spectrometer was improved initially by Langley to investigate small changes in the atomic composition of spacecraft metals that might cause structural fatigue. Results of the study indicated that such a device could detect gravitational anomalies from the air with sufficient accuracy to reveal mineral and oil resources.

The starting point of such an instrument is high-purity rhodium, free from magnetic and other impurities. Thus, research is proceeding this year to grow or otherwise purify source-absorber rhodium crystals of the required perfection.

recreation



Hang gliders for sport

Those daring young men on their flying trapeze-like kites are hanging beneath colorful wings originally designed to recover spacecraft.

The wing was designed in 1948 by Francis Rogallo at what is now the NASA Langley Research Center. Free Flight Systems Co. in Sylmar, Calif., used the Rogallo design to manufacture hang gliders for sport.

The sport is growing rapidly. Free Flight produces about 1,000 gliders a month, and other companies are entering the field.

The wing is simple to control. Pulling back on the control bar allows you to pick up speed and at the same time lowers your altitude. Pushing forward slows your speed and levels you off. You push left to go right and vice versa. Birdmen can choose from prone, upright, or swing-seat harnesses in either kits or ready-to-fly gliders.

'Esoteric' space technology comes down to earth dramatically in the form of recreational and consumer-product transfers.

Quartz-crystal clocks

A major problem in developing highly accurate timing equipment for the Apollo missions was obtaining a stable time base from which all mission times could be derived. Under contract with the Johnson Space Center, General Time Corp. developed a quartz crystal for the purpose, which later became the basis of consumer clocks and watches with an accuracy of one minute a year. The accurate watches are useful in timing sporting events as well as for general use.

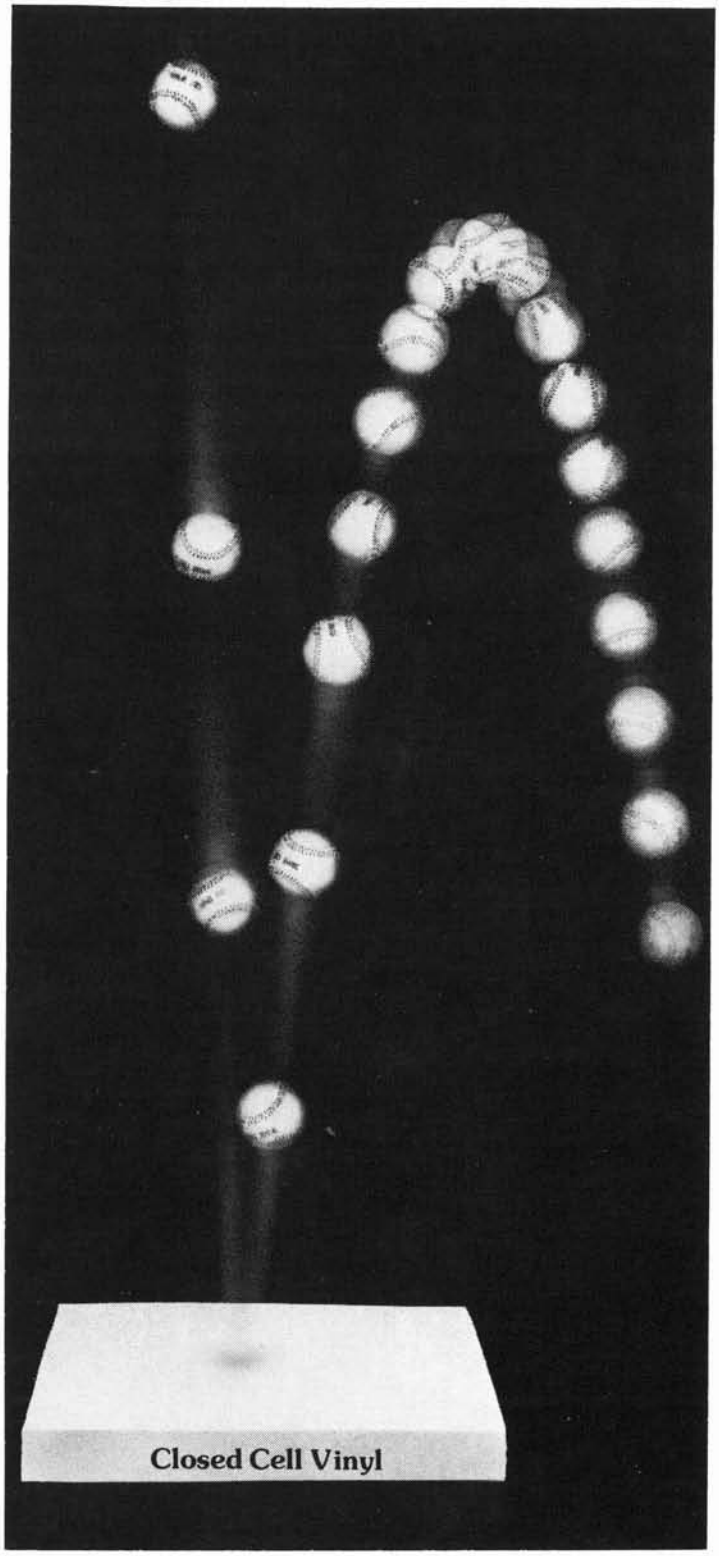
When quartz is electrically stimulated, it can vibrate millions of times a second. Since timepieces use a vibrating body to keep time, the incredibly fast vibration of a quartz crystal—up to 4,194,304 beats a second—opened a new horizon in accuracy.

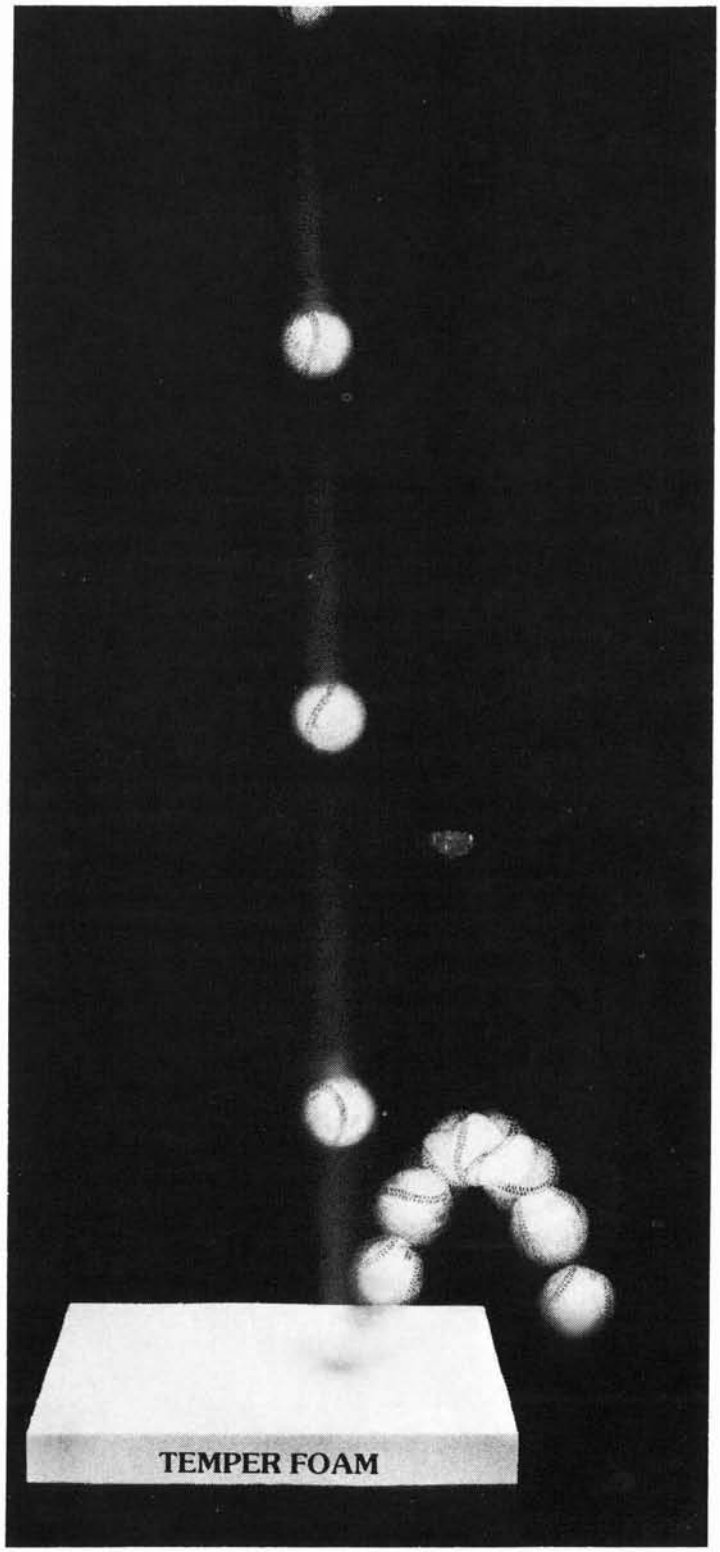
For the watches, General Time also incorporated micro-miniaturized integrated circuits to bring the quartz crystal into a usable configuration at reasonable cost. Called "quartzmatic," the clocks and watches now are sold under "Seth Thomas" and "Westclox" brand names.

