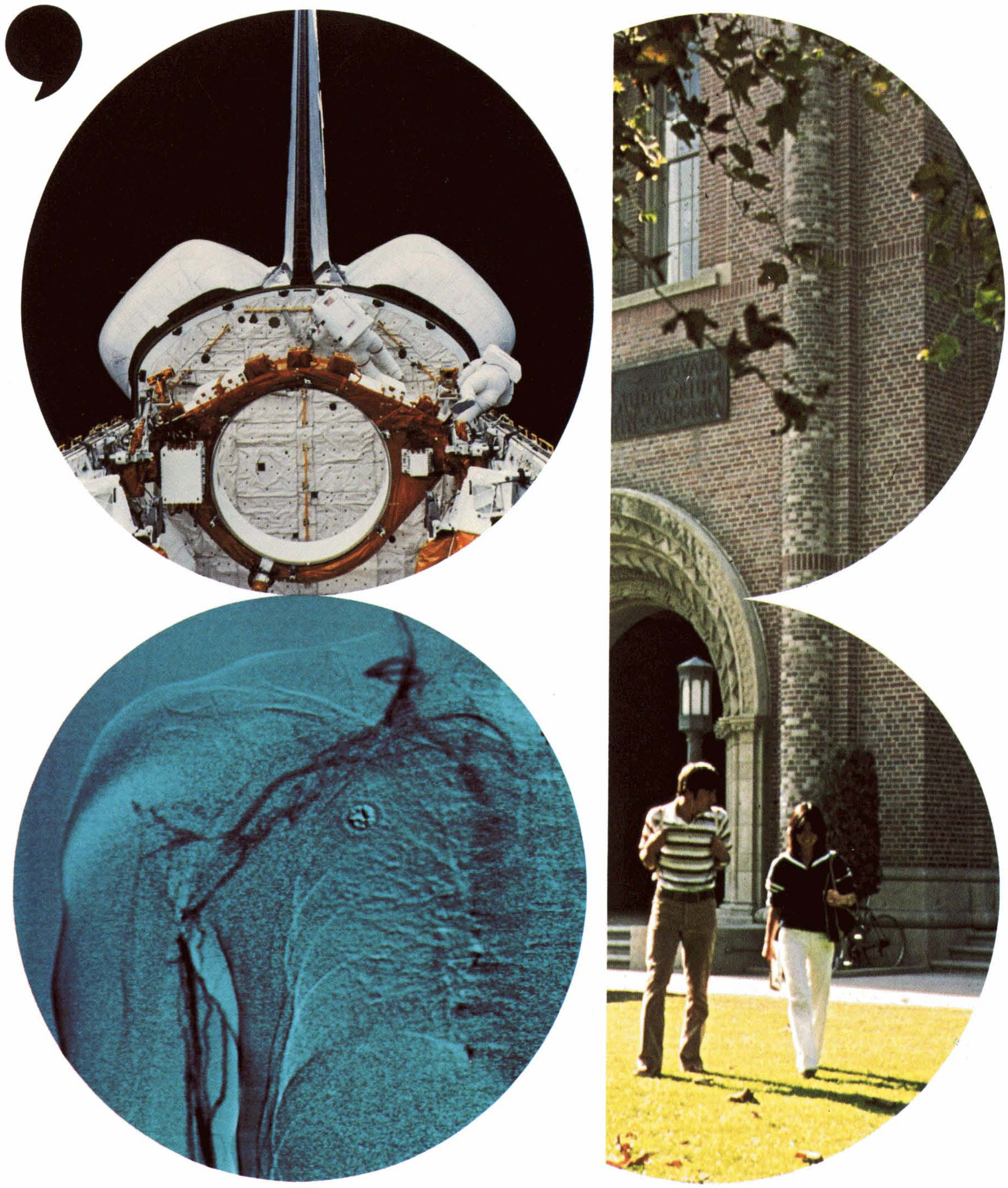
NASA
National Aeronautics and
Space Administration

SPINOFF
1983



FOREWORD

This year marks a major milestone for the National Aeronautics and Space Administration: its silver anniversary. It seems appropriate, on this occasion, to sum up how NASA has responded to the legislative charter that established the agency.

Among the responsibilities the Congress assigned NASA in the National Aeronautics and Space Act of 1958 were these:

- preservation of U.S. leadership in aerospace science and technology;
- cooperation with other nations in the peaceful application of technology;
- expansion of human knowledge of phenomena in the atmosphere and in space;
- pursuit of the practical benefits to be gained from aeronautical and space activities.

There can be no doubt that NASA's quarter century of effort has preserved the nation's leadership role and strengthened its posture in aerospace science and technology.

As for international cooperation, NASA has—since its inception—fostered the concept that the fruits of civil space research are to be shared with all mankind. The agency has provided technical assistance to scores of nations and has actively promoted cooperative ventures; indeed, virtually every major NASA space project today boasts some degree of foreign participation.

In the last 25 years, man has learned more about his planet, the near-Earth environment and the universe than in all the prior years of history. NASA's space science program has spearheaded this great expansion of human knowledge.

And, from the beginning, NASA has vigorously pursued the practical benefits that aerospace research offers. The agency pioneered in weather, communications and Earth resources survey satellites, the prime examples of space technology applied for Earth benefit, and it has built a broad base for expanding into new applications, some of which promise direct benefits of exceptional order. In aeronautical research, NASA has contributed in substantial degree to safer, better performing, more efficient, more environmentally acceptable aircraft. In support of the national energy program, NASA has successfully applied its technical expertise to development of alternative sources of energy and new ways to conserve it. Finally, the technology generated in all these mainline areas of research has been reapplied, literally thousands of times, to produce a broad range of indirect benefits, or spinoffs.

Thus, the response to the Congressional mandate of 1958 has been impressive. The people of NASA can be justly proud of the dramatic accomplishments made possible by their dedicated labors. But they were not alone; their partners in progress include many thousands of others in industry, in the academic community and in other government agencies. I extend an anniversary salute to all who played a part in making NASA's first quarter century an era of unparalleled technological advance that contributed in great measure to our nation's social and economic future.

James M. Beggs
Administrator

National Aeronautics and
Space Administration

SPINOFF 1983

National Aeronautics and
Space Administration

Office of External Relations

Technology Utilization and
Industry Affairs Division

by James J. Haggerty

May 1983

The Cover:

A graphic representation of the year 1983, the twenty-fifth anniversary of NASA.

For sale by the Superintendent of Documents
U. S. Government Printing Office
Washington, D.C. 20402

INTRODUCTION

For a quarter of a century, NASA has been developing advanced technology to meet its aeronautical and space research goals. Technology is simply knowledge, technical "know-how" and, like other forms of knowledge, is transferable; once developed, it can be reapplied to uses different—and often remote—from the original application. Thus, the great storehouse of technology that NASA has acquired constitutes a valuable national resource, a bank of know-how available for secondary application, or "spinoff."

Literally thousands of spinoff products and processes have emerged from reapplication of technology developed for NASA mainline programs. Each has contributed some measure of benefit to the national economy, productivity or lifestyle. Some spinoffs bring only moderate increments of economic gain or lifestyle improvement, but many of them amount to significant public gain with economic values running to millions of dollars. In the aggregate, they represent a substantial dividend on the national investment in aerospace research.

By Congressional mandate, it is NASA's responsibility to promote expansion of spinoff in the public interest. Through the Technology Utilization Program, NASA seeks to encourage greater use of its technological resource by providing a link between the technology and those who might be able to put it to advantageous use. The program's aim is to broaden and accelerate the transfer process, thereby to gain national benefit in terms of new products and new jobs.

This publication is an instrument of that purpose. It is intended to heighten awareness of the technology available for utilization and its potential for benefit.

The volume is organized in four sections, including a prefacing 25th anniversary pictorial resume that underlines the challenging nature of NASA programs and their extraordinary demands for technological input.

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

Section 2, the focal point of the volume, contains a representative sampling of spinoff products and processes resulting from technology utilization, or secondary application.

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

Ronald J. Philips

Director, Technology Utilization and Industry Affairs Division

Office of External Affairs

National Aeronautics and Space Administration

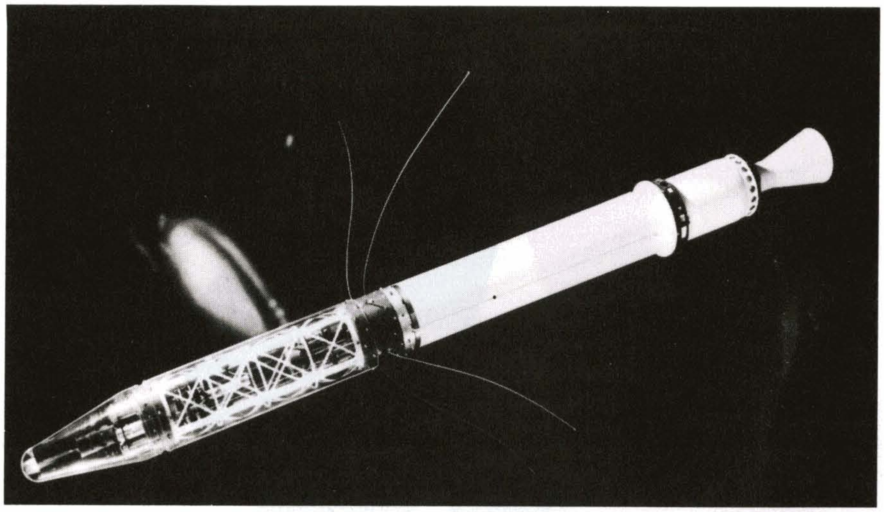
CONTENTS

NASA's 25 YEARS

A pictorial retrospective recalling a quarter century of exciting developments that contributed significantly to American scientific, technological and social progress

REFLECTIONS ON A SILVER ANNIVERSARY

NASA's 25 years of aerospace research have produced a wealth of scientific gain and a bountiful harvest of benefits to Earth's people



A 31-pound tapered cylinder, Explorer 1, the first U.S. satellite, discovered one of two radiation belts encircling Earth. Launched January 31, 1958 by the Army Ballistic Missile Agency, it was subsequently turned over to NASA.

The Tilt Rotor Research Aircraft is representative of a wide range of aeronautical research projects conducted by NASA, independently or jointly with other organizations, in 25 years of aerospace progress.

An anniversary is a time for retrospection, for reviewing the past as prelude to the future. As NASA marks its 25th year, it is fitting to recall the dramatic areospace happenings of the last quarter century and reflect upon their contributions to our mode of life.

It began on October 1, 1958; that was the first official day of NASA's existence. Ten days later, NASA launched its first spacecraft; the agency already had an ongoing aeronautical research program, inherited from a predecessor organization.

The initial years were difficult, marred by many failures and "partial successes" as the fledgling agency sought to find firm footing on the new and uncertain ground of space exploration. But in time the growing pain subsided and NASA became an organization known for its exceptional competence and imaginative management, the spearhead of a U.S. technological thrust of monumental scale. Teaming with the aerospace industry and university research groups, NASA developed a broad base for manned space activities,

Shown on its initial launch in April 1983, the Space Shuttle Orbiter **Challenger** *symbolizes NASA's broadened capability for exploiting the promise of space.*

pioneered the use of space to expand human knowledge and concentrated much of its effort on generating direct public benefit. Simultaneously, the agency conducted a highly productive aeronautical research and technology effort.

The operational weather and communications satellites now routinely serving the world's peoples trace their lineage to NASA's trailblazing work—in the early 1960s—on space "applications," systems designed to provide direct benefit. More recent applications include a remote sensing system for better management of Earth's far from limitless resources and a life-saving system for improved international search and rescue operations. Projects now under way offer promise of future benefit in such areas as better protection of Earth's environment through improved understanding of near-Earth space, and manufacture in orbit of superior products that cannot be produced on Earth.

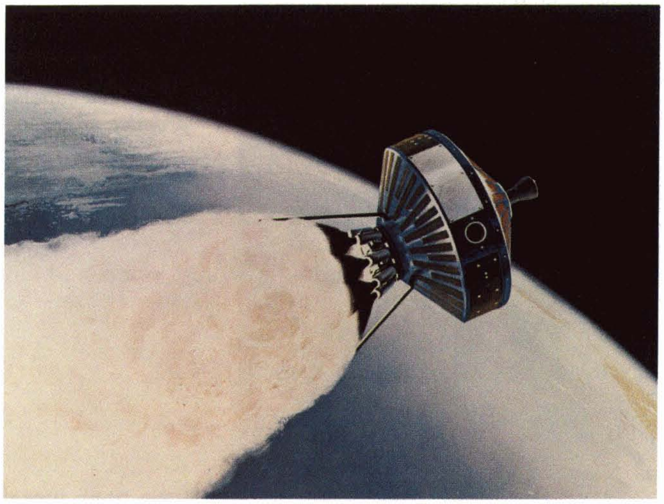
In space science, NASA successfully operated scores of spacecraft that investigated the near-Earth environs, explored the moon, probed the far reaches of the solar system and looked beyond, to incalculably distant galaxies. The vast fund of scientific knowledge thus acquired is among the most important benefits of space research, although perhaps the least understood. It is a benefit in itself: knowledge, an immensely valuable commodity to any society. It is also a practical benefit, a resource for tomorrow's employment, because science is the wellspring of technology; much of the knowledge generated will eventually find practical application in advancing technology.

In its aeronautical program, NASA probed the frontiers of atmospheric flight and produced a lengthy succession of technological advances that contributed to U.S. world leadership in aviation. This part of the NASA effort benefits Americans in many ways. It helps U.S. manufacturers build more efficient commercial aircraft, with attendant benefit to the U.S. economy; it contributes to strengthened national defense; it helps reduce the costs of flight to airlines, their passengers and shippers; it makes flight safer for all airplane users; and it eases the environmental impact of the airplane.

Technology from all these programs—space science, applications and aeronautical research—has spun off in secondary uses over a broad spectrum of public benefits. There have been literally thousands of such spinoffs, some of them only incremental improvements in products or processes, many of them important advances of substantial economic value. Collectively, they add up to significant bonuses in public convenience, human welfare, industrial efficiency and economic gain.

There is another, broader type of spinoff. The extraordinary demands of aerospace programs reach into virtually every scientific and technological discipline, spurring innovation in those fields to meet the aerospace need. Sometimes these aerospace-inspired innovations trigger momentous advances in other areas of technology, to the benefit of industry and the national economy. For example, development of sophisticated space systems demanded ever smaller but ever more capable microcircuitry, taxing to the hilt the ingenuity of electronic components designers. But they met the challenge of space miniaturization and, in so doing, were projected into explosive technological advance and multidirectional market expansion. Thus, the impetus of aerospace requirements generated a parallel thrust in non-aerospace microelectronics that resulted in a broad range of new applications from home computers to video games to computerized medical systems.

Perhaps the greatest gain of all is the significantly expanded technology base built by the government/industry/university team during NASA's first quarter century of aerospace effort, a new and broader plateau of technical capability that offers promise of even more dramatic achievements, even more rewarding applications in the years to come.

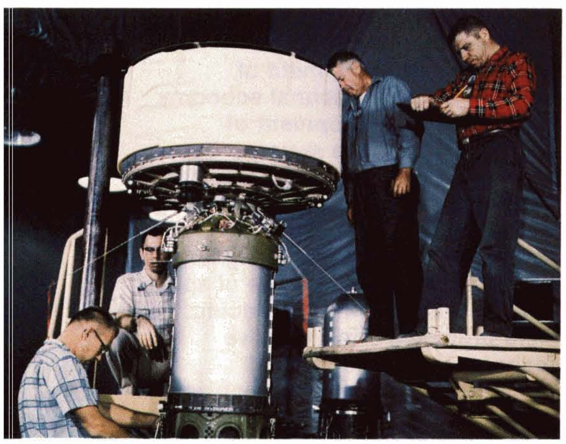


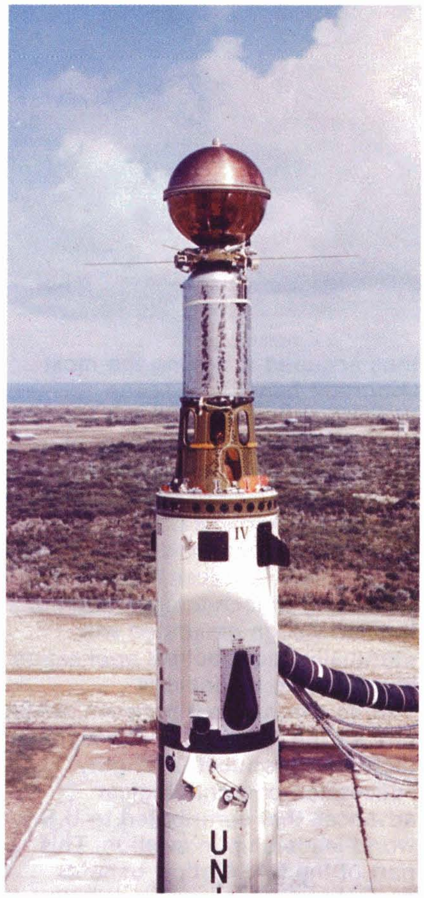
1958

The newly formed NASA launched its first spacecraft, Pioneer 1, which failed to reach the moon but climbed to a record altitude of more than 70,000 miles. Pioneer 1 was the forerunner of a highly successful family of solar orbiting probes that explored interplanetary space.

1960

Tiros 1, the first experimental meteorological satellite, introduced photography of Earth's cloud cover from orbit, providing a new informational input that greatly increased the accuracy of weather forecasting. A series of Tiros satellites helped refine photographic quality, transmission techniques and ground processing procedures, paving the way for today's operational meteorological and environmental satellites.