Test below illustrates superior ability of "Temper Foam" to absorb shock or bounce from impact. Baseballs are dropped from the same height on two same-sized pieces of padding material. The baseball at far left falls on conventional closed-cell vinyl and the other on the new open-cell polyurethane-silicone plastic foam transferred to a host of recreational and other uses from its original NASA application as better airplane seats.

Versatile padding

When NASA-Ames scientists began work on a padding concept in 1968 they were looking for a better airplane seat. They found it in a new foam material that today has all kinds of additional applications including wheelchairs, X-ray table pads, off-road vehicle seats, skiboots, and football helmet liners.

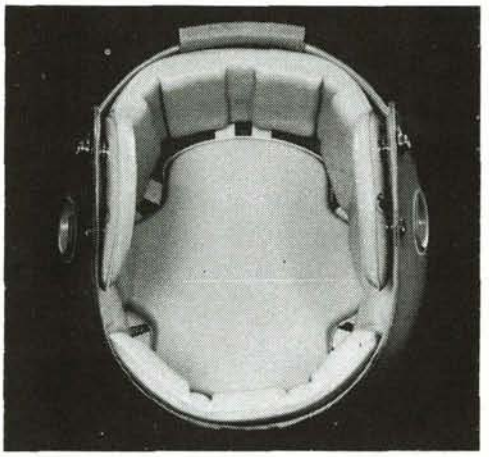


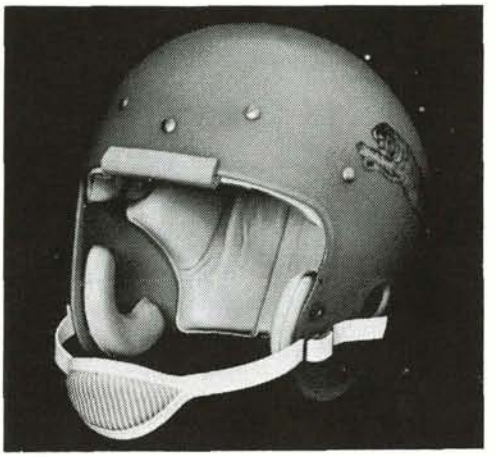


The material is an open-cell polyurethane-silicone plastic foam that takes the shape of impressed objects but returns to its original shape even after 90% compression. It absorbs sudden impacts without shock or bounce. For instance, the manufacturer claims a 3-in. thick pad can absorb all the energy from a 10-ft fall by an adult.

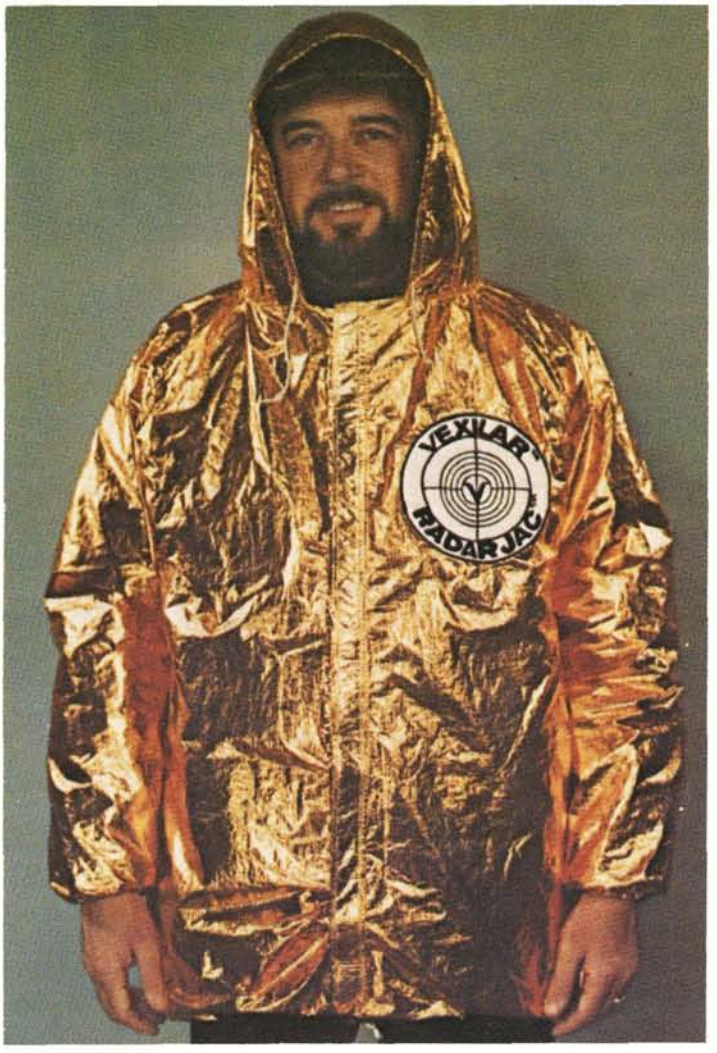
The material is temperature-sensitive, getting softer when warmed and firmer when cooled. Some formulations can be "frozen" at 60 F, yet take sustained temperatures in excess of 300 F—which also means the material can be dry-sterilized.

After the initial Ames work to improve safety and comfort in aircraft passenger seats, a contractor's employee invented the material, which he called "Temper Foam," and started Dynamic Systems Inc. to produce it. In 1974 the product line was bought by the Edmont-Wilson division of Becton, Dickinson &





Temper Foam, exhibiting about 340% less shock from impact, lines football helmets. The versatile padding today is utilized in wheelchair and hospital pads and off-road vehicle seats.



Co. in Coshocton, O., which last year began to make it in greater quantities.

Patients who could spend only a few hours at a time in standard wheelchairs now can use their chairs three times longer. Used in hospitals for orthopedic and other cases, it greatly reduces pain and bedsores.

Inside football helmets, it adjusts to the shape of the wearer's head without putting undue pressure on any one point. The helmet is safer because the new foam material absorbs far more of the impact energy than conventional padding used in the lining of most helmets.

The Dallas Cowboys have started to use the new helmets, along with other teams and schools. This year Temper Foam will be incorporated into a variety of athletic equipment such as body pads, chest protectors, and shin guards.

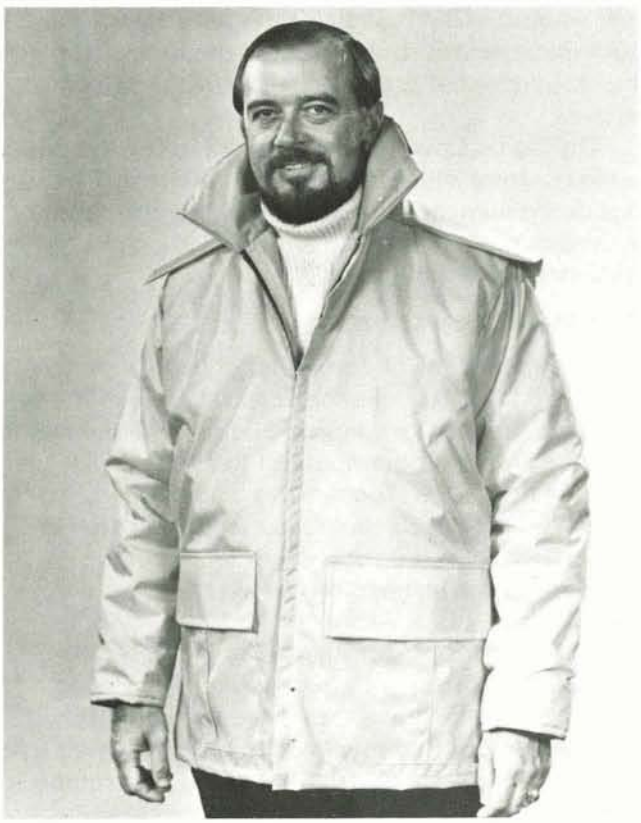
Comfort for sportsmen

Aluminized mylar developed originally for NASA-Goddard to make the Echo satellites more reflective, to insulate cryogenic fluids, and for space-suit insulation has been spun off to a variety of consumer products. Sportsman's blankets and jackets, ski parkas, sleeping bags, and even life-raft canopies (see "Rescue at sea" under "Your Mobility" in the first section of this report) are among them.

The sportsman's blanket, weighing only 12 oz, can be used equally well to keep heat away or to keep available heat in. It has many uses for the outdoor enthusiast because of its large size (4½ x 7 ft).

The emergency rescue blanket has heat reten-

Camping blanket above and jacket below have been spun off from cryogenic and other space applications. The survival jacket is manufactured by Vexilar Inc. using King-Seeley Thermos Co. gold-metallized polyster "superinsulation" that is highly visible, radar reflective, lightweight, and waterproof.



tion qualities similar to those of the sportsman's blanket. It is strong enough to be used as a litter, yet folds up so small you can carry it in your shirt pocket.

One of the latest products is a light-weight jacket fabricated by several companies from the super-insulation originally developed for NASA-Lewis and now manufactured by King-Seeley Thermos Co., Winchester, Mass.

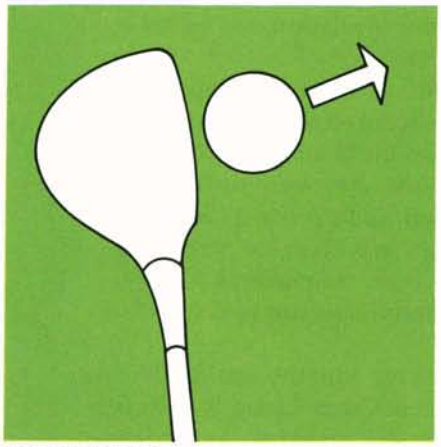
The 10-oz reversible jacket absorbs warmth from the sun. The silver-colored side next to your body retains a large portion of body heat. In warm weather, you wear the silver side out to reflect the sun's rays.

In a similar model, a gold metallized polyester film is bonded to a tear-resistant fabric to allow radar reflection, as well as higher visibility under all light conditions. Like the other jackets, the material protects against heat or cold and doesn't absorb moisture.

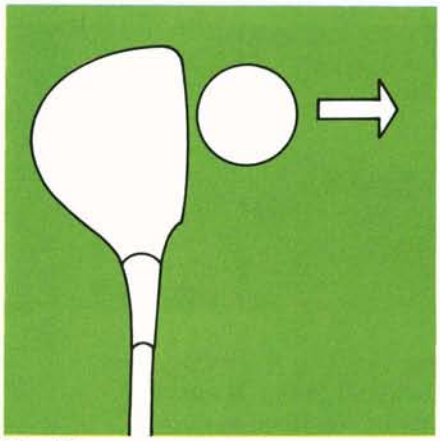
Composite golf clubs

Composite materials developed for the Marshall Space Flight Center are being used by Babcock & Wilcox Co., Alliance, O., for golf clubs. The reinforced composites provide the combination of shaft rigidity and flexibility that provides maximum distance.

The company used Marshall's data summary file originally compiled to consider new materials for the shuttle program. The file summarizes typical-processing techniques and mechanical and physical properties of graphite and boron-reinforced composite materials.



Conventional



DynaTorque

Materials for better golf clubs developed from NASA composite-material data have been designed by Babcock & Wilcox Co. The "DynaTorque" graphite composite allows a lighter shaft in relationship to the club head, resulting in easier swings and better control as shown above.

Packaged food

NASA-Johnson's experience in producing spacecraft food and food systems is being spun off to develop meal packages that don't require refrigeration.

Congressional studies have found that many elderly persons don't eat adequately either because they can't afford to, because of limited mobility, or because they just don't bother.

Reacting to a request from the Texas Governor's Committee on Aging, the Johnson Space Center is developing shelf-stable foods processed and packaged for home preparation with minimum effort. Various food-processing techniques and delivery systems are under study. The program, an applications project of the Technology Utilization Office is a cooperative venture including the University of Texas, Texas Research Institute for the Mental Sciences, and United Action for the Elderly Inc.

Food taste, package designs, and a delivery system developed by Technology Inc. were tested late last year in seven central-Texas rural areas. A three-month field test of the entire system will be conducted this year to evaluate foods, packaging, delivery systems, distribution logistics, and reactions of the users.

Compressed and freeze-dried foods developed by Johnson originally for space flight applications

also are being marketed by Innovative Foods Inc. in California for campers and as compact emergency food rations.

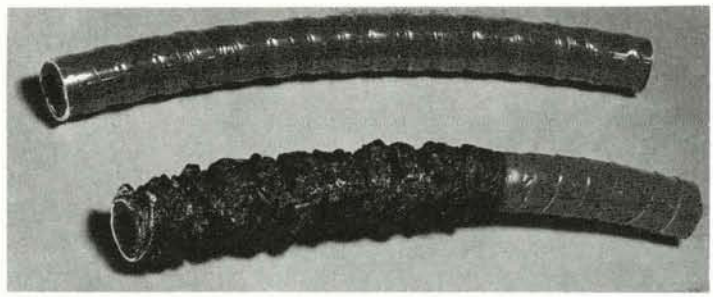
Safer pleasure boats

One of the main hazards of gasoline-fueled pleasure boats is fire or explosion. An Ames Research Center coating developed to protect air- and spacecraft now has been transferred to reduce this danger.