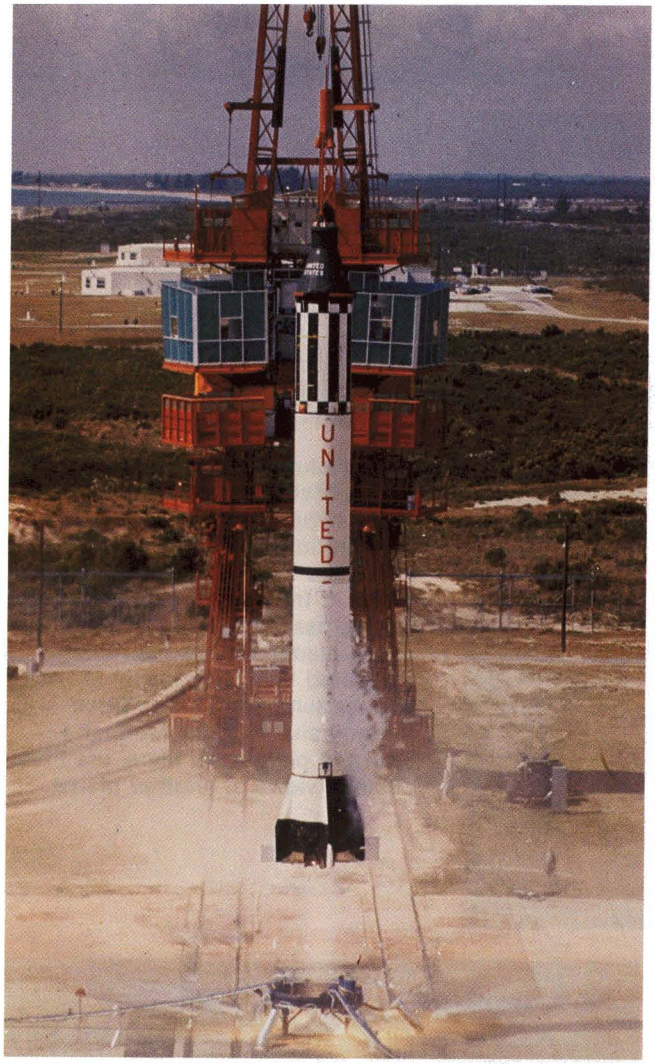


1960

Packed inside a spherical canister and unfolded in space to 100-foot diameter, Echo 1 was the first of two balloon satellites, experiments in reflecting radio signals to relay communications between two points on Earth. Visible to the naked eye, Echo 1 stimulated interest in space on the part of millions around the world who viewed it.

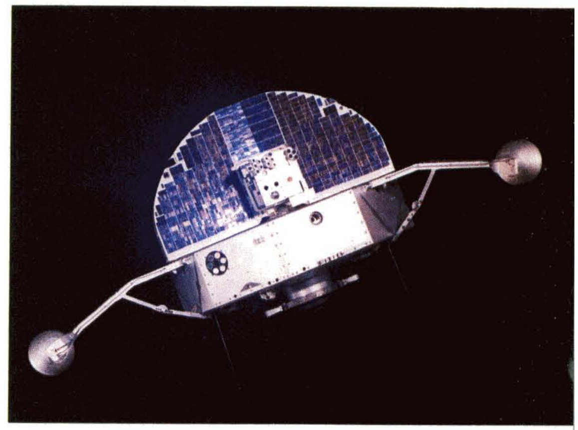
1960

NASA began flight tests of the X-15 rocket-powered research airplane that continued throughout the 1960s. The X-15 provided scientific data from altitudes of more than 40 miles, where man had never been before, and topped 4,500 miles per hour, the fastest a winged vehicle had ever flown. With the X-15 in this photo is one of its pilots, who later became the first man to set foot on the moon—Neil A. Armstrong.



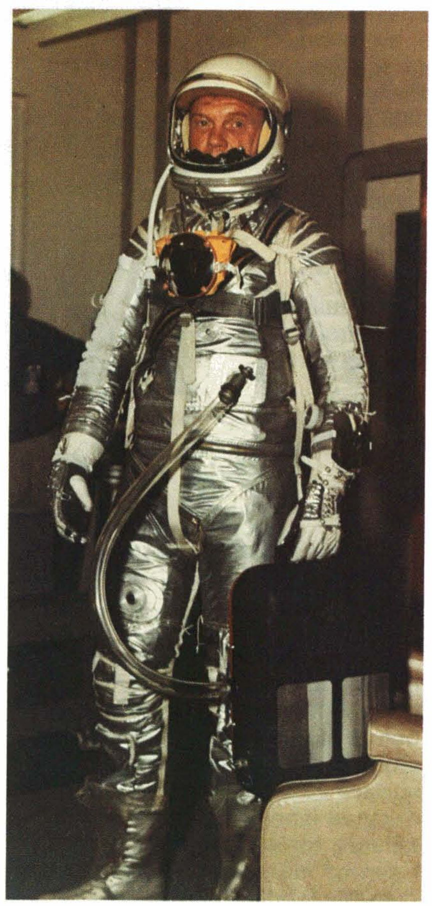
1961

Perched atop the Mercury Redstone 3 launch vehicle is the *Freedom 7* manned capsule that inaugurated U.S. manned space flight only 23 days after the Soviets orbited the first cosmonaut. Alan B. Shepard's suborbital flight of 15½ minutes duration was hailed as a momentous achievement and a sign that the Soviet space lead was narrowing.



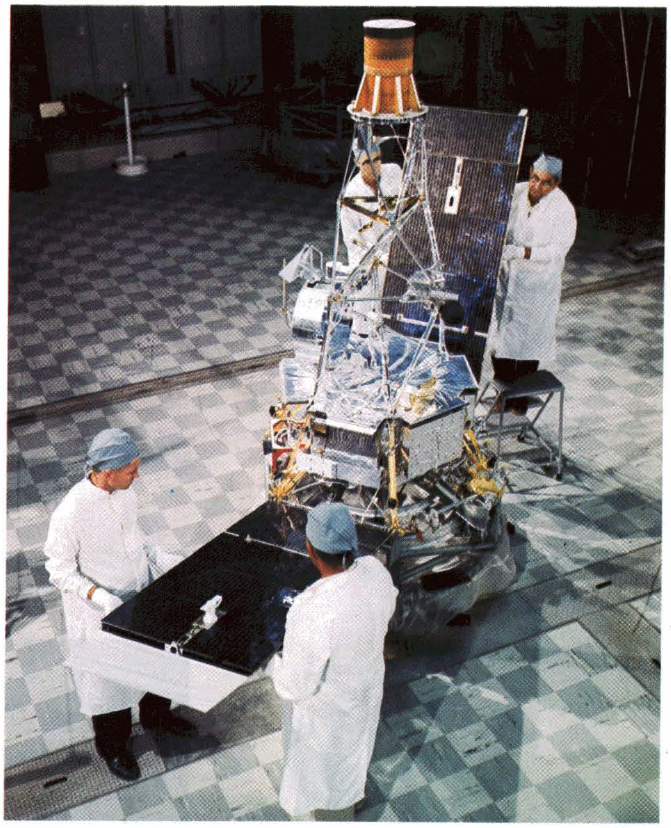
1962

Astronaut John Glenn is shown preparing to board his Mercury spacecraft *Friendship 7* for the first U.S. manned orbital flight, three orbits, five hours. Project Mercury involved six highly successful one-man flights over a two-year span; it provided a strong technological and managerial base for the greater manned space efforts to come.



1962

With OSO-1, NASA initiated a series of six Orbiting Solar Observatories for continuous monitoring of the physical processes taking place on the Sun and the various types of solar radiation emitted. OSO-1 was the first of the "observatory class" satellites operated during the 1960s and well into the 1970s; large, multi-instrument spacecraft for comprehensive solar, geophysical and astronomical studies, they represented a major advance in NASA's capability for gathering scientific data.

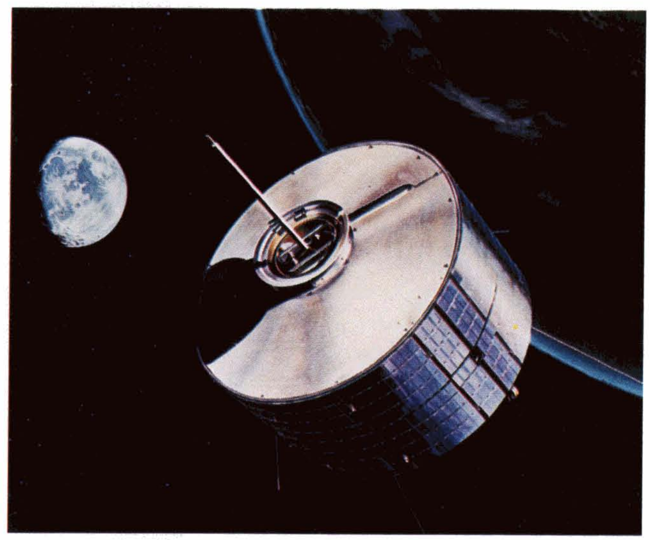


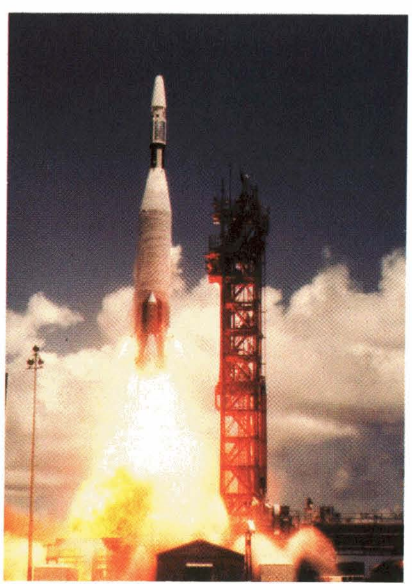
1962

Pictured in final fabrication status, Mariner 2 scored a major U.S. triumph in the space competition with the Soviet Union: it was the first successful planetary probe. It traveled 48 million miles to Venus, passed within 22,000 miles of the planet, and its instruments measured Venus' atmosphere, surface temperature and other phenomena. In 1965, Mariner 4 returned pictures of Mars, the first closeup views of another planet.

1963

Early communications satellites operated in low Earth orbit, hence could transmit signals only when "in view" of a ground station. For full 24-hour service, satellites had to operate in synchronous orbit 22,300 miles high. That required a big advance in space technology. NASA accomplished it with Syncom 2 (pictured) and Syncom 3, establishing the basic principles for design and operation of synchronous satellites and building a foundation for the commercial communications satellite networks that followed.



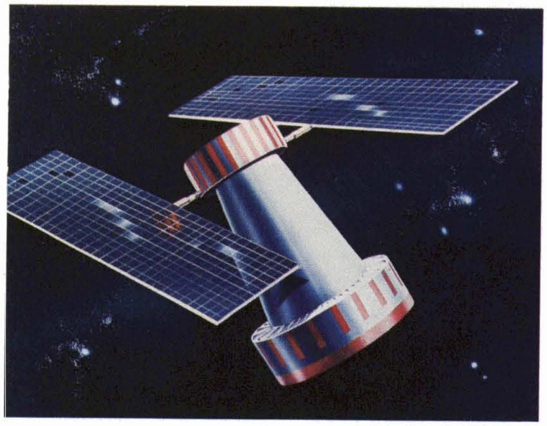


1964

The launch of Ranger 7 marked a turning point in NASA's trouble-plagued Ranger program, objective of which was to acquire closeup photos of the moon's surface as a preliminary step toward manned landings. After six prior failures, three Ranger spacecraft returned more than 17,000 views of possible landing sites.

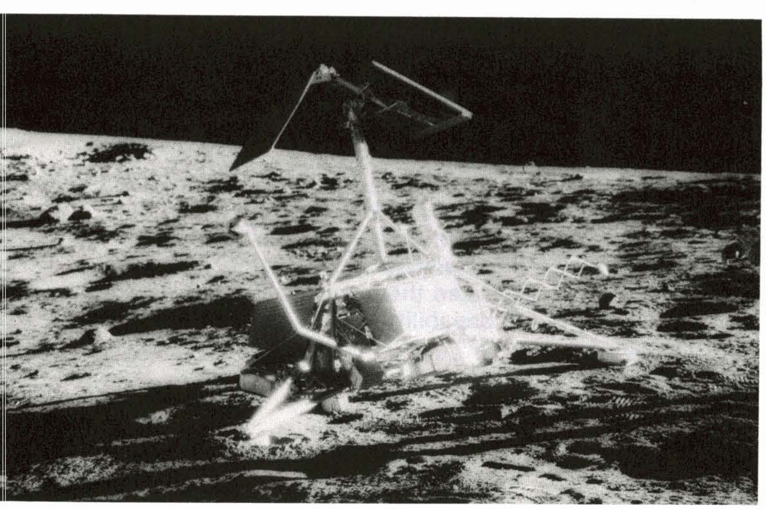
1964

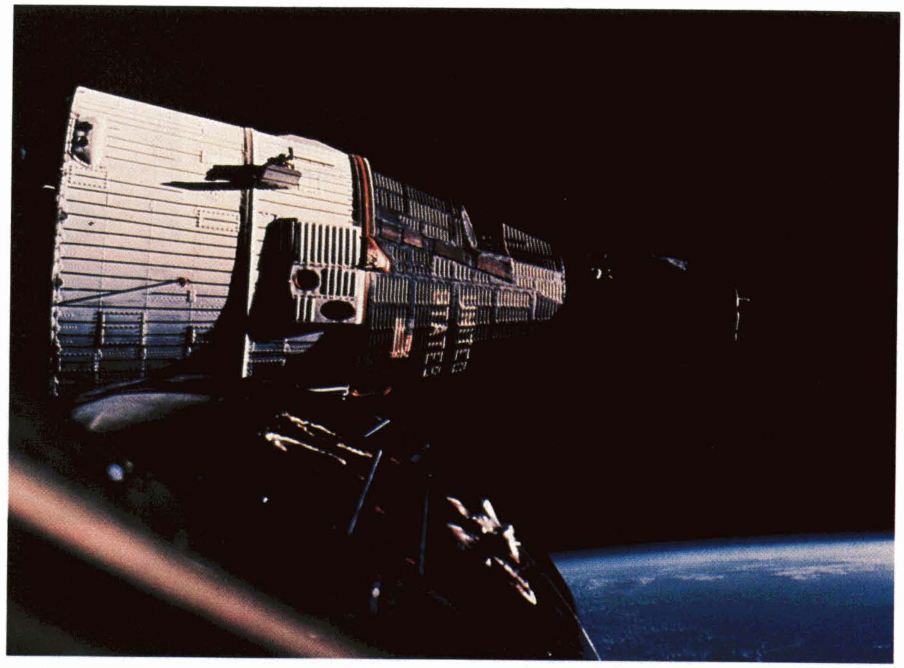
In its continuing effort to develop advanced technology for weather satellites, NASA launched the first of several Nimbus spacecraft. Nimbus had an improved camera system, a radiometer for taking cloud cover photos at night and instruments for atmospheric measurements, all improvements over the earlier Tiros satellites.



1966

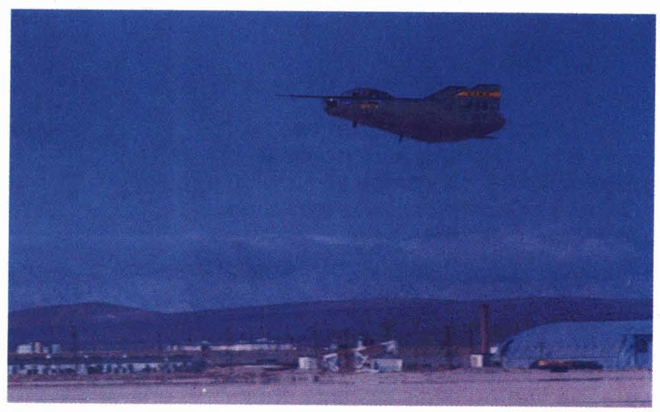
The photo below shows Surveyor on the moon, the first U.S. landing on another celestial body; it was taken by Apollo astronauts who visited the site four years later. Surveyor photographed the moon from surface level and conducted experiments to demonstrate that the surface would support a manned spacecraft. Surveyor's companion was the Lunar Orbiter, which photographed the moon from orbit. In 11 successful flights (six Orbiters, five Surveyors) the two spacecraft returned thousands of photos for use in selecting Apollo landing sites.





1965

Another first—a picture of Gemini 7 taken from Gemini 6, the first photograph of an orbiting spacecraft, made during the first rendezvous between two spacecraft. Along with the first U.S. spacewalk, the rendezvous was a highlight of the 1965–66 Gemini program, in which two-man crews flew 10 successful missions.

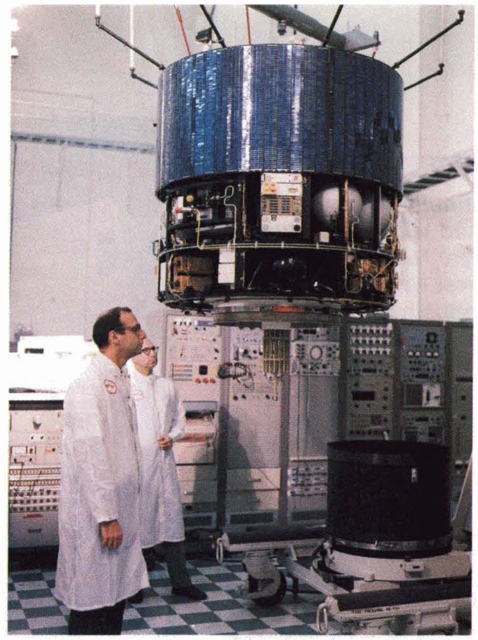


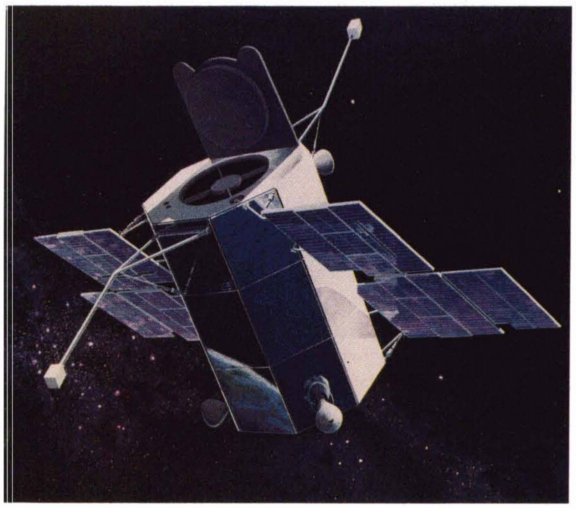
1966

NASA began a six-year program of research on "lifting body" vehicles such as the M2F2 shown, the first to fly among several craft in the program. Lifting body vehicles have no wings but derive lift from body contours and aerodynamic control surfaces. The program provided data toward design of hypersonic aircraft and Earth re-entering spacecraft like the Space Shuttle Orbiter.

1966

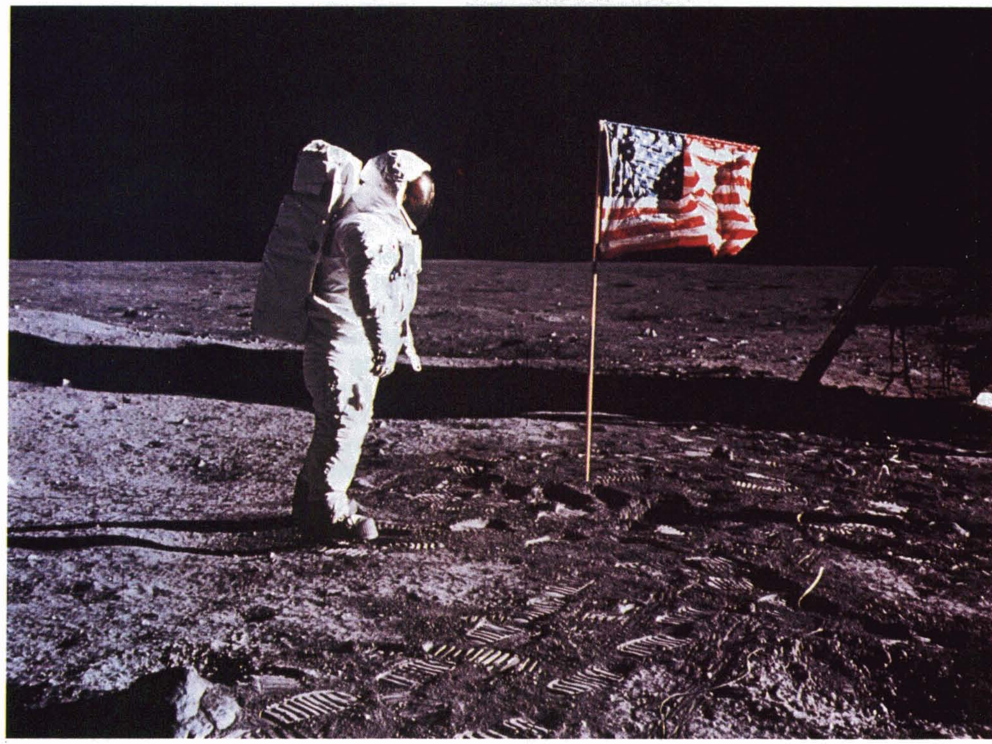
Shown undergoing pre-launch checkout, ATS-1 was the first of six Applications Technology Satellites launched during 1966–74 to provide orbital information toward developing technology for "applications" spacecraft, those designed to provide direct Earth benefit. The first five ATS made a comprehensive study of the synchronous orbit environment and tested a variety of experimental devices. ATS-6 conducted many demonstrations of direct broadcasting, pioneering a communications technique that is growing rapidly today.





1968

OAO-2 was the first of two successful Orbiting Astronomical Observatories; its companion, OAO-3 or *Copernicus*, was launched four years later. These big observatory class satellites, weighing well over two tons, brought a new dimension to space astronomy; with their arrays of sensitive instruments and extremely precise star-pointing systems, they provided volumes of new data about the stars and galaxies.



1969

This historic photo depicts one of the proudest moments in the history of the United States: the planting of the American flag on the moon, witnessed live or in delayed telecast by two-thirds of the world's people. The astronaut pictured is Edwin E. Aldrin; photo by Neil A. Armstrong. The flag speaks eloquently of the Apollo program's contribution to American prestige, as do the footprints in the lunar dust—*all* the footprints ever made on the moon were American-made.

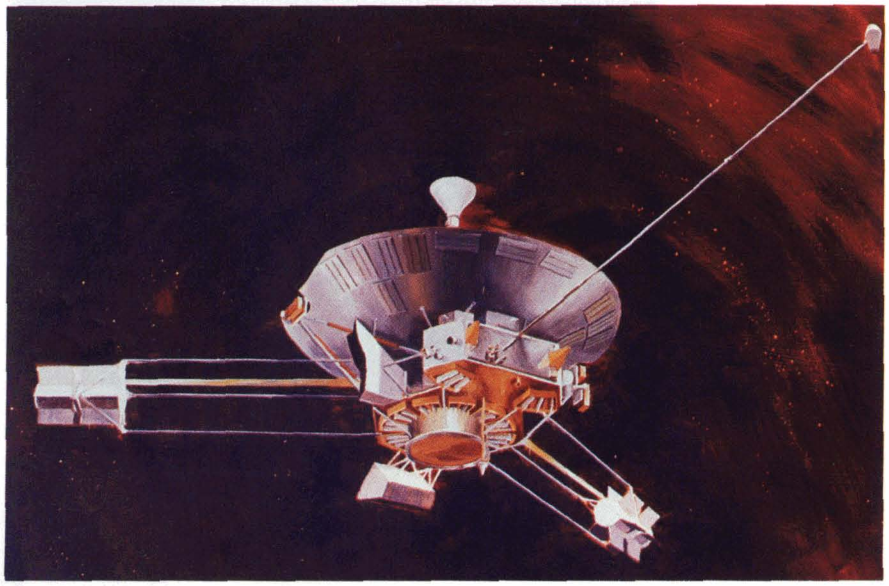
In 1968–72, there were 11 manned Apollo flights involving 29 astronauts, 12 of whom walked on the moon; there were two manned Earth orbital preliminaries, three circumlunar flights and six lunar landing missions. Apollo was man's greatest feat of exploration, a monumental triumph of American scientific and technological prowess. It firmly reestablished the United States as world technological leader and restored an earlier-tarnished national reputation; it generated major advances across a wide spectrum of scientific disciplines; and it demanded technological giant steps whose accomplishment elevated the nation to a new plateau of capability.

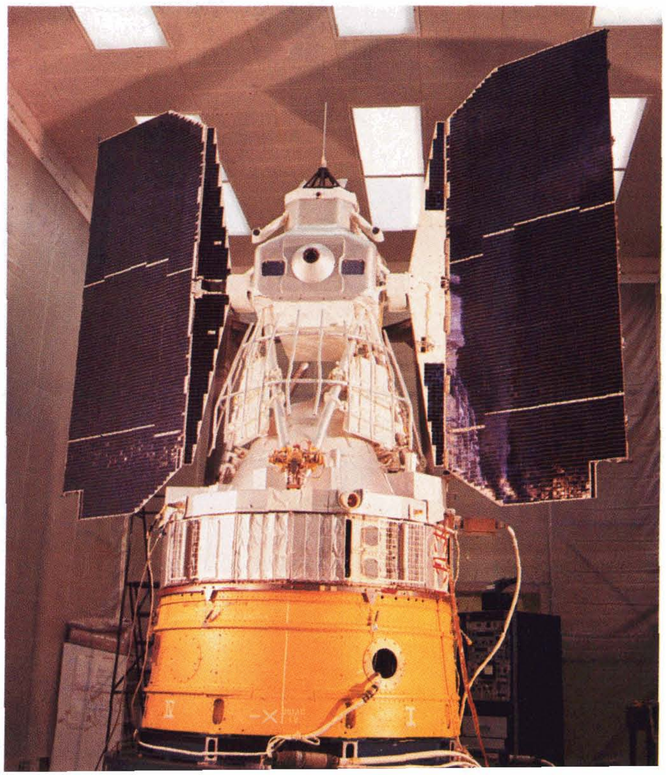
1971

Dr. Richard T. Whitcomb of Langley Research Center examines a wind tunnel model fitted with a "supercritical" wing, an advanced airfoil that has a different shape: it is flattened on the upper surface and the trailing edge curves downward. These design features delay the buildup of air drag at high speeds, allowing an airplane to fly faster or farther for the same amount of fuel. Whitcomb and his Langley associates developed a whole family of supercritical wings for various types of aircraft. Now finding wide acceptance, the technology is considered one of the most important recent advances in aerodynamics.

1972

Pioneer 10 departed Earth, with Pioneer 11 a year behind, on man's first attempts to send automated vehicles beyond the solar system. The two interplanetary explorers sent back data and photos of Jupiter and Saturn, then continued onward toward infinity. Eleven years out of home port Earth, and still returning data, Pioneer 10 is now at the edge of the solar system; Pioneer 11 is not far behind. They will leave the solar system to roam for millions of years, perhaps forever, in intergalactic space.



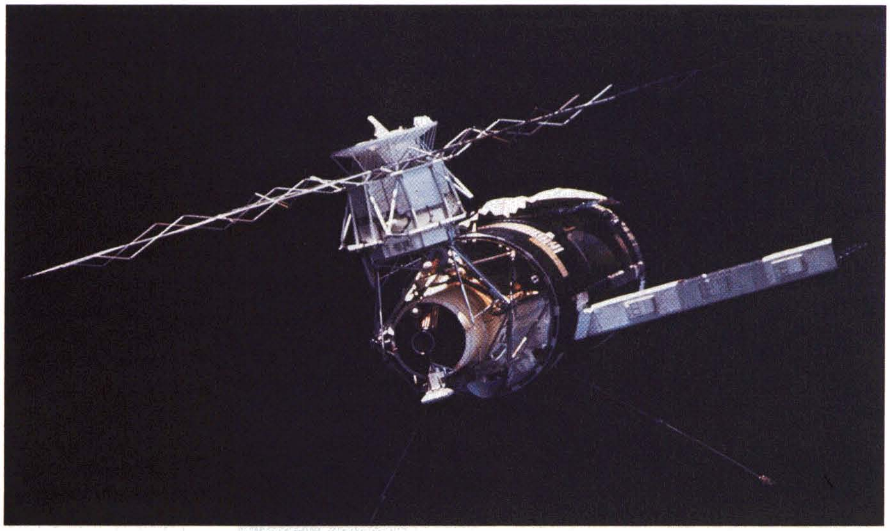


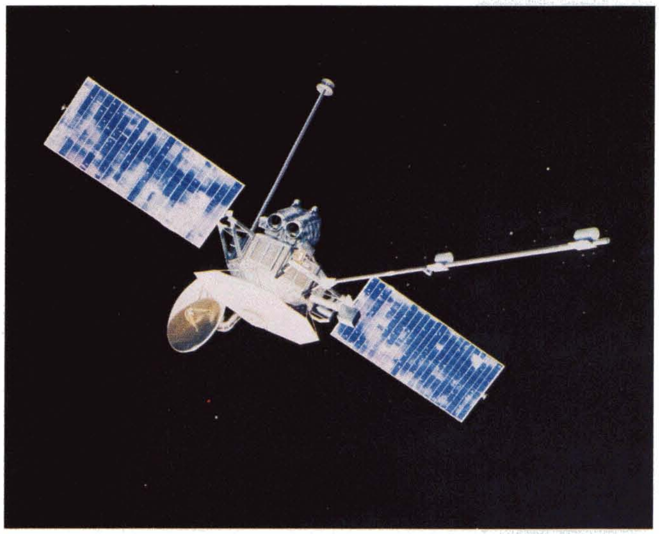
1972

Landsat 1 was the first of four Earth resources survey satellites, each more advanced than its predecessor, launched in 1972–82. Equipped with cameras and sensors, they offer a means of monitoring changing conditions on Earth's surface for practical benefit in such applications as agricultural crop forecasting, mineral and petroleum exploration, forest management, mapping, land use management, water quality evaluation and disaster assessment. NASA's development and interim operation of the Landsats built a foundation for a possible commercial system with enormous potential benefit in improved management of Earth's resources.

1973

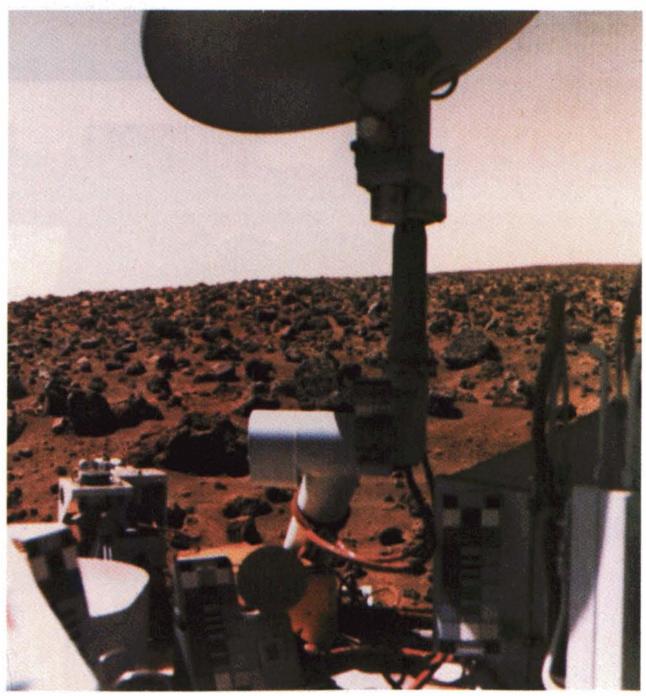
Skylab was an interim space station, a large manned orbiting laboratory that included the most powerful telescope ever orbited, a furnace for experiments in space materials processing, and a broad array of scientific instruments. Three three-man crews manned the station in 1973–74 for stays of 28, 59 and 84 days. Skylab provided important medical data on the effects of long duration weightlessness; a great amount of invaluable astronomical and Earth resources data; and a technology base for planning a permanent space station.





1973

Another first—Mariner 10 provided the first closeup views of Mercury, smallest of the solar system's nine planets and the most difficult to observe from ground-based telescopes because it is close to the Sun. En route to Mercury, the spacecraft flew by Venus, adding new volumes of information on that planet. It marked the first time a space probe visited two planets on a single mission.

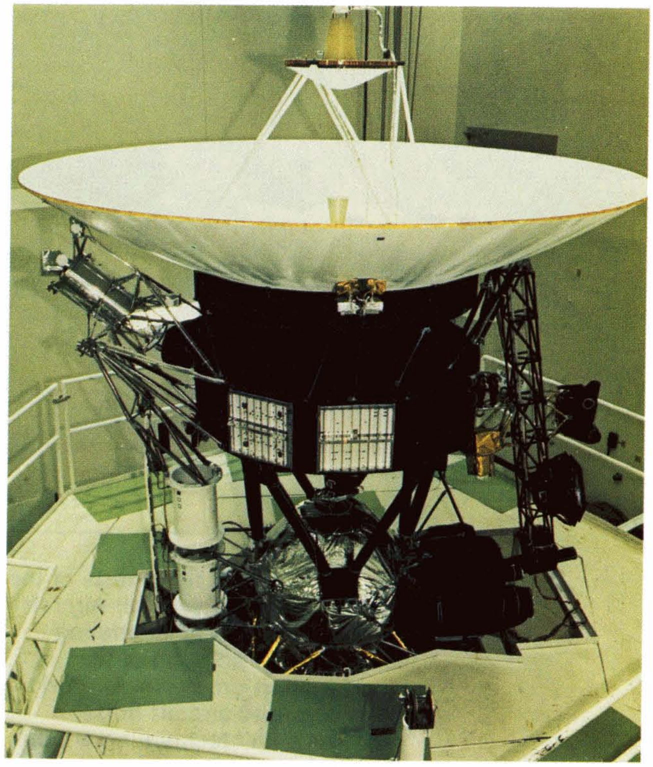


1976

A technological triumph of Apollo-like dimension, the Viking program involved landing two spacecraft on Mars, 40 million miles distant, and putting two others in orbit around the Red Planet. The Orbiters mapped the Martian surface and relayed communications from the Landers, which took photos of the surface, sampled the soil and the atmosphere, and conducted a search for extraterrestrial life signs.

1977

Shown undergoing prelaunch vibration testing is one of two Voyager spacecraft that returned tens of thousands of photos and countless volumes of scientific data on Jupiter and Saturn during their grand tour of the solar system. Voyager 2 is en route to encounters—in the latter 1980s—with Uranus and Neptune, neither ever visited by spacecraft. The exciting odyssey of the Voyagers underscores the extraordinary reach NASA has attained in its first quarter century.



1978

Representative of many technology advances accomplished in NASA's Aircraft Energy Efficiency (ACEE) program, the winglet pictured is an aerodynamic innovation designed to improve fuel consumption and generally improve airplane performance. ACEE is generating new technology in aerodynamics, propulsion, structures and control systems; some advances have already been incorporated in new civil and military aircraft.

1978

The illustration shows the two separate elements of the Pioneer Venus spacecraft team, at left the "multiprobe" that reported data while descending through Venus' atmosphere and, at right, the Venus Orbiter that mapped nearly all of the planet's never-seen surface. The Pioneer Venus program provided important data about Earth's closest planetary neighbor, information that offers clues to greater understanding of Earth's own environment and how to protect it.

1978

NASA began flight tests of the Quiet Short-haul Research Aircraft (QSRA), which is demonstrating technology for solution of two major aviation problems—airport congestion and aircraft noise. A "propulsive lift" technique permits the QSRA to climb and descend at steep angles and operate from very short runways; design factors and soundproofing make the QSRA extremely quiet. The experimental craft is a pathfinder for future short-haul transports operating from close-to-city airports, which would alleviate congestion at major terminals.