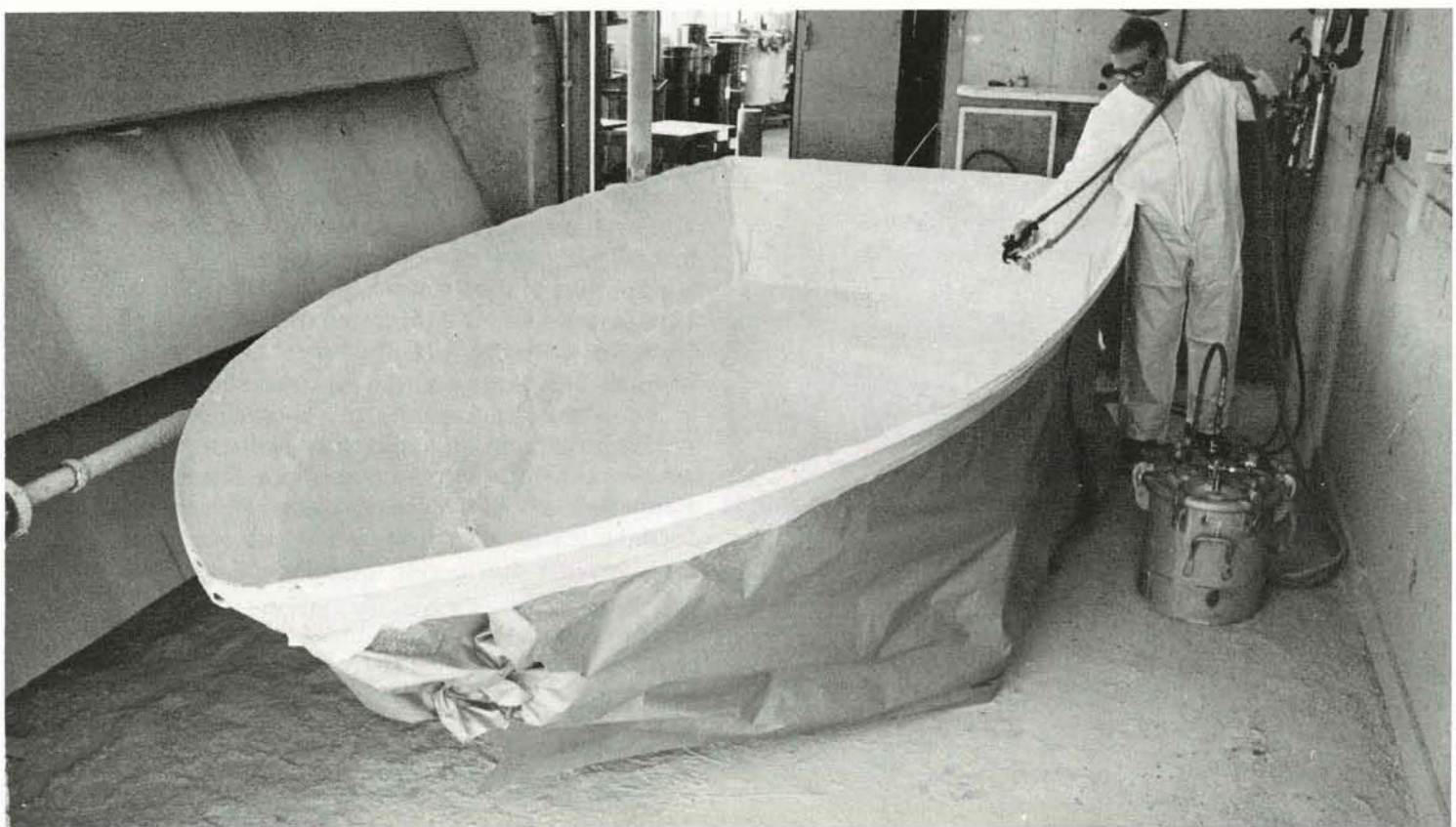
The Ames coatings contain dispersions of nitro-amino-aromatic compounds that decompose and swell the original coating 70 to 200 times its original thickness. The decomposition gases, water, and sulfur dioxide all quench fires. And the low-density foam that remains provides insulation and forms a char that can re-radiate heat.

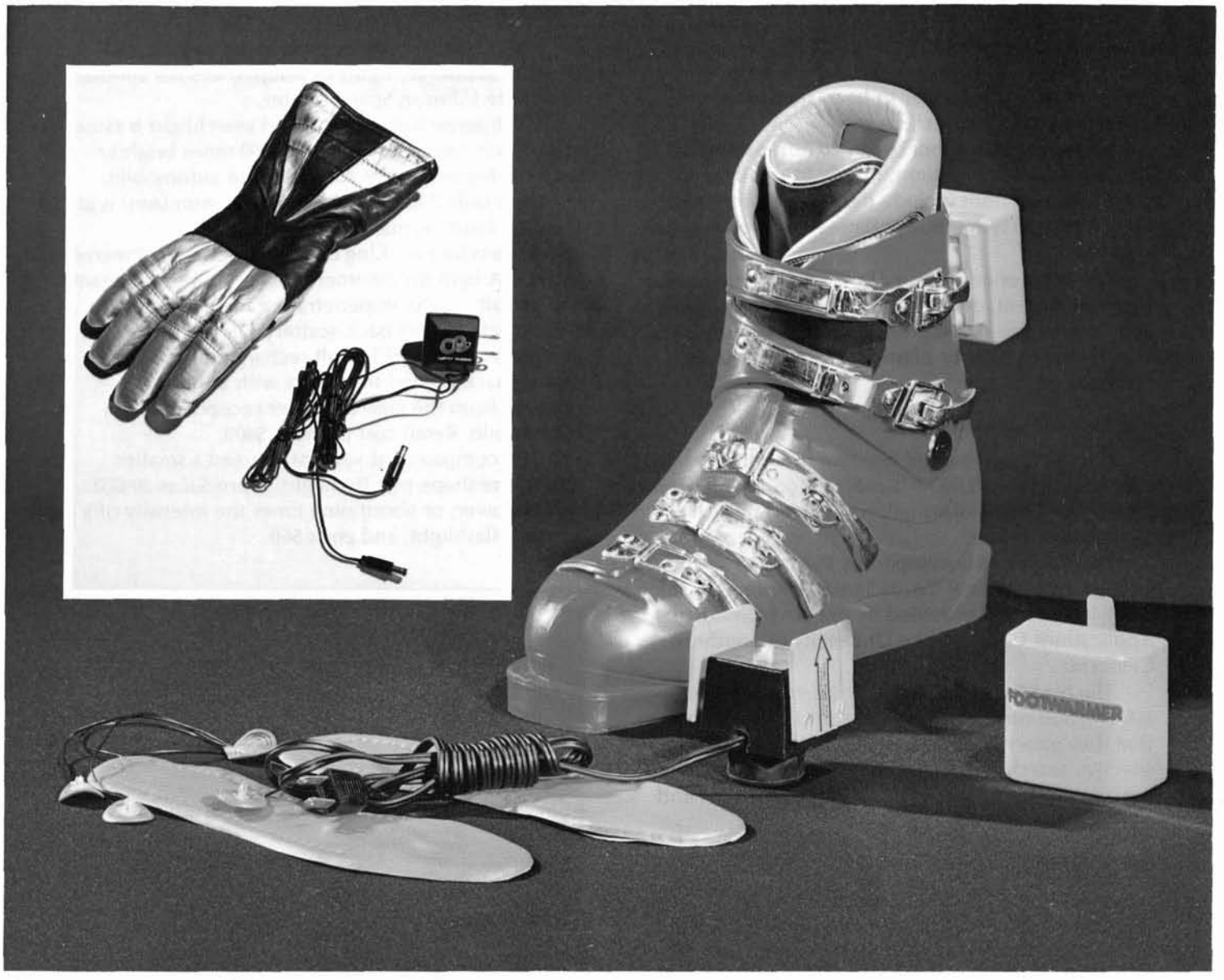
Avco Corp. contracted with Ames to test these coatings and foams, was licensed to practice the technology to protect fuel tanks and fuel lines of military aircraft. From there, they were further developed as tapes and coatings to protect fuel hoses on inboard pleasure boats as well as for protecting the interior of fiberglass hulls. As much as 100,000 sq ft of the covering material now are sold monthly to hose manufacturers.

Avco is working this year with the Boating Industry Association and the U.S. Coast Guard to develop adaptations of the coating for fuel tanks and engine-compartment walls.



"Flamarest," coating developed by Avco Corp. for NASA to protect fuel lines and tanks, is sprayed on the interior of a polyester boat hull in a commercial application. About 30 mils of the coating prevented structural damage to this hull during a test in which a 13-minute interior gasoline fire was started. An unprotected hull would begin to burn in 30 seconds. Above, the same material applied as tape to wrap fuel lines effectively insulates the bottom hose when charred, while also reducing the spread of flame.





Footwarmer, small powerpack at right in photo above, fits on back of skiboot to activate heating circuit in soles. Powerpack is rechargeable with device shown in center. In photo above left, thermal gloves are heated similarly. Boot and glove warmers, which can be turned on only when needed, have been adapted from spacesuit designs that kept astronauts warm on the moon.

Warm hands and feet

Another space development can keep your hands and feet warm in even the coldest weather. Adapted from spacesuit designs that kept astronauts warm or cool in the temperature extremes of the moon, the gloves and boots are electrically heated.