1981

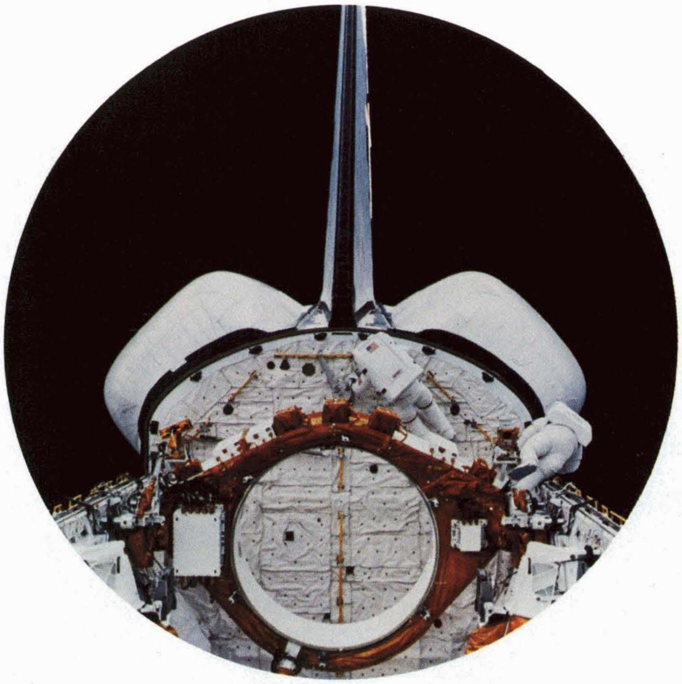
A major milestone—the Space Shuttle *Columbia* lifts off the pad at Kennedy Space Center on its maiden voyage, ushering in a new era of U.S. capability, an era of operational regularity and expanded opportunities for the practical benefits space promises.

1983

Launch of the Infrared Astronomical Satellite (IRAS), shown being prepared for flight, inaugurated NASA's silver anniversary year. IRAS is making an immense contribution to astronomical science by detecting "cold" objects that do not shine in visible light but emit radiation in the infrared wavelengths. Its sensitive instruments have discovered stars being born, stars dying, and galaxies so small and so distant they have been viewed only dimly before, some not at all.

1

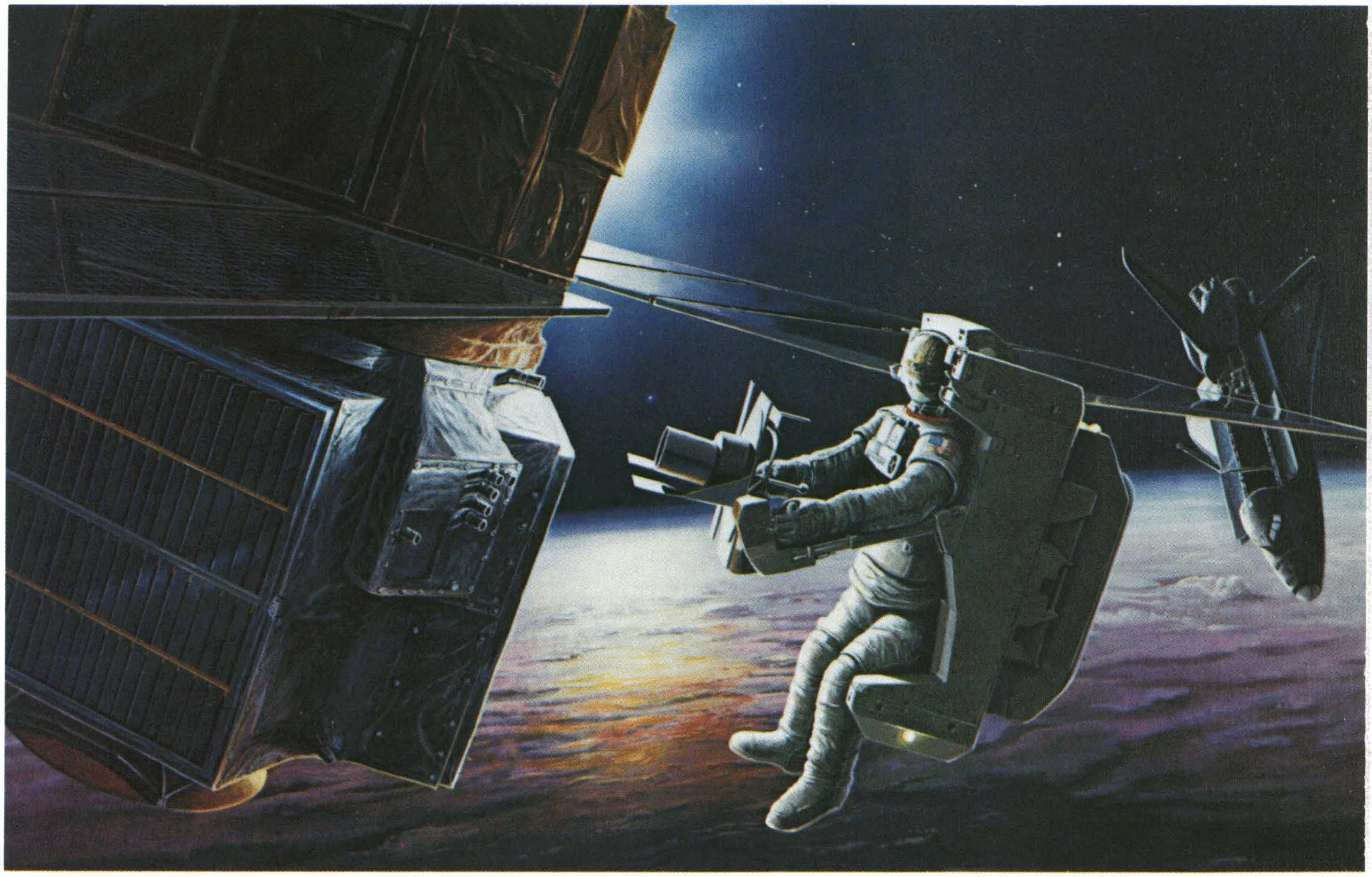
AEROSPACE AIMS



An illustrated summary of NASA's major aeronautical and space programs, their goals and directions, their promise for the future, and the many ways in which they are producing benefits for Earth's people

THE SPACE SHUTTLE: VERSATILE WORKHORSE

The Shuttle's ability to perform many different jobs offers unprecedented flexibility in space operations



The artist's concept shows an astronaut preparing to dock with the troubled Solar Maximum Mission spacecraft, or "Solar Max," using a backpack thrusting system known as the Manned Maneuvering Unit (MMU). The astronaut's job is to stabilize the rolling satellite by firing the MMU's thrusters. Solar Max will then be taken on board the Shuttle Orbiter, repaired and returned to duty. This first on-orbit spacecraft servicing will take place next year.

In February 1980, NASA launched an important scientific satellite known as the Solar Maximum Mission spacecraft, or "Solar Max." Its primary assignment was to observe solar flares, enormously forceful Sun eruptions whose sudden energy release is at times equivalent to the energy used by the entire world over many centuries. Expanded information about these flares, and about the Sun's total radiation output during cyclical periods of waxing and waning activity, is important to better understanding of the energetic processes of other stars.

For almost a year, Solar Max performed splendidly and returned a wealth of data. Then problems developed in its attitude control system, preventing precise pointing of instruments at the Sun. The satellite is still operating, but three of its seven instruments are unable to make solar measurements; much valuable data is being lost.

Had Solar Max malfunctioned a decade ago, it would have been doomed to limited operation for the rest of its useful life. But the operational advent of the Space Shuttle gives the satellite a second chance. Solar Max, built by

Goddard Space Flight Center in the late 1970s, was the first of a new breed of spacecraft designed for Shuttle retrievability—meaning that it has special fittings which the Shuttle Orbiter's robot arm can grapple to "capture" the satellite. So, next year, NASA will do just that—retrieve Solar Max and fix it in orbit to allow resumption of its solar investigations.

It's an immensely important mission because this will be the first demonstration of retrievability, a basic element of NASA's grand design for the Space Transportation System. Retrievability allows a lengthy extension of a satellite's working lifetime—and savings in replacement costs—either by repairing it on orbit or by returning it to Earth for refurbishment. It also provides a new measure of design latitude; spacecraft fabricators can design satellites whose initial set of instruments can be replaced later with more advanced equipment, simply by on-orbit substitution of a new module for the original. Some expensive space systems might not be considered feasible on the basis of, say, a three-year lifetime—but they become feasible in consideration of the fact that orbital servicing can extend their lives multifold. In future years, servicing on-orbit is expected to become routine, perhaps handled by permanently space-based maintenance craft.

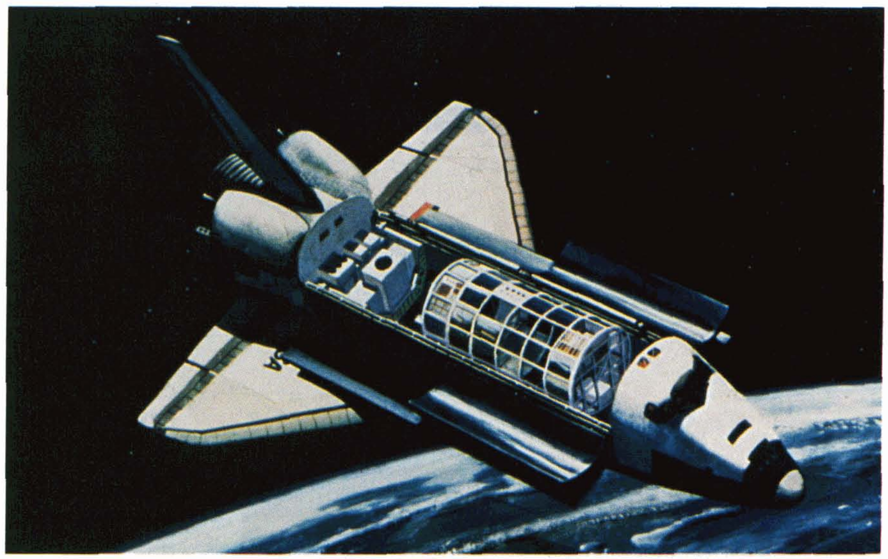
The Solar Max capture, however, will be anything but routine, because it is a "first" and it will involve the initial service use of a new space system called the Manned Maneuvering Unit (MMU)—although the system will be space tested on two prior Shuttle flights. Built by Martin Marietta Aerospace for Johnson Space Center, the MMU is a one-man spacecraft that comprises an open cockpit for its operator, flight controls, thrusters for maneuvering and a fuel supply for the thrusters.

On the ninth operational Shuttle flight, STS-13, the key job in the capture of Solar Max will be handled by Mission Specialist Dr. George D. Nelson, an astronaut/astronomer who will be on his first mission. Shuttle Commander Robert L. Crippen and Pilot Francis R. Scobee will guide the Orbiter to a rendezvous with Solar Max, maintaining a safe distance between the spacecraft; then Nelson will fly the MMU to a docking with the 13-foot satellite and, using his MMU thrusters, stabilize its rolling motion to ease the job of capture. The Orbiter's crew will maneuver closer to Solar Max and, while Nelson remains attached to the satellite, grasp it with the remote manipulator arm and place it in the Orbiter's cargo bay. Nelson will secure the satellite and, with the help of fellow Mission Specialist Dr. James D. van Hoften, will install a new attitude control module in Solar Max. After checkout, the satellite will be redeposited in orbit by the robot manipulator arm.

Prior to the capture operation, flight STS-13 will feature another space first, deployment of a satellite to be returned to Earth after a year in orbit. Managed by Langley Research Center, the satellite is the Long Duration Exposure Facility, a 30-foot cylinder containing a variety of samples, including materials, coatings, solar cells, electronic parts and biological specimens. Scientists want to find out what happens to such samples over a long period of space exposure, information important to the design of future spacecraft and on-board equipment. When they have had a year in the space environment, the Shuttle Orbiter will retrieve the LDEF and return it to Earth for detailed examination of the specimens.

The ability to retrieve an orbiting satellite is one of several features that underline the versatility of the Space Shuttle. It has already demonstrated the reusability of its key components, which affords more economical access to space and reduces the cost of delivering a payload to orbit. But the Shuttle is much more than a payload delivery vehicle; it is a flexible system that can perform many different tasks, including some never before accomplished.

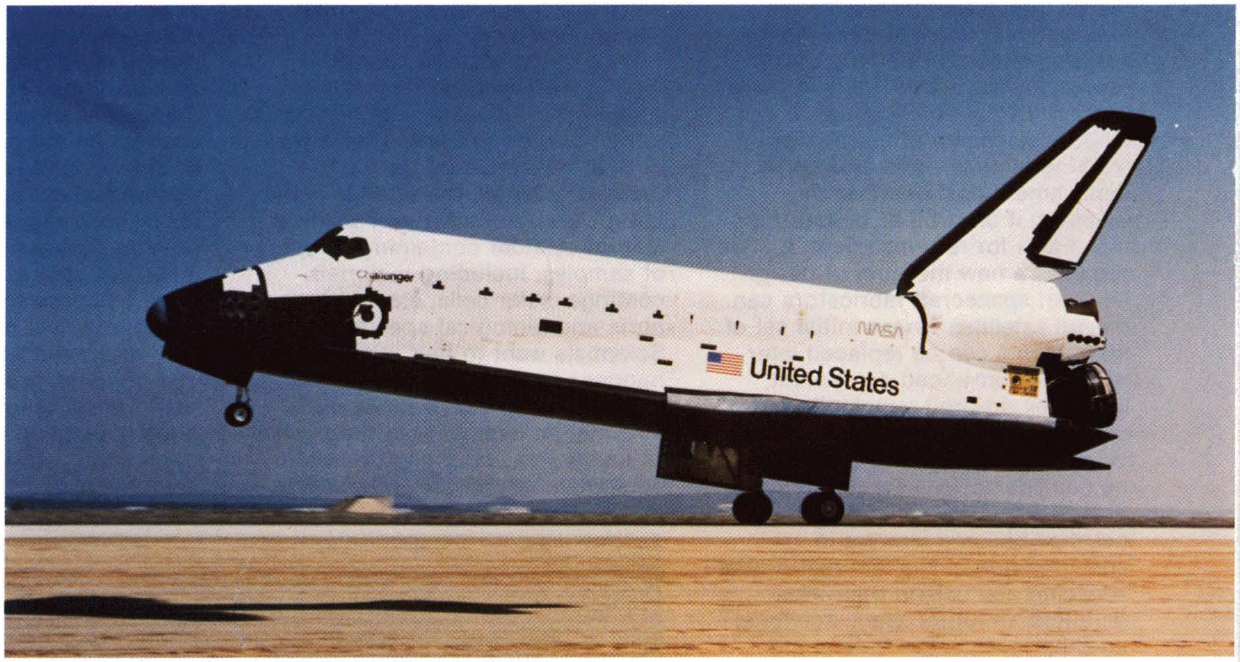
With its Spacelab installed in the cargo bay, the Shuttle Orbiter becomes a laboratory for human-directed experiments. The Orbiter's time in space, nominally five to seven days, can be extended to as much as 30 days by means of new technology NASA is developing. Equipped with an upper stage "space tug," the Orbiter becomes a launch facility for sending interplanetary spacecraft into deep space trajectories. It can also serve as a base for deploying large, unfoldable structures or for erecting even larger structures too big for Shuttle launch—for example, contemplated supersize antennas for far-reaching advancement of communications technology. And, if NASA's plan for a permanent manned space station is approved, the Shuttle will play a key role in its deployment; it will deliver the components, provide a work platform for their assembly and, once the station becomes operational, serve as its link with Earth.



On the same flight as the capture of Solar Max, the Shuttle crew will deposit in orbit the Long Duration Exposure Facility pictured, a 30-foot cylinder containing scores of specimens. The Orbiter will retrieve the cylinder a year later and return it to Earth; detailed examination of the specimens is expected to provide important information for design of future spacecraft and equipment.

CHALLENGER'S DEBUT

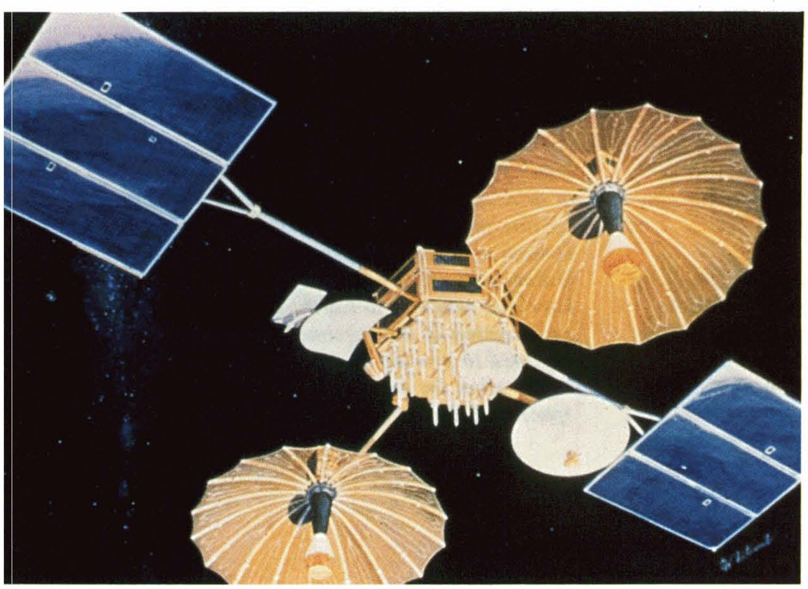
Shuttle flight STS-6 concluded on April 9 when the Orbiter *Challenger* made a perfect landing at Edwards Air Force Base in California's Mojave Desert (below). It marked the first flight for *Challenger* and the second operational flight of the Space Shuttle. From the standpoint of the Orbiter's performance, STS-6 was nearly flawless; officials described it as the best of the Shuttle's six flights.



Paul J. Weitz was Commander of STS-6; his crew included Pilot Karol J. Bobko and Mission Specialists Donald H. Peterson and Story Musgrave. The flight covered 80 orbits over a five-day span.

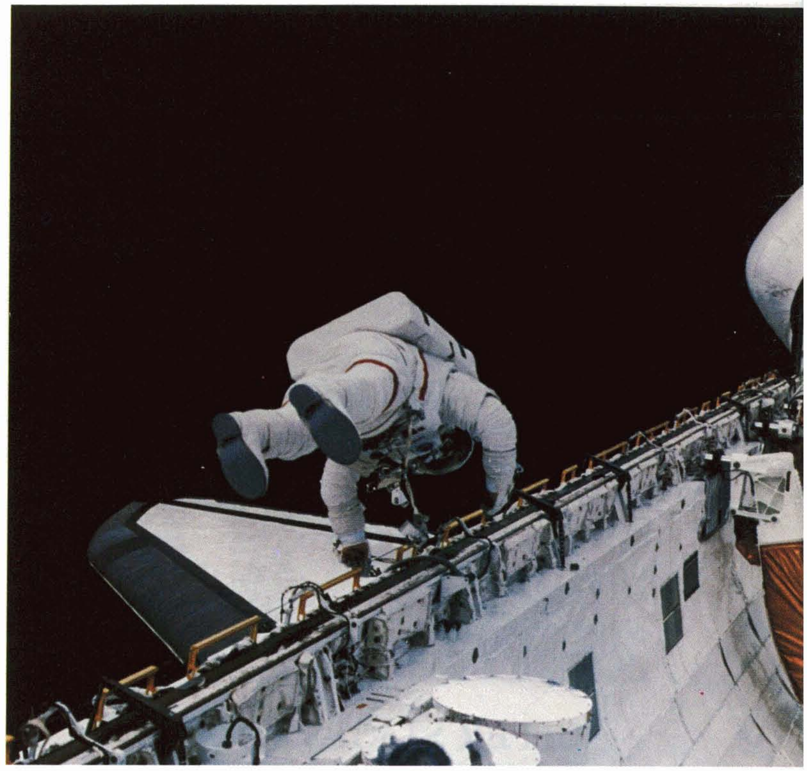
Externally similar to its predecessor *Columbia,* the Orbiter *Challenger* is different in a number of respects, principally because it was intended from the start as an operational vehicle while *Columbia* was initially configured for the flight test program. *Challenger* has new "uprated" engines, meaning that they operate at 104 percent of rated thrust where *Columbia's* engines operated at 100 percent. This added thrust allows Challenger to carry an extra 4,000 pounds of payload.

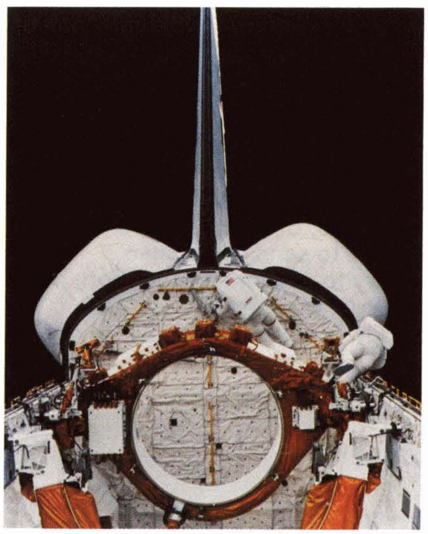
Challenger is also about a ton lighter than *Columbia,* due to use of lighter materials in certain internal components, elimination of the ejection seats carried on test missions, and a changed thermal protection system that is lighter in some areas. In addition, STS-6 marked the first use of the lightweight external fuel tank that weighs some 10,000 pounds less than earlier tanks. The two solid rocket boosters are also lighter, each weighing about 4,000 pounds less than its predecessors. The combination of new engines and weight reductions in all three major components of the Shuttle adds up to an increase in cargo-lifting capability of several tons.

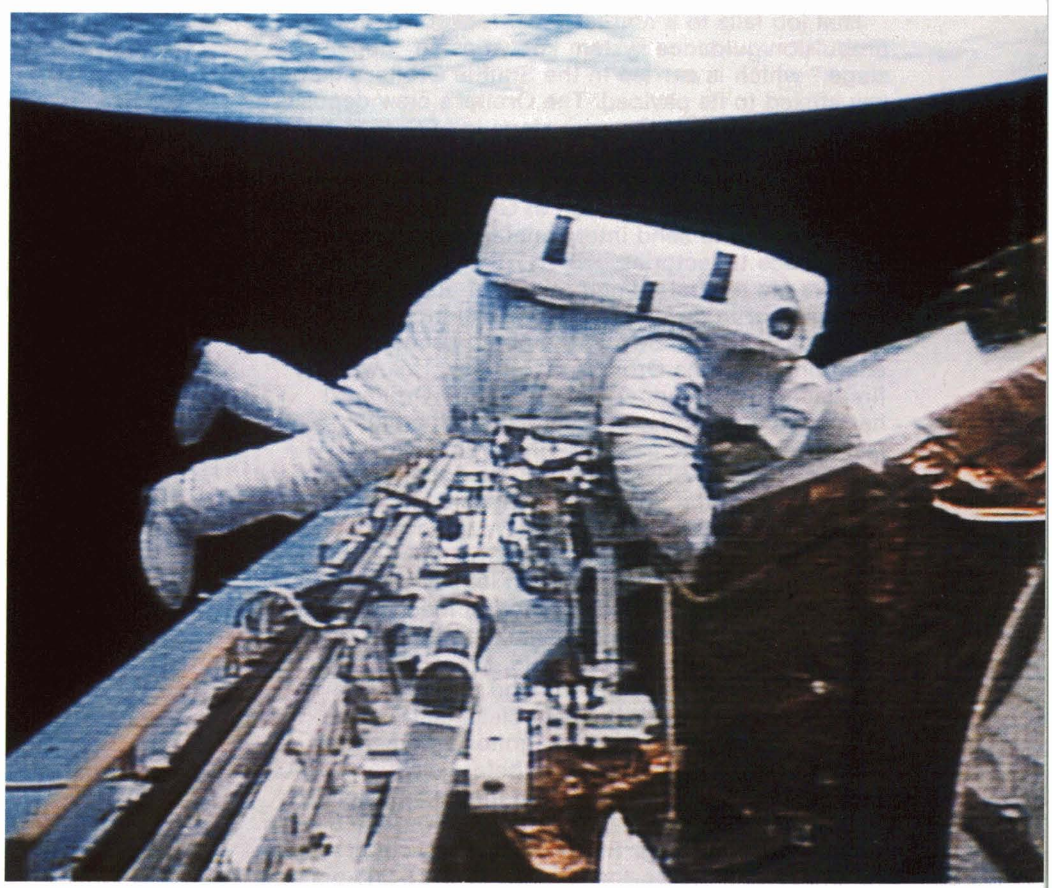


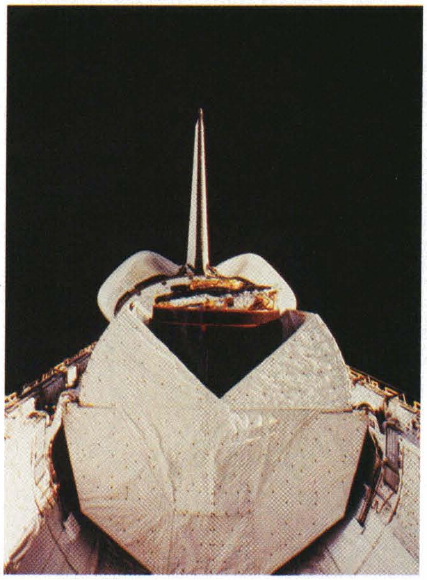
The STS-6 mission was flawed, during its second day, by a problem in delivery of the 5,000-pound Tracking and Data Relay Satellite (TDRS) to synchronous orbit. Shown at left, the TDRS was successfully deployed from the Orbiter's cargo bay, but a malfunction occurred during the secondary boost provided by an Inertial Upper Stage. The TDRS was unable to attain the orbit planned; instead, it went into an elliptical orbit with an apogee (high point) considerably lower than intended. NASA planned a series of later maneuvers, using the satellite's own thrusters, to boost the TDRS into higher orbit. The TDRS was the first of three to be operated for NASA by Space Communications Company; they are built by TRW Inc.

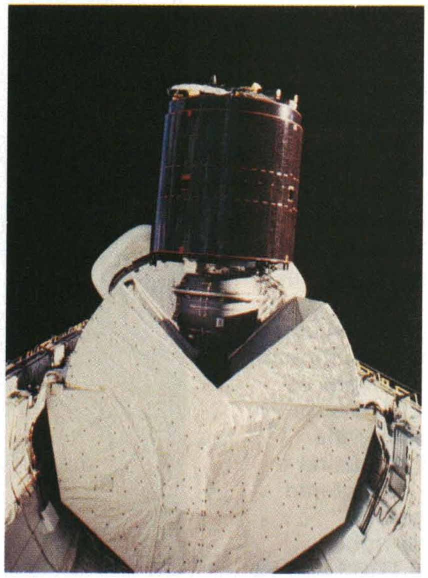
The highlight of the STS-6 mission was the first Shuttle spacewalk, or extravehicular activity (EVA). Peterson and Musgrave donned new space suits called Extravehicular Mobility Units, spent a preliminary three hours breathing pure oxygen to prevent "bends," then moved through an airlock into the Orbiter's open cargo bay. They spent almost four EVA hours running through a sequence of practice jobs, including movement up and back the length of the cargo bay to check out tether lines, slidewires and handholds; testing the space suits' communications equipment; and using a variety of tools to perform tasks that will be required on later Shuttle missions. At right, Musgrave is evaluating the starboard handrail. At lower right, Peterson is examining the area where the TDRS and its Inertial Upper Stage were mounted prior to their deployment. At lower left, both astronauts are setting up a winch for a test operation.

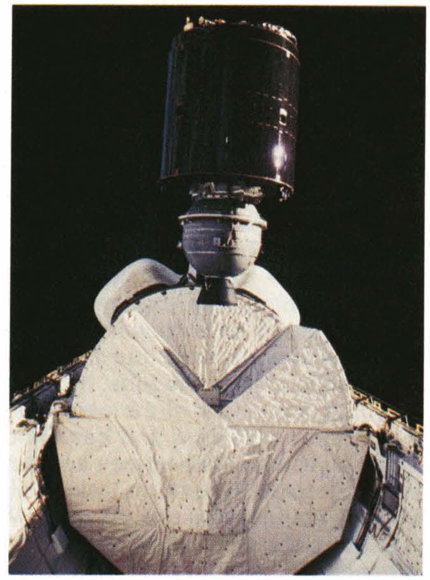












UPPER STAGES

Some spacecraft—commercial communications satellites, for example—operate in geosynchronous Earth orbit, or GEO, where their velocity is synchronized with Earth's speed of rotation. That makes them figuratively stationary with respect to a point on Earth, with a high-perch "view" of a large segment of Earth, for observations or for beaming line-of-sight radio transmissions. The requisite altitude for GEO is 22,300 miles, but the Space Shuttle operates in low Earth orbit (LEO) at altitudes below 700 miles. So satellites destined for GEO need a secondary boost after they are Shuttle-delivered to LEO.

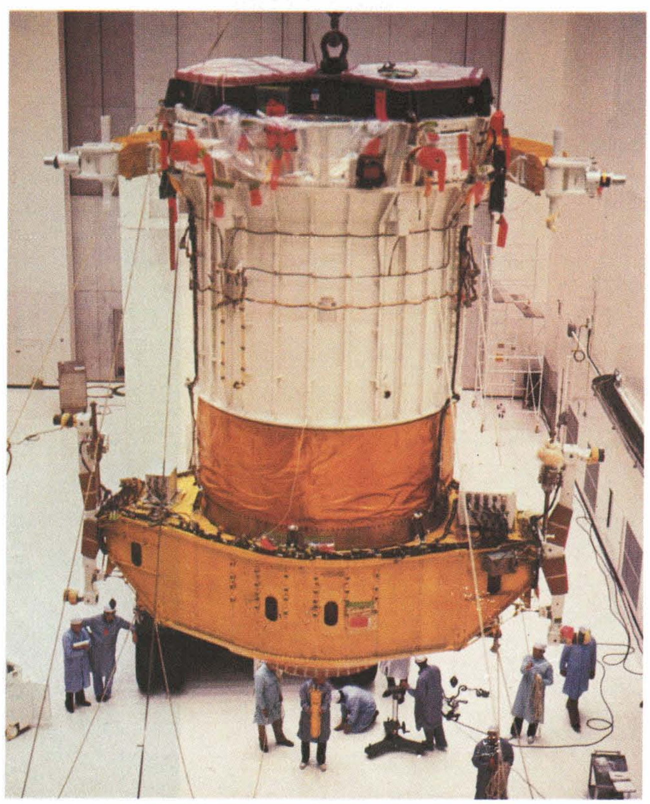
That job falls to a non-reusable rocket propulsion/guidance system known as an "upper stage," which is carried in the Shuttle Orbiter's cargo bay affixed to its payload. The Orbiter's crew deposits the combined payload/upper stage in LEO, then the upper stage rocket ignites, boosting the payload through a series of maneuvers until it eventually reaches its assigned position in GEO. Upper stages are similarly used to send interplanetary spacecraft into deep space trajectories.

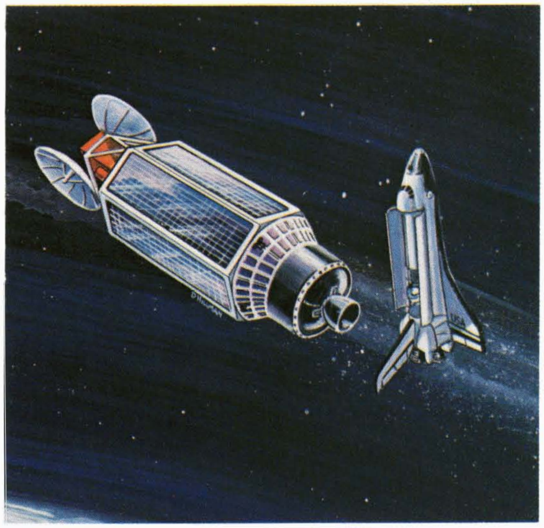
There are several different types of upper stages in service or in development for different sizes of payloads. One is shown in the photo sequence (above) emerging from the Orbiter's cargo bay. This was the first launch of an upper stage from the Orbiter; it happened on the first operational Shuttle flight, STS-5, last November. The payload—the drum-shaped system—was the SBS-3, third of the Satellite Business System series; the upper stage (sphere and nozzle) was the Payload Assist Module (PAM), developed by McDonnell Douglas Astronautics Company. At top left, a spin table has started PAM and its payload spinning—for stability—and a spring mechanism has popped them out of the clamshell cradle that protected them from intense heat and cold. In the other photos of the sequence, propulsion unit and payload have emerged further, to drift a safe distance from the Orbiter before PAM ignites; it ignites automatically 45 minutes after being armed just before ejection. PAM is built in two versions for small to medium payloads.

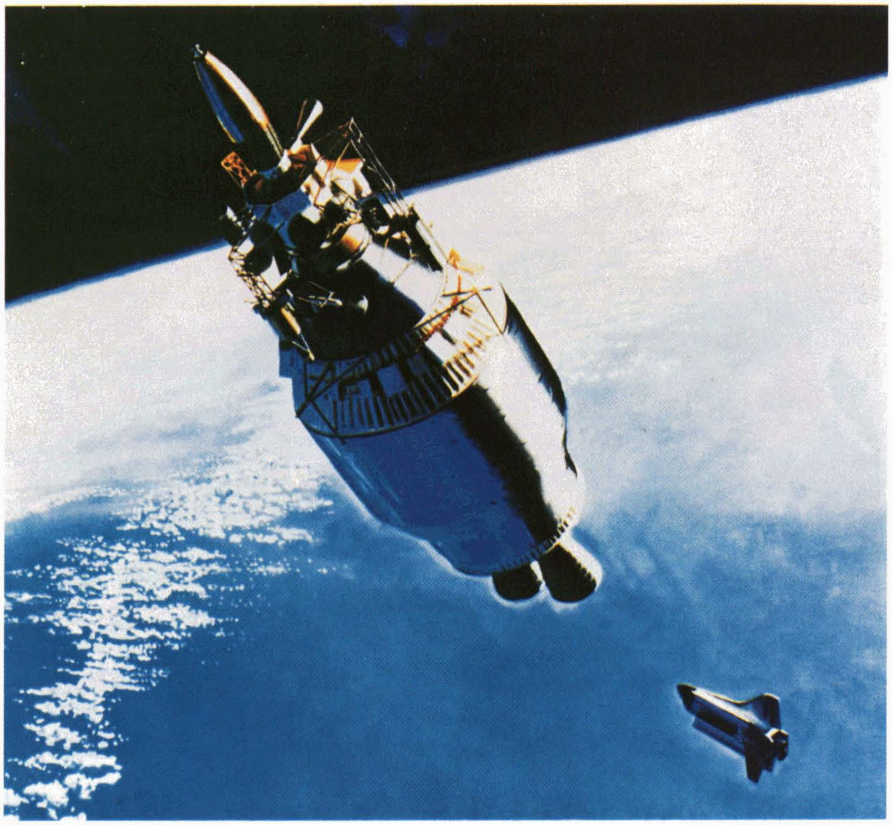
The second upper stage to operate from the Shuttle was the Inertial Upper Stage (IUS), a two-stage system for boosting large payloads, such as the 5,000-pound Tracking and Data Relay Satellite it boosted on STS-6 in April. The IUS is shown below undergoing pre-launch checkout at Kennedy Space Center. The system was developed by Boeing Aerospace Company under contract with the Air Force Systems Command; Marshall Space Flight Center is NASA's manager for the IUS and other upper stages.