Batteries worn inside the wrist of the glove or sealed in the sole of a skiboot are rechargeable hundreds of times. They operate a flexible resistance circuit which is turned on periodically when the wearer wants to be warmer.

The thermal gloves and boots also utilize space-insulation materials and techniques. Unheated thermal gloves would be adequate as long as the insulation stays dry. The problem is that it does not. Moisture from without or from perspiration saturates conventional insulations.

In a product developed by Comfort Products Inc., Aspen, Colo., the monofilament open-mesh material used in lunar spacesuit boot liners "wicks away" the moisture. The heater circuits, the same as those used in the Apollo command module, consist of chemically etched foil circuits in a mylar-glass laminate. Even the flexible joint concepts developed for Space Shuttle gloves are incorporated.

In an example of "people transfer," Johnson Space Center personnel who designed the spacesuit gloves later joined Comfort Products and were responsible for the cold-weather glove and the thermal boots.

Fogless ski goggles

Keeping ski goggles from fogging is just one of dozens of uses for the anti-fog coating developed at the Johnson Space Center to keep spacecraft windows clear before launch.

NASA has issued more than 60 non-exclusive licenses for the compound, mostly to small companies. Applications include deep-sea diving masks, fire-protection helmets, eyeglasses, and vehicle windows.

The basic composition of the coating includes a liquid detergent, deionized water, and an oxygen-compatible, fire-resistant oil. Two thin coatings are applied to the glass or plastic surface and buffed lightly.

Portable home welder

A small do-it-yourself welding torch that weighs only 7 lbs, gives a 5,000 F flame, and costs only about $40 resulted from information provided by a NASA applications center.

The torch was developed by Pyronetics Inc., a Cordon International Co. in Santa Fe Springs, Calif., using information provided by the NASA Industrial Applications Center at the University of Southern California.

The NASA center provided the company with information on chlorate candles, which are unique in that they generate oxygen while burning. A retrospective search undercovered information on composition, hazards, applications, manufacturers, and shipping regulations.

Showride!

A new entertainment product—a cross between an amusement-park ride and a widescreen movie —has been developed with the help of the NASA Industrial Applications Center at the University of Southern California. "Showride" synchronizes sight, sound, and feelings of movement.

Future General, the research arm of Paramount Pictures, sought the NASA center's help in providing literature searches of holographic display systems, motion cues, piloted flight simulation, and other sophisticated technologies.

The result is billed in Hollywood fashion as "a total sensory experience." Participants sit in small, 12-person cabins that can reflect any design scheme such as a spaceship, submarine, or room. The front of each cabin is completely filled by a giant movie screen. A four-track audio system envelopes you in sound.

The cabin is mounted on a steel frame. Movement is generated by hydraulic jacks that turn, shake, glide, or bounce the unit and its passengers in synchronization with the motion picture.

The first commercial installation is planned for late this year.

Hand-held searchlight

The brightest hand-held light yet produced is a result of xenon-arc lights developed as solar simulators at the Johnson Space Center.

The intense battery-powered searchlight is rated at a million candlepower—some 50 times brighter than the high-beam headlights of an automobile. It weighs only 7 lbs. Lifetime of the xenon lamp is at least 200 hours at maximum intensity.

Streamlite Inc., King of Prussia, Pa., reengineered the NASA light for commercial use. Its intense beam is especially useful in penetrating fog and smoke since it returns less back-scattered light. It operates either on a standard 12-volt rechargeable portable battery pack carried separately with a shoulder strap, or from the cigaret-lighter receptacle of an automobile. Retail cost is under $400.

The company last year introduced a smaller unit in the shape of a flashlight. It produces 20,000 candlepower, or about nine times the intensity of a two-cell flashlight, and costs $60.

Portable xenon-arc searchlight is rated at a million candlepower, yet weighs only 7 lbs. Another model not shown is in the form of a large flashlight. Both are spinoffs from solar simulators developed at NASA's Johnson Space Center.

Aerospace spinoffs rarely occur automatically. They are an outgrowth of dynamic interactions of people—from space technologists and inventors to the ultimate users in industry.

Technology Utilization At Work

catalyzers of technology transfer

Aerospace spinoffs rarely occur automatically. They are an outgrowth of dynamic interactions of people—from space technologists and inventors to the ultimate users in industry. Between these two extremes a new kind of professional works in government, education, and industry constantly seeking opportunities to reapply and utilize aerospace technology in new ways. Technological gatekeepers provide a viable link between the producers of technology and its potential users, in effect "catalyzing" the transfer process.

The essential role of imaginative catalyzers to stimulate secondary utilization of aerospace technology was recognized early in NASA's history. NASA established its technology utilization program in 1962 and since then, has assisted industry, states, and local governments in bridging the sometimes formidable gap between space research advances and their use here on earth.

The Technology Utilization Office has organized its activities on a nationwide basis to promote effective utilization of the vast amounts of new technology and other technical information generated by the space program. The function of these different activities is described briefly in this section.

Why technology utilization?

In drafting the legislation that formed NASA, Congress recognized the potential value of knowledge to be generated in pursuit of the exacting requirements of space exploration, by establishing the following goal:

"The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof"

An awareness of three separate, but related, considerations of the technology-transfer process led to establishing the technology utilization program:

1. Rigid requirements of space research and development provide incremental advances in the state of the art that can be useful to others.

2. Products and processes are seldom, if ever, applied in the form in which they were developed to meet space-mission objectives.

3. The large volume of technical information generated from space research represents a valuable national resource of use to industry.

The goal of the Technology Utilization Office, headquartered in Washington, is simply to bring about the secondary use or new application of technology already developed and paid for by the taxpayer. Less obvious are the mechanisms and strategies employed by the office to transfer technology to both the private and public sectors.

Technology utilization officers located at each of the 10 NASA field centers act as regional program managers and extend the Technology Utilization Offices catalyzing function by implementing its policies and projects in the areas they serve.