Shown at right is a new upper stage in early development. Called the Transfer Orbit Stage, it will be capable of carrying payloads weighing up to 13,000 pounds from shuttle orbit to GEO.

For interplanetary missions, NASA will use the most powerful of the upper stages, Centaur G. At far right, Centaur G is shown about to send the Galileo spacecraft on a trajectory to Jupiter; that mission, the first planned for Centaur G, is scheduled for 1986. Centaur G is a wide-body, Shuttle-compatible version



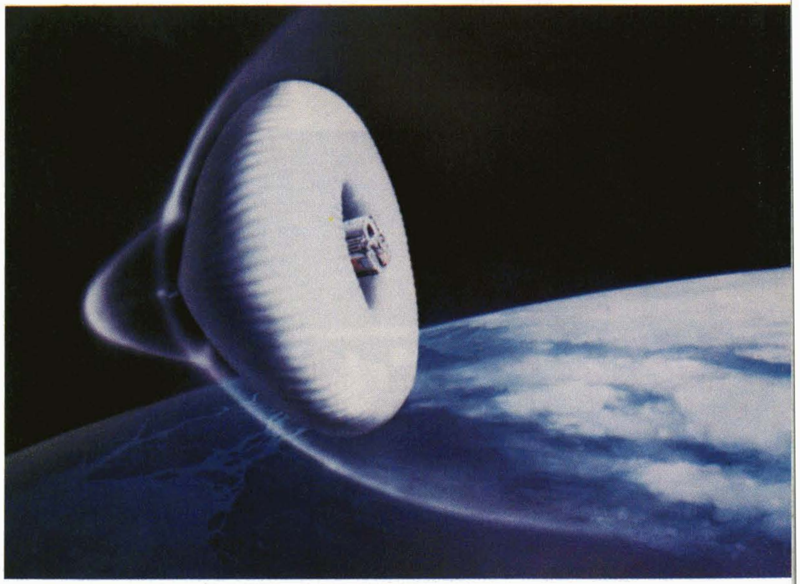




of a system used for years as an upper stage on the Air Force's Titan launch vehicle. It is being developed by General Dynamics Corporation in two versions for NASA and Air Force Shuttle use.

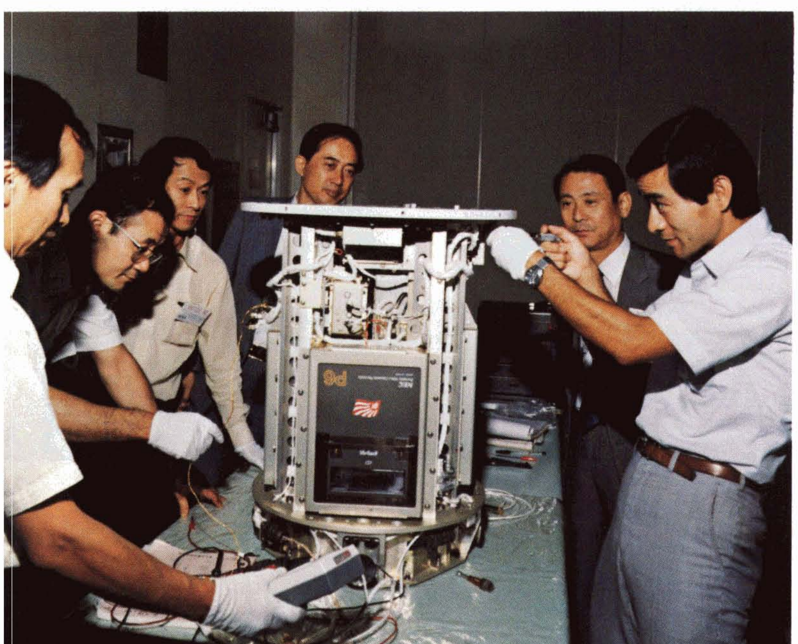
Looking to the future, NASA is exploring advanced upper stages known as Orbital Transfer Vehicles (OTVs), which would be reusable. They would add a new dimension of space capability by permitting retrieval of satellites from GEO; they could be returned to the Shuttle Orbiter or a space station in LEO for servicing or refurbishment. In later years, OTVs may be manned vehicles providing on-orbit servicing of satellites in either LEO or GEO and linking both orbits with the proposed space station.

An example of one type of reusable OTV under study is shown at right. Operating from the Shuttle Orbiter, this vehicle would deliver a payload to GEO, then retrieve another GEO payload in need of servicing and return it to the Orbiter waiting in LEO. To re-attain low orbit, it is necessary to decelerate the OTV; this could be accomplished by firing the rocket engine, but that would take a lot of fuel. Marshall Space Flight Center has come up with a fuel-saving approach in which the atmosphere would be used as a brake. The OTV would deploy a balloon-like device as it dipped into the upper atmosphere and the resulting drag would slow it sufficiently for return to LEO; the fuel saved would translate into a two-to-fivefold increase in payload capability. Under contract with Marshall, Boeing Aerospace and General Electric Reentry Systems are studying this "aeroassisted" type of OTV.



GETAWAY SPECIALS

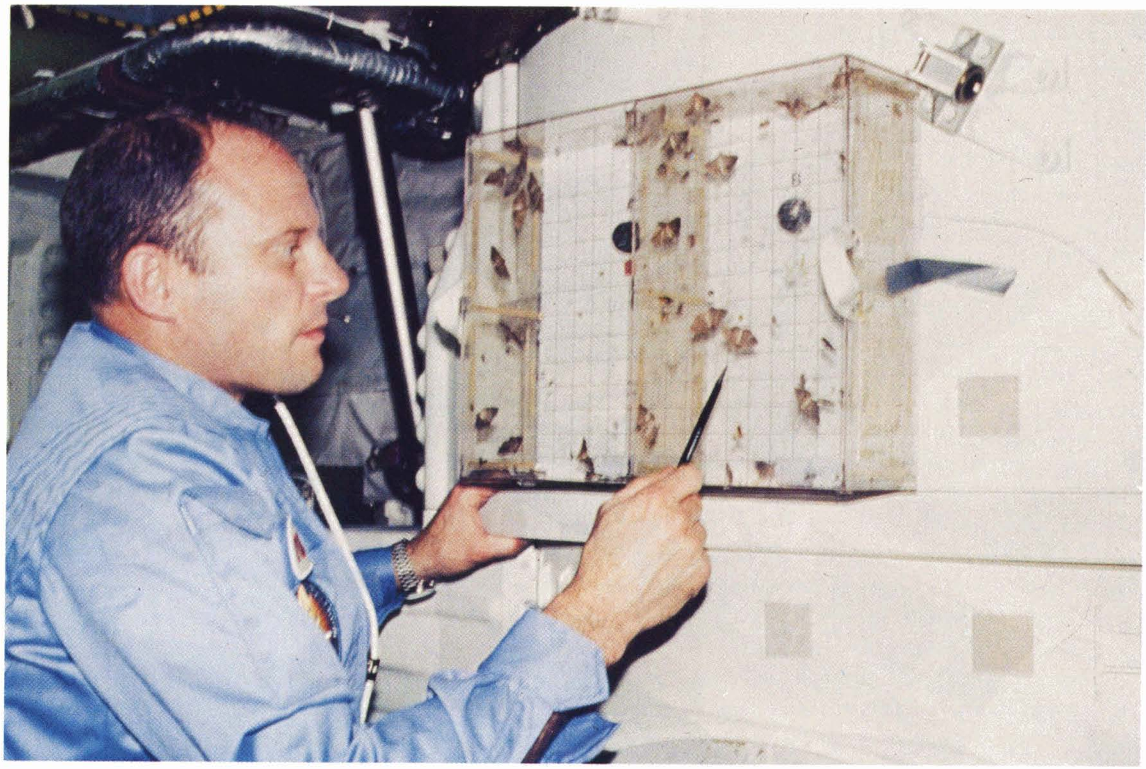
On some Shuttle flights, there is leftover space in the Orbiter's cargo bay after primary payloads have been accommodated. NASA is taking advantage of this space availability to allow low-cost Shuttle use by experimenters who could not justify or could not afford the expense of a primary payload—small companies, educational institutions, research organizations or private individuals. At "Getaway Special" rates of $3,000 to $10,000, researchers can put aboard the Orbiter small, self-contained payloads of their own design. The payloads are housed in NASA-supplied canisters of three sizes, ranging in volume from two and a half to five cubic feet and in weight from 60 to 200 pounds.



At top right, technicians are installing a five cubic foot canister in the Orbiter's cargo bay prior to the fourth Shuttle flight last year; this was the first Getaway Special flown, a payload of 10 experiments prepared by students at Utah State University and Weber State College, Utah. Payloads must be of a scientific research nature; they are exposed to the space environment in the open cargo bay, then returned to Earth for analysis.

The aim of the Getaway Special program is to stimulate broader interest in space research by the large segment of the scientific community not engaged in development of primary payloads; by attracting a new group of investigators, NASA hopes to expand the national space capability for future years. Managed by Goddard Space Flight Center, the program is already a resounding success; NASA has received reservations for some 370 payloads.

STS-6, the first 1983 Shuttle flight, carried three Getaway Specials, including the one illustrated at upper left, prepared by a group of cadets at the U.S. Air Force Academy, Colorado Springs, Colorado. It contained five experiments in zero-gravity metallurgy and another on the effects of weightlessness on microorganism development. A second STS-6 payload was sponsored by Asahi Shimbun, Tokyo, one of Japan's largest newspapers. Designed and built by Nippon Electric Company, Japan's leading satellite fabricator, the payload (left) was an experiment in observing—by TV cameras and videotape recorders—the growth of artificial snow crystals under weightless conditions. The experiment was designed to contribute to crystallography, especially to growth of commercial crystals for semiconductors. A third payload included 40 varieties of fruit and vegetable seeds. Sponsored by George W. Park Seed Company, Greenwood, South Carolina, it was intended as a first step in determining how seeds must be packaged to withstand space exposure, toward 21st century space operations where crews of interplanetary spacecraft or lunar bases may have to grow their own food.



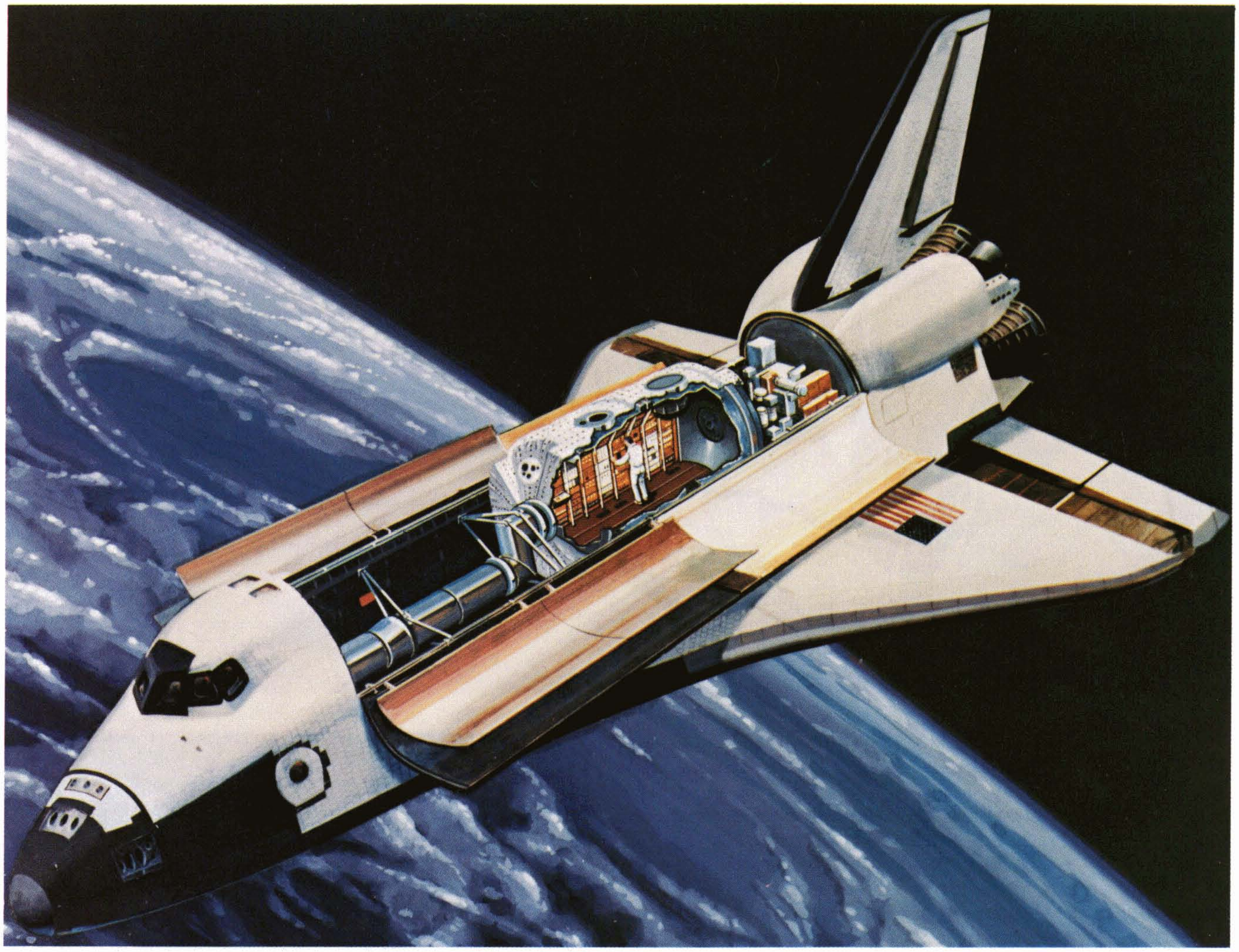
STUDENT EXPERIMENTS

To stimulate interest in science and engineering among secondary school students, NASA and the National Science Teachers Association are jointly sponsoring an annual nationwide competition—the Shuttle Student Involvement Project—to select proposals by young scientists for experiments to be flown aboard the Space Shuttle. Proposals are based primarily on scientific/engineering merit and originality. The first seven winning experiments, selected from some 1,500 entries, were flown aboard three Shuttle flights last year; a new selection project is now in progress.

Each student winner is paired with a corporate sponsor and a NASA scientist or engineer, who work with the student to determine the feasibility of developing the proposal into an actual flight experiment. If a winning proposal closely parallels a professional experiment already planned for a Shuttle flight, NASA may arrange to supply the student with data from the professional experiment. In some cases, minor modification of professional experiments, including collection of special data from existing instruments, may be made to accommodate a winning student proposal. Proposals that require new hardware may be developed with the assistance of the corporate sponsor and integrated by NASA into a Shuttle mission on a space available basis. Finalists whose proposals are judged not feasible for flight may be assigned to work as part of a NASA research team on a project in the student's field of interest. In all cases, sponsors and advisors help the student analyze the data and report the experiment results in a scientific format.

Carried on flight STS-3 in March 1982, the initial student experiment selected was developed by Todd Nelson, then a high school senior from Adams, Minnesota, and sponsored by Honeywell Inc. Avionics Division. Entitled "Insects in Flight Motion Study," the experiment involved investigation of the flight responses and other activities of flies, bees and moths under weightless conditions. In the top photo, astronaut Jack Lousma is making one of a number of inspections of the insect colony during STS-3.

At lower right, student scientist Scott Thomas of Johnstown, Pennsylvania, at right, briefs astronaut Dr. Joe Allen on details of his winning experiment "Convection in Zero Gravity," a study of the circulation patterns occurring in weightless liquids. Allen tended the experiment on STS-5 last November, using the apparatus pictured, which was conceived by Scott Thomas and fabricated by his corporate sponsor, Thiokol Corporation's Wasatch (Utah) Division.



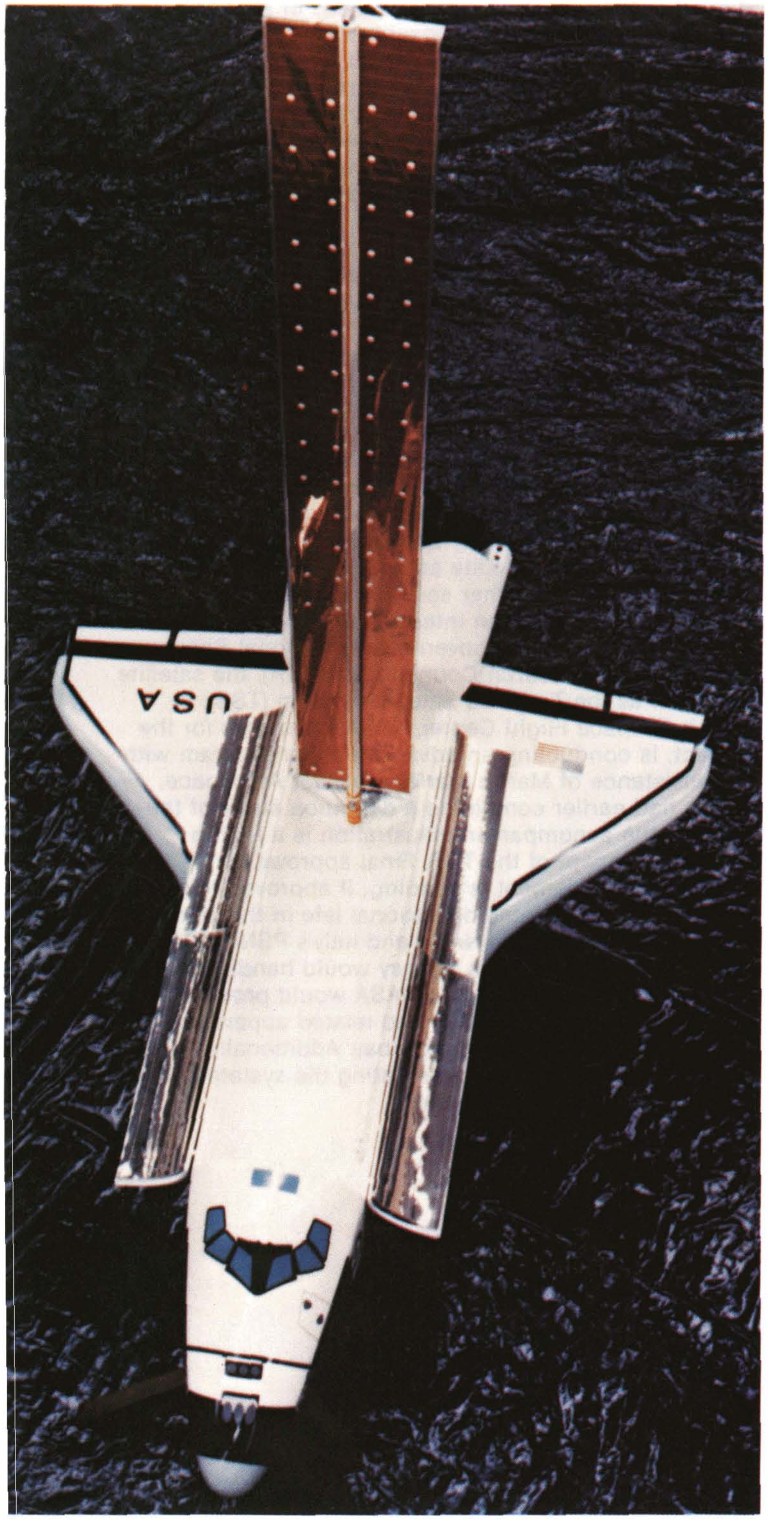
SPACELAB

The ninth Space Shuttle flight late this year will feature the debut of Spacelab, a unique orbital laboratory carried in the Orbiter's cargo bay that makes possible a broad variety of human-directed experiments in the space environment. The Spacelab 1 mission will mark the return to service of the Orbiter *Columbia,* which flew the initial four Shuttle test missions and the first operational mission; it was removed from active duty for modifications to convert it from experimental to operational configuration.

Developed by the European Space Agency (ESA), with U.S. coordination provided by Marshall Space Flight Center, the Spacelab system includes a two-segment pressurized module, where up to four investigators can work in shirtsleeve environment, and non-pressurized pallets mounted in the open cargo bay for experiments that require direct exposure to space. These elements can be flown in a number of different combinations, for example, a short (single-segment) pressurized module with three pallets; a two-segment manned module with one or two pallets; or as many as five pallets without the manned module. In the latter instance, experiments are controlled from the Orbiter's rear flight deck.

The illustration above shows the configuration for the Spacelab 1 mission: a two-segment laboratory with one experiment pallet in the aft section of the cargo bay. In the fore section is an airlock and tunnel connecting the laboratory and the flight deck.

The joint NASA/ESA Spacelab 1 mission will include, in addition to Commander John Young and Pilot Brewster Shaw, a four-man science crew—two Mission Specialists and two Payload Specialists. Mission Specialists are NASA astronauts who have had scientific training; for Spacelab 1, they will be Dr. Owen Garriott and Dr. Robert Parker. Payload Specialists are non-astronaut scientists representing the international group of investigators for a given mission; they conduct most of a Spacelab mission's scientific activities. NASA's Payload Specialist for Spacelab 1 will be Dr. Byron K. Lichtenberg, a biomedical engineer. Payload Specialist for ESA will be Dr. Ulf Merbold, a physicist from the Federal Republic of Germany's Max Planck Institute. Lichtenberg and Merbold will use 38 different scientific packages located both inside and outside the habitable module to conduct experiments in life science, astronomy and solar physics, space plasma physics, materials processing, atmospheric physics and Earth observation. The two Payload Specialists will be representing more than 70 investigators from the U.S., Europe and Japan.



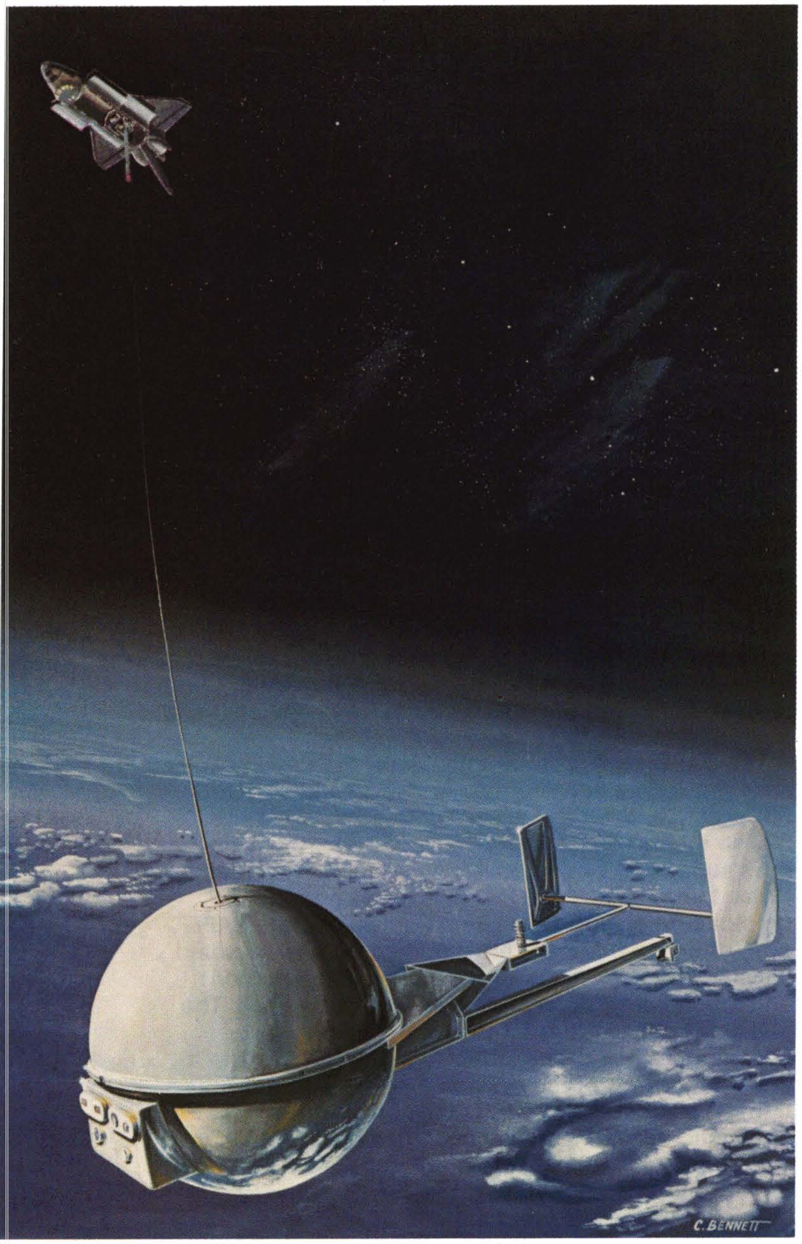
SPACE POWER SYSTEM

Within a decade, NASA hopes to have a manned space station in low Earth orbit, perhaps also a number of unmanned multipayload platforms for long-duration science and applications experiments. Additionally, there may be a requirement for Space Shuttle missions of much longer duration than the current five to seven days. These and other future considerations have a common need: electrical power in large amounts, for such essentials as life support systems, experiments, communications, data handling and heat control.

To meet the requirement for considerably greater power than has been available to date, NASA is developing large arrays of solar cells that convert sunlight into electrical energy. The first of these king-size solar "wings", shown at left, will be flown aboard the Shuttle Orbiter next year on a seven day test called the Solar Array Flight Experiment (SAFE). Marshall Space Flight Center manages the SAFE project; Lockheed Missiles & Space Company built and is ground testing the array.

The SAFE system is not only larger than earlier solar arrays, it differs considerably in design and structure. For example, the solar array employed on the 1973–74 Skylab interim space station was composed of silicon cells supported by a relatively heavy aluminum frame; it was folded in sections for delivery to orbit, then unfolded on station to create a flat wing. In the SAFE array, the very thin cells are mounted on a two-layered plastic "blanket," made of a material called Kapton and much lighter than aluminum support frames. The blanket is carried to orbit compactly folded in a containment box in the Orbiter's cargo bay. Next to it is the other part of the system, a fiberglass epoxy mast tightly coiled in a canister. On initiation of the automatic deployment sequence, the mast uncoils into a straight spar, pulling with it the Kapton blanket from the adjacent box. When fully extended, the array measures about 105 feet long and 13 feet wide.

To minimize cost of the experiment, only one of the array's 84 solar panels will have live cells on the 1984 test; in later service, with all panels live, the wing will generate 12.5 kilowatts of electricity. The SAFE test is a first step toward contemplated development of even larger space power systems ranging in power capability from 25 to 500 kilowatts.

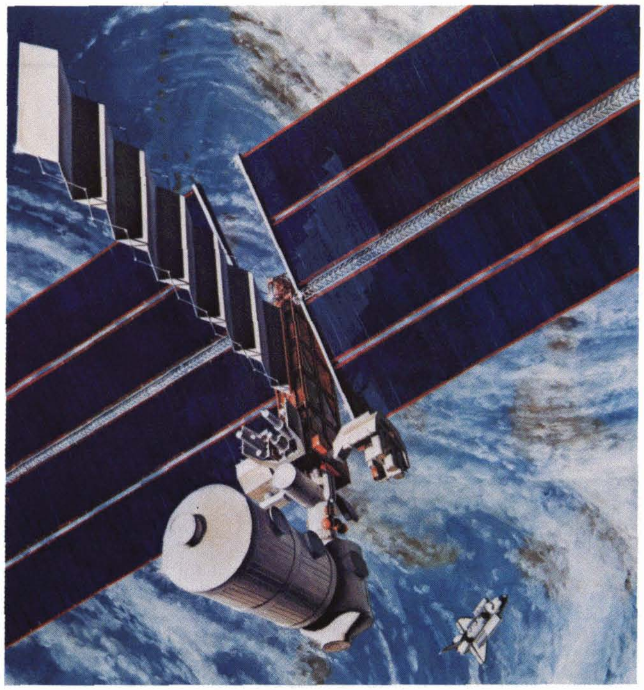


TETHERED SATELLITE

There is a near-Earth region that has not been explored as extensively as other parts of Earth orbital space because there are limited means of studying it. The region is the upper atmosphere, roughly 60 to 90 miles above Earth's surface. Aircraft and balloons can't operate at those levels. And, because there is a very thin but appreciable atmosphere, a satellite would be slowed by air drag and would not remain in orbit long. Instrumented sounding rockets have probed the upper atmosphere, but these non-orbital systems gather data for short periods ranging from seconds to a few minutes.

To meet the need for more information on this region, NASA has embarked on development of a satellite that would be lowered from the Space Shuttle Orbiter and towed through the upper atmosphere. It would be suspended from the Orbiter's cargo bay by a tether line up to 60 miles long and would troll the upper atmosphere for days at a time gathering magnetospheric, atmospheric and gravitational data. Since gravity is neutralized in Earth orbit, the tethered satellite could also be deployed *upward;* this would permit simultaneous study at two different levels—from instruments in the satellite and in the Orbiter—of electrodynamic and other scientific phenomena.

To be developed as an international cooperative project with the Italian government's National Space Plan/National Research Council (PSN/CNR), the satellite is known as the Tethered Satellite System (TSS). Marshall Space Flight Center, NASA's manager for the project, is conducting an advanced study program with the assistance of Martin Marietta Denver Aerospace, which had earlier completed a definition study of the system; the accompanying illustration is a Martin Marietta concept of the TSS. Final approval for full-scale development is pending; if approved this year, the TSS would become operational late in this decade. An agreement between NASA and Italy's PSN/CNR spells out the tasks each agency would handle: Italy would build the satellite and NASA would provide the deployment system, the reel and related apparatus that would fit in the Orbiter's cargo bay. Additionally, NASA would be responsible for integrating the system and conducting mission operations.



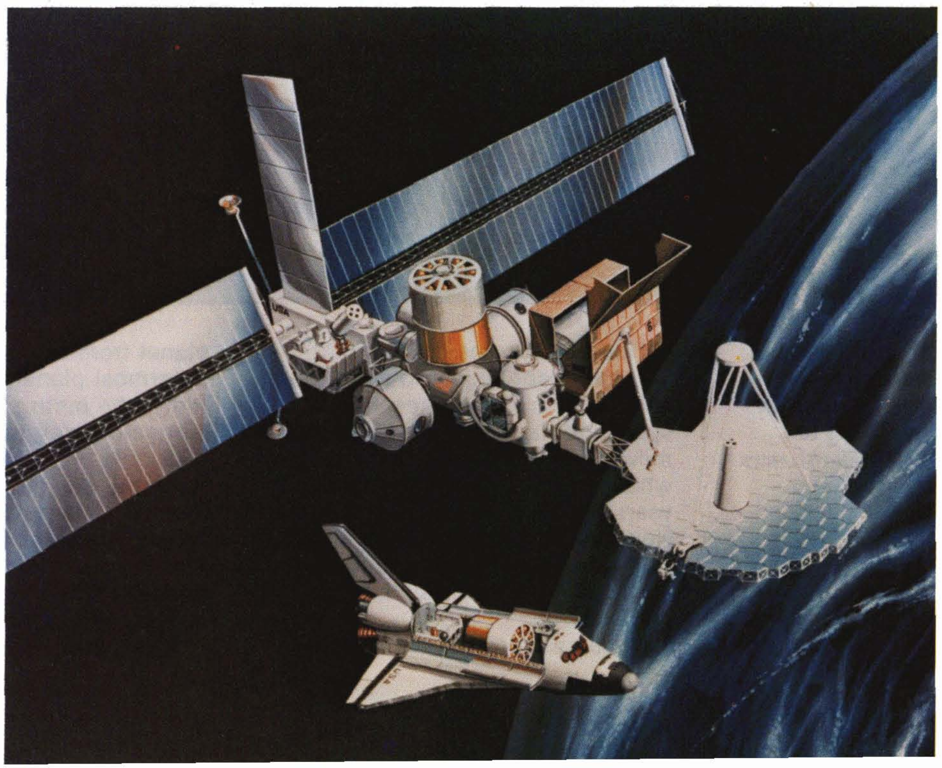
SPACE STATION

With the Space Shuttle now operational, the next logical step in space development is a space station, containing both manned and unmanned elements, in permanent orbit around Earth. With the assistance of several contractors, NASA is conducting extensive analyses to get a thorough grasp of what specific missions would be performed, in what time frame, what attributes the station would have to have to carry out such missions and what technologies are involved, together with a firm fix on schedules and costs. This study-in-depth strategy is intended to avoid premature emphasis on design and configuration and to reduce the likelihood of technical roadblocks in a future hardware development phase. For planning purposes, target date for deployment of the station is 1991.

The space station would serve as both a laboratory and an operations base. As a laboratory, it would permit long-duration observations of the land and oceans for scientific, commercial or defense purposes, or scientific observations in the opposite direction—toward the Sun, the planets and the stars. It would also provide a facility for private sector space processing experiments, perhaps later an orbital factory for manufacture of products not producible in Earth's gravity. Man's presence in the space station would afford an extra measure of capability for observations where human skill and judgment are important, for example, in instrument selection and adjustment, in managing the data acquired by the instruments, and in overall system maintenance.

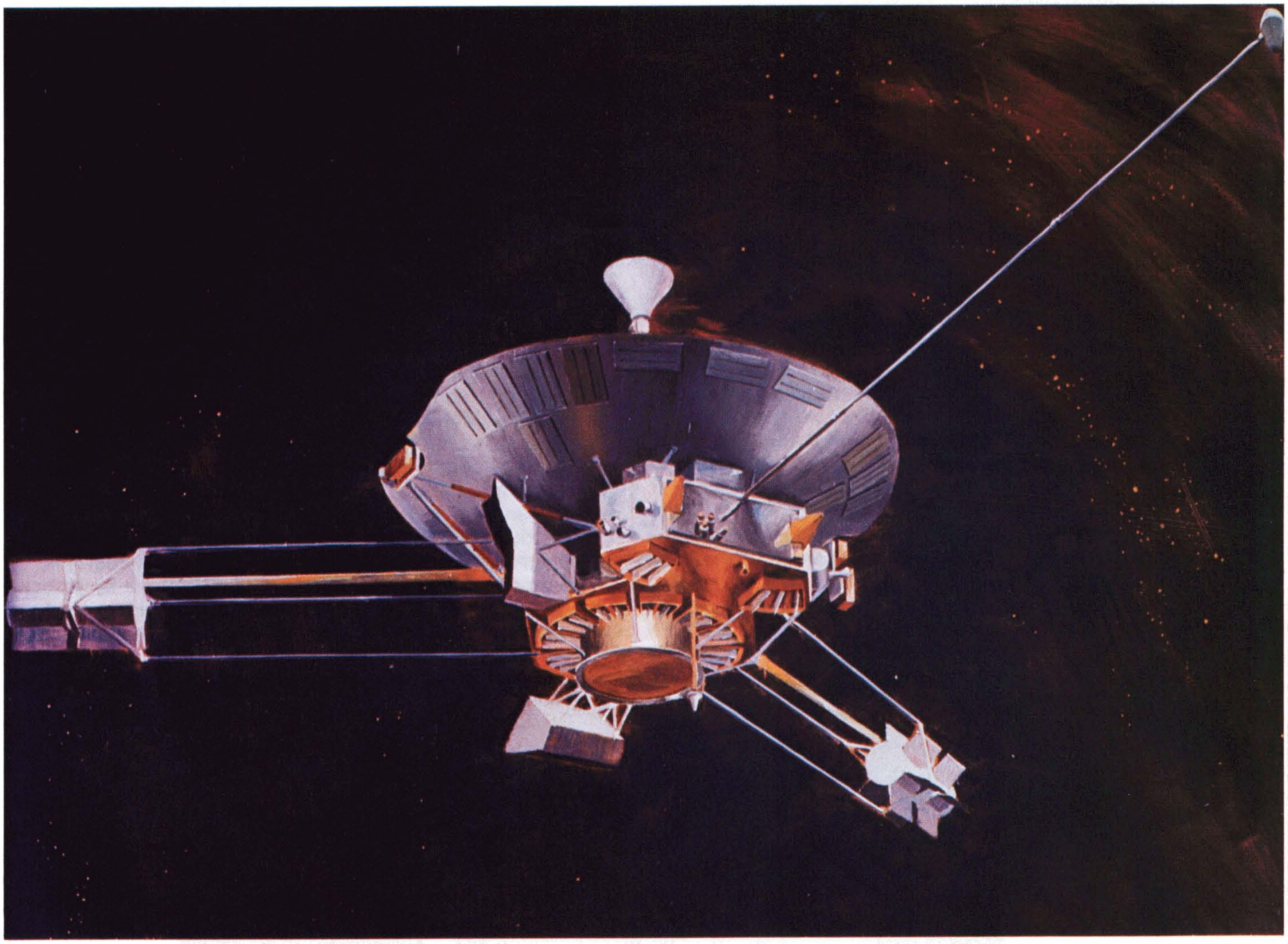
As an operations base, the space station would allow continuous rather than intermittent operations and thereby increase the amount of useful work that can be performed in orbit. It would serve as a base for maintaining and servicing free-flying unmanned satellites; as a depot for permanently space based Orbital Transfer Vehicles capable of delivering and retrieving Earth-orbiting payloads; as a departure point, like the base camp of a mountain climb, for missions to the moon, the planets, asteroids and comets; and as a construction base for erecting systems too large for launching directly from Earth. The space station might be developed as an international cooperative venture; Japan, Canada and member nations of the European Space Agency have evinced interest.