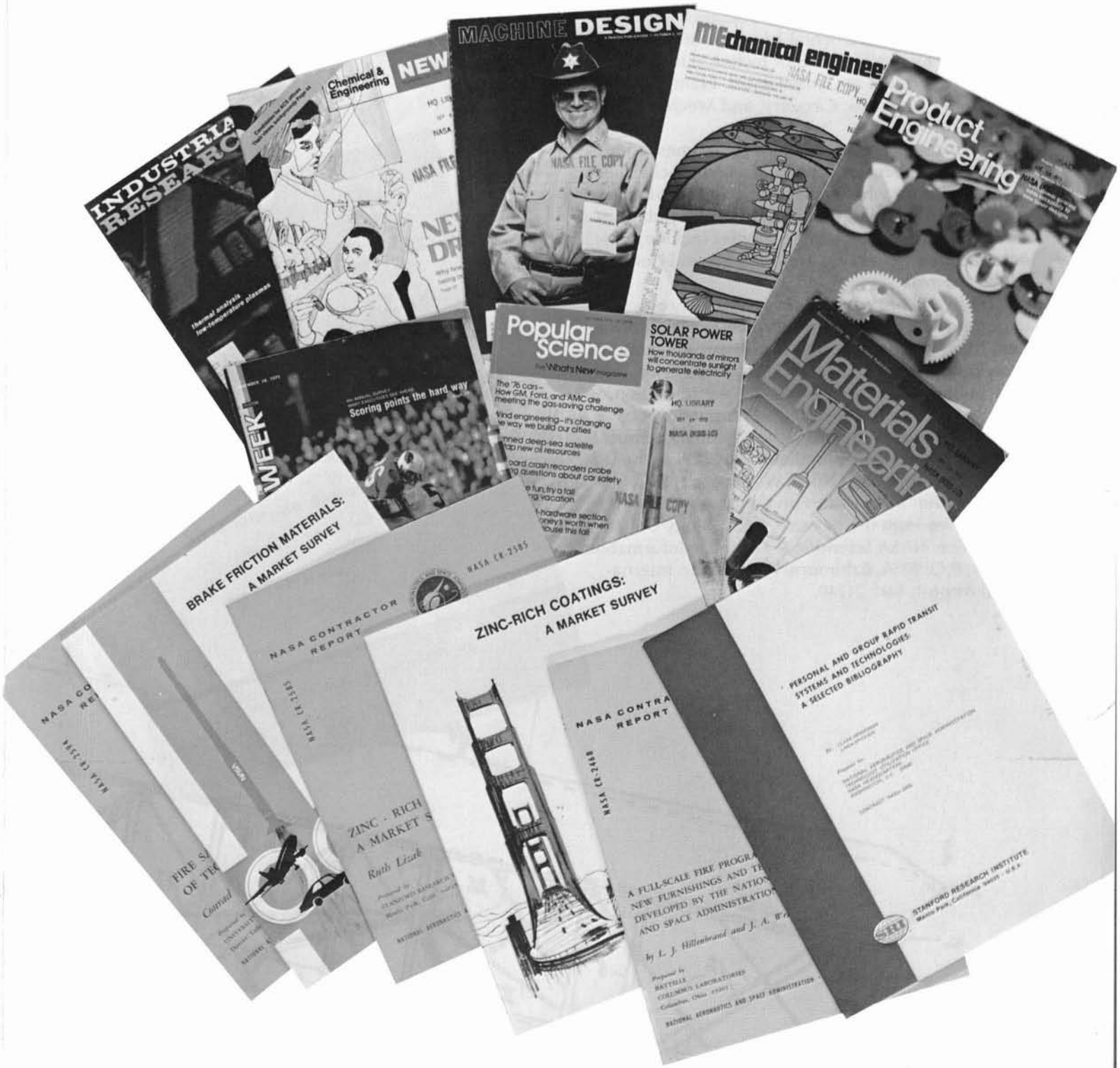
Getting the word out

"Each contract . . . shall contain effective provisions under which such party shall furnish . . . a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work"
—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

The excerpt above gives NASA the authority to require all R&D contractors to document and report new technology. NASA contracts are unique in this respect, and it is this requirement that forms the basis for the innovations and improvements that are announced in *NASA Tech Briefs,* the best known of all NASA publications.

Tech Briefs are one- or two-page straightforward announcements of potentially transferrable

More than 6,000 NASA Tech Briefs *and dozens of* Compilations *published since 1962 have produced some 300,000 inquiries for more information about transferable space technologies.*



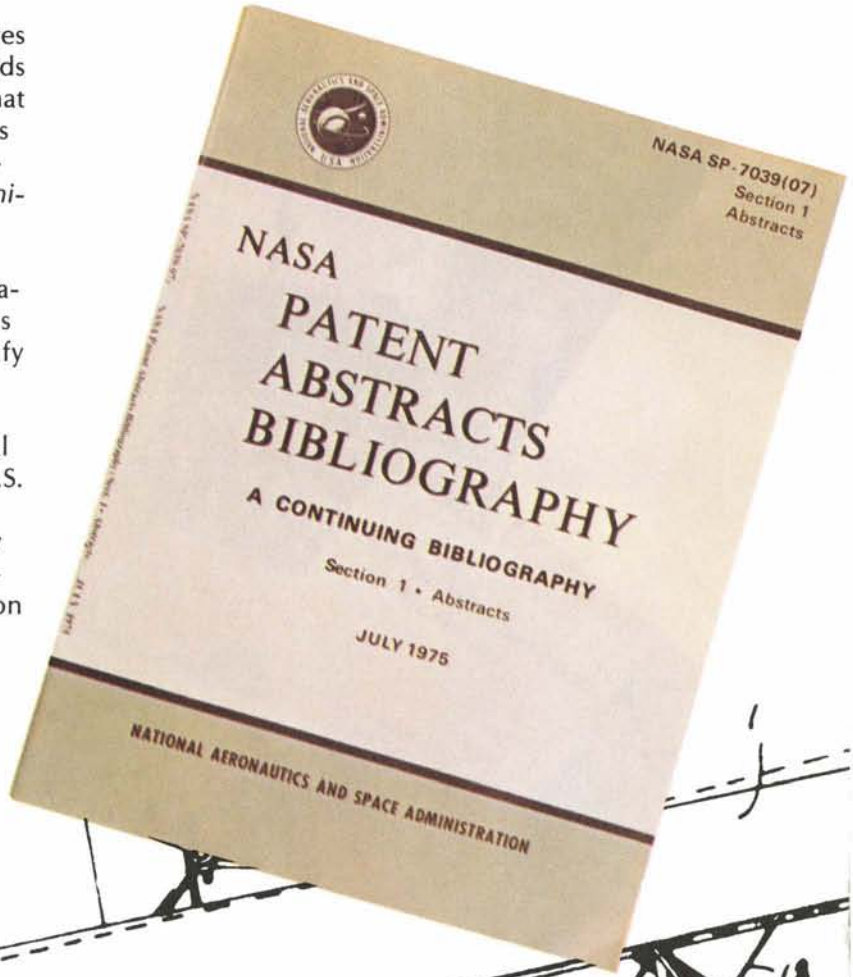
Trade magazines, above, help inform scientists, engineers, and technical managers about possible space spinoffs. Special surveys and reports also describe NASA developments of interest to industry.

space technology. Interested readers can receive supporting documentation from the applicable NASA field center's technology utilization officer. These and other incremental advances often are aggregated by specific areas of technical interest, and then published as *Compilations.* Examples are *Hand Tools, Electronic Circuitry,* and *Mechanical Fasteners & Fixtures.*

The nature of space missions sometimes requires that NASA make major contributions in specific fields or even advance whole new technologies. When that occurs, the Technology Utilization Office publishes surveys and reports. Recent examples include, *Human Factors Engineering, Holography,* and *Contamination Control.*

Trade and professional magazines play an important role in communicating technical information. Many not only republish aerospace inventions described in selected *Tech Briefs,* but they also notify their readers where to get additional information.

Tech Briefs and the other NASA publications described are available from the National Technical Information Service, Springfield, Va. 22151 or the U.S. Government Printing Office, Washington, D.C. 20402. Further information on their availability may be obtained from the director, Technology Utilization Office, NASA Scientific & Technical Information Facility, P.O. 8756, Baltimore/Washington International Airport, Md. 21240.



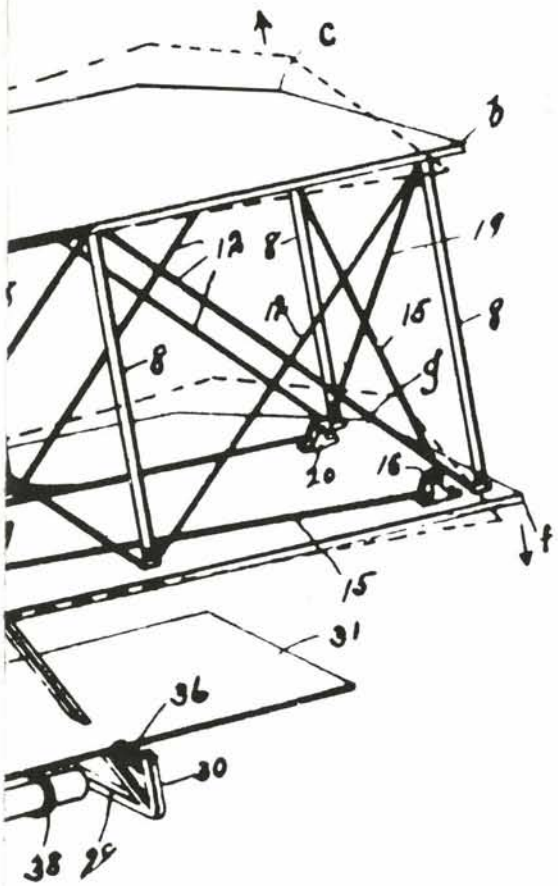
Patents for the asking

New government regulations promote faster commercial use of space technology by enabling patent licenses to be granted without the two-year waiting period formerly required. NASA can now grant an exclusive license even before a patent is issued—in some cases as early as nine months after the application has been filed.

Whether an exclusive license is granted depends primarily upon the necessity for exclusivity in bringing about practical application. Nonexclusive licenses also are granted, in those areas—such as the anti-fog coating compounds mentioned in this report—where many companies can participate effectively in commercializing the patent.

About 90% of NASA's patent licenses have been awarded to small business, although there certainly are no restrictions against large firms. All available patents are documented twice annually in an 800-page, nine-dollar bestseller called *NASA Patent Abstracts Bibliography.*

Patent Abstracts Bibliography *documents all available NASA patents twice each year. Patent drawing, below, of historical interest is the Wright brothers' "flying machine," patented in 1906.*



Search before research

While *Tech Briefs,* other publications, and the trade press are valuable in disseminating technical information to industry, personal interaction often is required to transfer space technology. Toward that end NASA has established a network of industrial applications centers at universities across the nation to provide information retrieval services and technical assistance to industry.

Imagine, if you can, a perfect information-retrieval machine. Such a machine would yield instant access to all of earth's latest, and oldest, technological developments. All you would have to do is talk to this machine in your office, tell it what you want to know, and a few seconds later you have on your desk exactly what you need. If such a machine were suddenly available today, would industry rush to get it? Probably not. Of course the information retrieval systems that exist today are not perfect. But even if they were, usage of existing technology depends on many factors other than mere availability. Information specialists trained in understanding users' needs are required to match available data with a company's specific technical objectives.

The network of industrial applications centers begun by the Technology Utilization Office in 1963 serves industry both by searching the literature and by helping to evaluate and apply the results. Searching what has become, by far, the world's largest technical data bank—and applying the resultant information selectively to industry's problems—now is daily routine for these NASA centers located on six campuses across the country. East to west, the centers are located at the University of Connecticut, the Research Triangle Park in North Carolina, the University of Pittsburgh, Indiana University, the University of New Mexico, and the University of Southern California. The geographic coverage, of the applications center network, shown on the adjacent map, is being expanded each year. For example, new territorial offices recently have been opened in such areas as Boston, New York, Cleveland, Chicago, Philadelphia, and San Francisco.

The network has access to more than 8-million documents, worldwide—and this vast storehouse of information is growing at the rate of 50,000 documents each month. It contains about 800,000 space-related reports as well as 10 times that many documents from private and non-space governmental sources.

The network's resources include technical and management information on air pollution, chemicals, education, engineering, nuclear energy, food, textiles, metallurgy, medicine, business, economics, and many other fields in addition to NASA's space technology. These resources cover the contents of more than 15,000 scientific and technical journals

throughout the world, plus thousands of specialized governmental and industrial research reports.

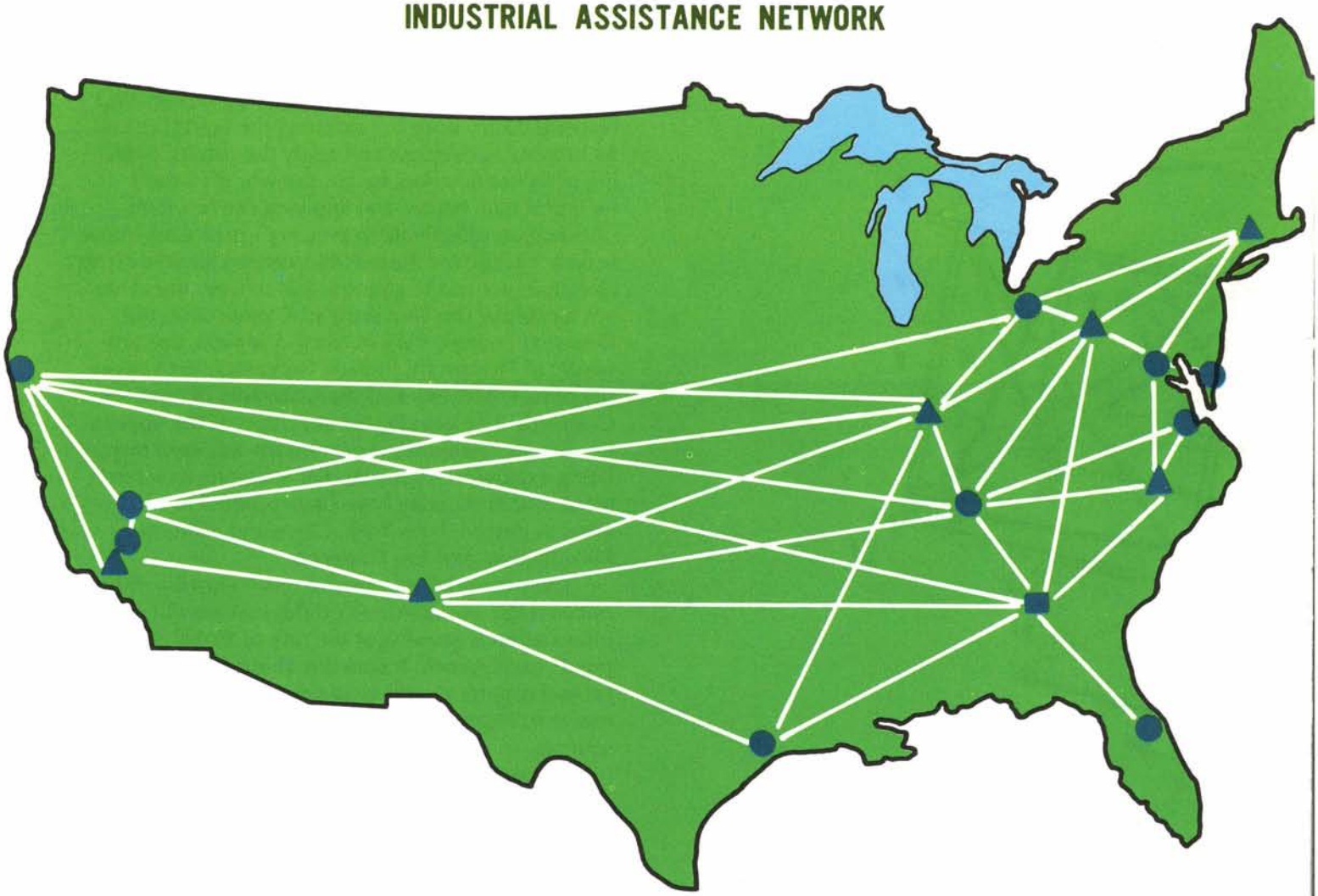
The NASA Industrial Applications Centers essentially offer three services: *retrospective searches* that reveal what others have done in the past, *current-awareness searches* that provide timely updates on specific new technical areas, and *technical assistance* designed to help industry apply the results of existing research or technology.

To further strengthen the industrial applications centers' capabilities for transferring NASA technology to industry, experienced "technology coordinators" now have been placed in several of the major NASA field centers. These men have had extensive experience in working with NASA and possess broad knowledge of the space agency's R&D programs. Their function is to assist the applications centers by matching problems posed by industry to appropriate NASA scientific and engineering expertise.

Several thousand companies now use the service annually. Technical information services provided on a confidential basis to these companies, over the years, have led to many useful applications and commercial ventures. Respect for the client's proprietary interests is a basic criterion in the successful operation of the applications centers. Examples of processes and products improved as a result of their services, have been described earlier in this report. They include development of thin "rigidized" panels that have the strength of heavier sheeting, a truck-body fabricator who expanded into solar collector manufacturing, heat pipes for the Alaska pipeline, microwave drying of thermoplastics, and the "show-ride" entertainment vehicle.

The network has access to more than 8-million documents, worldwide .

INDUSTRIAL ASSISTANCE NETWORK



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the technical basis for implementing pollution laws in Alaska, California, Ohio, and elsewhere.

A system developed by NASA to store and retrieve bibliographic materials has become the primary operating software for the National Criminal Justice Reference Service, a central computerized information system serving the nation's law enforcement agencies. Operational since 1972, the system has 30,000 registered users and now performs some 300,000 searches annually.

These programs are only a few of some 1,600 now available for other uses. COSMIC's software storehouse is applicable to solving problems in pollution control, health care, law enforcement, energy, manufacturing, communications, construction, consumer products, transportation, agriculture, management, and of course computer technology.

To announce new programs, NASA publishes a quarterly catalog called the *Computer Programs Abstract Journal.* It is available by subscription through the U.S. Government Printing Office.

Matching technology with public needs

Application of aerospace technology to public problems often requires technology demonstrations with user participation. To assist with these tasks the Technology Utilization Office has established application teams staffed by professionals from a variety of disciplines. In operation since 1965, these groups are divided into biomedical and technology application teams which are located at research institutes and universities. Both go out to public sector agencies or medical facilities to learn what significant problems might be solved by the application of NASA technology.

Four *biomedical* application teams work with research doctors and other medical personnel in

Helicopters are among the dynamic structures designed more efficiently with NASTRAN computer program available from COSMIC. NASTRAN, for "NASA structural analysis," is the most widely used of all NASA programs.

Computer programs

One of the nation's largest software libraries of engineering analyses and other programs is maintained by NASA at the Computer Software Management & Information Center, or COSMIC, located at the University of Georgia. The center provides, at a fraction of their original cost, programs developed not only by NASA but, also by other government agencies. Much of this software can be incorporated into existing commercial or educational operations with little or no modification.

COSMIC is a clearinghouse where software is transferred from government agencies to industrial or other users. Its inventory of programs is increasing steadily. For instance, as NASA moves more and more into helping solve the nation's energy problems through solar and other power sources, computer programs such as the new NASA energy cost-analysis program become available to industry.

The world of COSMIC is filled with intriguing and seemingly baffling acronyms. NASTRAN and GREMEX are among the program inventory at the University of Georgia, along with MIRADS, VICAR, and—yes—EXILE.

But there is no mystery to these strange words when spelled out. NASTRAN becomes the NASA structural analysis computer program described earlier in this report that has saved millions of dollars in the design of skyscrapers, freight cars, ships, and aircraft. It is the most widely used of all NASA programs.

GREMEX is Goddard Research Engineering Management Exercise, a man-machine management-training game. MIRADS, or Marshall (Space Flight Center) Information Retrieval And Display System, provides a fast method of getting at stored data. VICAR is a Video Image Communication And Retrieval system used to correct distortions in space and other photographs. And even EXILE becomes less foreign as EXploration Investment LEveling, a program used for the stimulation and optimization of mineral-exploration investments.

Computer programs used to send men to the moon have been adapted to more than 30 air- and water-quality models. These models have provided

One of nation's largest software libraries of engineering analyses is maintained by NASA at Computer Software Management & Information Center (COSMIC) at University of Georgia.

COSMIC computer program to determine chemical equilibrium is a basic tool in designing pollution-abatement plants and equipment. Hydrogen section of a California petrochemical plant built by Ralph Parsons Co., above, used the program to achieve stringent environmental standards.

Wheelchair padding is among host of applications for "Temper Foam," a new open-cell polyurethane-silicone plastic foam enabling patients to spend up to three times longer in their chairs. A NASA biomedical application team stimulated the medical use of the material.

Part of a NASA user-requirements committee, which includes fire chiefs and fire department communications experts, reviews short-range firefighters' radio specifications.

The application teams act as couplers between these projects and the user. An approach used by Public Technology Inc. is the establishment of user-requirements committees. For example, the firefighters' short-range communications system committee is made up of fire chiefs, a city manager, and fire service experts in short range communications. The committee performs tasks such as identifying the principal problems of currently used systems and helps NASA define its performance requirements and cost goals as well as critiquing the development effort at periodic intervals. Field tests of the resulting equipment are held in cities represented by committee members.

Intergovernmental cooperation

The Technology Utilization Office cooperates with many federal agencies. These cooperative efforts often flow to state, local, and county jurisdictions as previously described in the case of the short-range communications device for firemen. Since federal agencies have specific mission objectives, NASA relies on them for understanding of problem needs, evaluation of proposed solutions, as well as joint funding of applications projects. Examples include cooperation with the National Cancer Institute in the storage of blood cells and the U.S. Department of Housing & Urban Development on the "Tech House" project, described in section one.

In addition, the Technology Utilization Office works actively with state and local governments. Last year, several NASA technologists worked full time with city officials of Baltimore and state agencies in Illinois and Louisiana. Other efforts are underway in Washington, D.C., Philadelphia, and the Delmarva peninsula. These technologists work much like application teams in defining problems and then searching for appropriate NASA technology. A land-use planning project for Tacoma, Wash., for instance, resulted from this activity.

Small companies benefit

Almost half the companies utilizing the services of the industrial applications centers are small businesses. And many small manufacturing firms regularly use *Tech Briefs* and *Compilations* to keep abreast of the technical innovations and inventions stemming from aerospace research.

The Technology Utilization Office and the Small Business Administration work together to assure that the small-business community derives positive assistance from available new technologies. Previous successful joint programs have led to a new NASA-Small

defining significant biomedical and health care problems that might be solved by adapting space technology. Two *technology* application teams work in much the same way with public sector agencies, concentrating primarily in the fields of public safety, urban construction and safety, and transportation.

The Research Triangle Institute, Martin Marietta-Denver Corp., Stanford Univerity Medical School, and the University of Wisconsin manage the biomedical teams. The technology teams are located at the Stanford Research Institute, and Public Technology Inc.

Last year the scope of the teams was broadened to include the whole spectrum of activity from the definition of the problem to acting as catalysts for widespread public use of resulting products. One approach is commercialization which is achieved when products can be purchased and delivered within a reasonable time. When commercialization is not an objective, a technology transfer is complete when the institution or governmental agency has taken over full implementation of the process or product.

Back to the laboratory

Aerospace technology usually must be adapted to be applied usefully to public-sector problems, which the users identify in cooperation with the application teams. The Technology Utilization Office method is "applications engineering," or the effort to redesign or reengineer aerospace technology for a specific application. This activity often results in the development, evaluation, and field testing of prototype hardware.

Aerospace products and processes, with modifications, can be useful for other purposes. It is usually the technologist at a NASA field center who recognizes the opportunity for such adaptations to meet public sector needs. His proposed projects are carefully reviewed by the Technology Utilization Office for compliance with certain criteria such as technical feasibility and final product cost before funding is provided.

Applications engineering often results in the development, evaluation, and field testing of prototype hardware.

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Business Administration agreement signed last fall. Work under this agreement will benefit small firms in several ways. For example, the SBA, after careful screening of available *Tech Briefs* and *Compilations* will prepare special joint NASA-SBA publications for tailored distribution to thousands of different small firms.

In addition, several small businesses is in southern California are to be selected by SBA to receive special services from the Industrial Applications Center at the University of Southern California. Results of this experiment in technology transfer will be useful in designing future cooperative projects.

In order to encourage minority enterprise participation in the technology utilization program, NASA and the Office of Minority Buisiness Enterprise, U.S. Department of Commerce, executed an interagency agreement to encourage minority enterprise development through the application of space technology. The Technology Utilization Office has been working under this agreement with the minority business agency and the NASA Office of Equal Opportunity Programs in planning and carrying out regional minority-business seminars.

Six technology transfer seminars for the benefit of minority businessmen were held last year in Houston, Los Angeles, Boston, San Francisco, Chicago, and Atlanta. The seminars provided relevant technology-transfer information to manufacturers and service companies.

Firms that attended the seminars were provided with professional assistance and computer searches to retrieve technical and management data from one of several NASA industrial applications centers. An on-site computer terminal was set up at some of the seminars to demonstrate how technical information can be obtained through NASA's remote computer terminal system.

Increasingly, small companies as well as large corporations and local governments are seeking technological solutions to their business and social problems. When aerospace technology can be spun off to help solve these problems, the main purpose of NASA's Technology Utilization Office is realized.

A graphics terminal displays city-street networks, allowing planners to coordinate aerial photographs, maps, and census records for allocating optimum land-use resources. The project is an example of an applications engineering project sponsored by the Technology Utilization Office in cooperation with city officials in Tacoma, Wash.

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