To hold down costs, NASA has adopted a modular design approach in which the initial space station would be a relatively simple core unit, manned by a crew of two to four, with a large solar array for power and with equipment for such functions as power distribution, communications, data management and thermal control. The station would be expanded over time by addition of Shuttle-delivered modules. The illustration above pictures the station in its initial phase; the Orbiter is approaching with an additional module. The concept below shows what the station might look like after several evolutionary steps; it is composed of three manned modules joined by airlocks, a number of rotating experiment pallets, and a work platform where a large antenna is being assembled.



PROBING THE COSMOS

Exploration of the solar system and the galaxies beyond is producing a wealth of knowledge about planet Earth and its place in the universe



Destined to become the first man-made object to depart the solar system, Pioneer 10 is more than three billion miles from Earth on a journey to infinity. It may coast between the stars for millions, even billions of years.

Soon to become the first man-made object to leave the solar system, the Pioneer 10 spacecraft is more than three billion miles from home port Earth, whence it departed more than 11 years ago. It is beyond the orbit of Neptune, so far away that a signal from the spacecraft, traveling at the speed of light, takes six hours to reach Earth.

Neptune, normally the eighth planet from the Sun, is now the outermost planet; that's because Pluto, the ninth planet, has an elongated orbit and for the next 17 years will be "inside" the orbit of Neptune. So you could say that Pioneer 10 has already left the solar system. However, NASA has decided that the historic departure will officially take place when the spacecraft crosses the mean orbit of Pluto, 3.67 billion miles from the Sun. That will happen in October 1986.

Originally designed for the first close-up reconnaissance of Jupiter—which it successfully accomplished a decade ago—Pioneer 10 has had a remarkably long and productive career. It has traversed the potentially hazardous asteroid belt, survived a barrage of micrometeoroid hits, weathered Jupiter's intense radiation and, except for the loss of one instrument, has operated flawlessly, sending back to Earth more than 125 billion bits of information.

Built by TRW Inc. and managed by Ames Research Center, Pioneer 10 is still working and engaged in a new enterprise: investigating the behavior of the extended atmosphere of the Sun, the magnetic "bubble" that contains the Sun and all the planets. Called the heliosphere, the bubble is created by the million-mile-an-hour solar wind that streams outward from the Sun in all directions.

From outside, the bubble would appear to be teardrop-shaped due to a streaming effect as the solar system moves through an ocean of interstellar gas. The heliosphere is much larger than anyone expected, according to information supplied by Pioneer 10. The spacecraft's primary assignment for the next several years will be to define the true boundary between the bubble and interstellar space, and to continue to provide data on the outermost extension of the solar wind. It's immensely important work because the Sun is the only star scientists can measure from "close up" and Pioneer's data will tell them a great deal about the Sun itself, the interstellar gas surrounding the solar system, and stars in general.

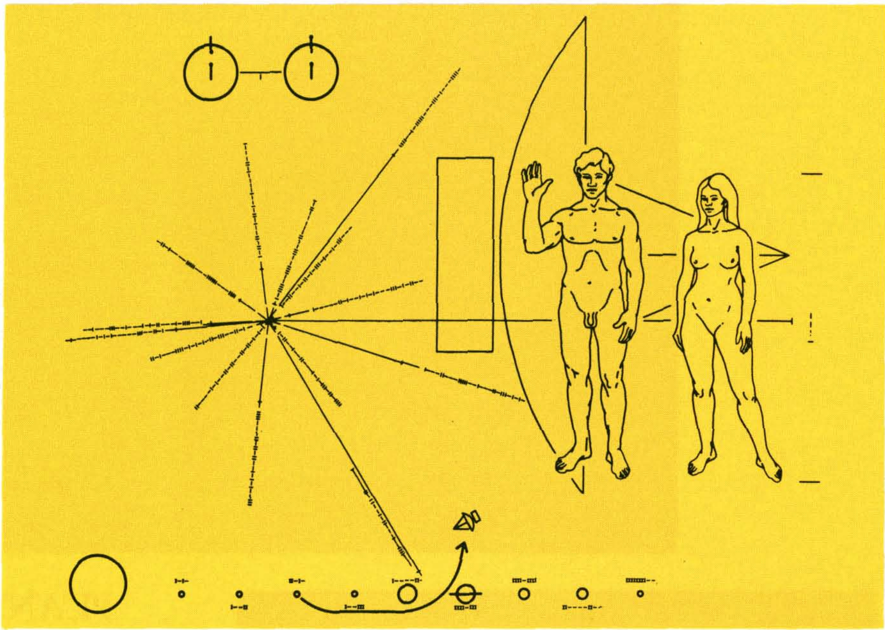
Along with Pioneer 11, which left Earth a year later, Pioneer 10 will also participate in an exciting search for a "mystery object" that may exist somewhere from five to 100 billion miles beyond the outermost planet. Irregularities in the orbits of Uranus and Neptune suggest that some large celestial body may be exerting a gravitational influence on these planets. It could be a low mass dark star that emits little light, hence has escaped telescopic discovery; or a 10th planet. Data from the Pioneers as to the degree of gravitational pull they encounter over a period of years can provide clues as to the size and direction of the mystery body, a starting point for a more comprehensive investigation.

Power for the Pioneers' transmissions is supplied by a nuclear source rather than solar cells, so the spacecraft can continue to report long after they have departed the Sun's sphere of influence. Scientists believe that they can maintain contact with the Pioneers until the mid-1990s. At that time, they will be billions of miles into interstellar space, but really just beginning their cosmic journeys; it will take them 40,000 years just to reach the distance of the nearest star. Needing no further propulsive energy, they will coast through the universe for millions, perhaps billions of years. It is an eerie thought that they may exist longer than the planet that spawned them.

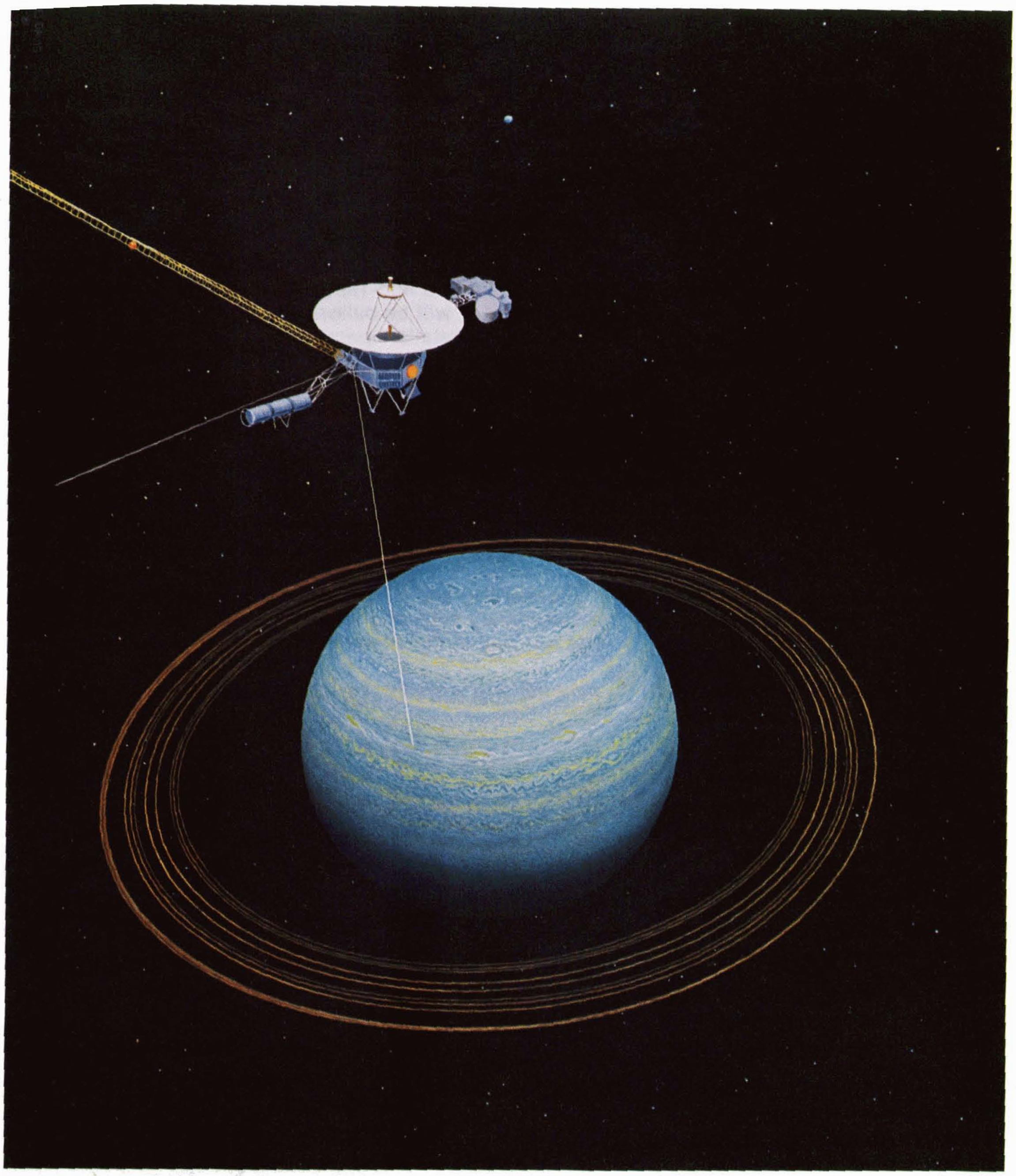
Pioneers 10 and 11 underline the extraordinary scientific reach man has attained in his efforts to uncover the mysteries of the cosmos. The two spacecraft are part of NASA's broad space science program, which employs deep space probes like the Pioneers, Shuttle-based manned and unmanned experiments, Earth orbiting satellites, non-orbiting sounding rockets, aircraft, balloons, ground telescopes and research laboratories in a sweeping study of space phenomena.

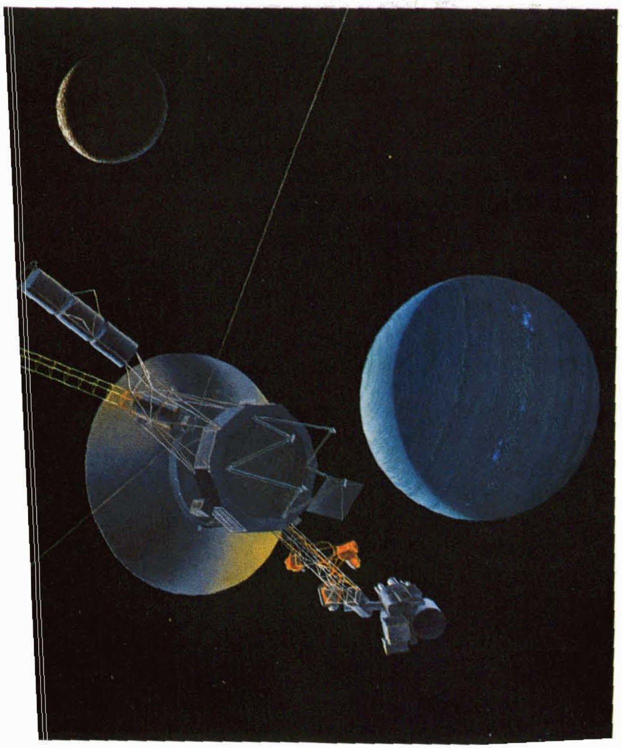
The space science program has four main avenues of effort: solar system research, or investigation of the planets—including Earth—and other objects within the solar system; solar terrestrial research, study of the Sun's energy processes and their interactions with Earth's environment; astrophysics research, study of the distant stars and galaxies; and life sciences research, which is aimed at understanding the origin and distribution of life in the universe. The latter area of effort also seeks improved knowledge in medicine and biology through utilization of the space environment.

This comprehensive program has many goals, but they can be reduced to a common denominator: fitting the tiny planet Earth into the cosmic puzzle of how the universe began, how it evolved and how it is structured. The volumes of new scientific knowledge being generated represent an incalculably valuable resource, not just for scientists but for everyone, because science is the foundation of advancing technology, the informational base for tomorrow's practical applications.



Should Pioneer 10 someday encounter intelligent life, it carries a gold plaque that tells graphically of man, planet Earth, the solar system, and where the Sun lies in cosmic terms.





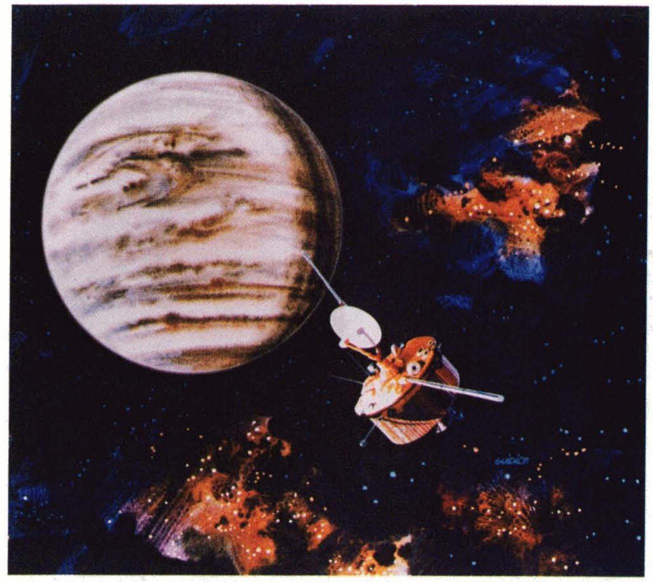
PLANETARY EXPLORATION

Having scored unparalleled successes in their 1979–81 investigations of Jupiter and Saturn, Voyagers 1 and 2 are continuing their journeys through the solar system on widely divergent flight paths. Moving 75,000 miles farther from Earth each hour, Voyager 2 is bound for two more planetary encounters, with Uranus, the seventh planet from the Sun, and Neptune, the eighth planet. These are immensely important encounters because little is known about either planet; neither has been visited by spacecraft. About two billion miles from the Sun, Uranus takes 84 years to complete an orbit; Neptune, a billion miles more distant, makes a circuit of the Sun once every 165 years. Voyager 2 will fly by Uranus in 1986 (above), transmitting back to Earth close-up pictures and other scientific information, then it will fly on to Neptune for its last planetary encounter in the summer of 1989 (left).

Around 1990, Voyager 1 and Voyager 2 will be nearing the still-undefined edge of the solar system. The two spacecraft will help define it, trying to find the boundary line of the Sun's sphere of influence, the place where the solar wind can no longer be detected. Then the Voyagers will turn their instruments toward interstellar space. NASA's manager for the Voyager project is Jet Propulsion Laboratory (JPL).

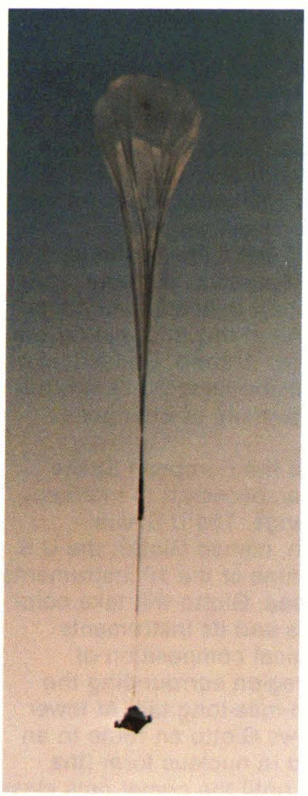
At Venus, the Pioneer Venus Orbiter (right) continues to circle the cloud-shrouded planet and relay data on Venus' atmosphere and weather system. Pioneer Venus is managed by Ames Research Center. NASA is planning development of a new Venus Radar Mapper spacecraft that will radar-map Venus' surface with a degree of resolution—clarity of detail—20 times better than that provided by Pioneer Venus.

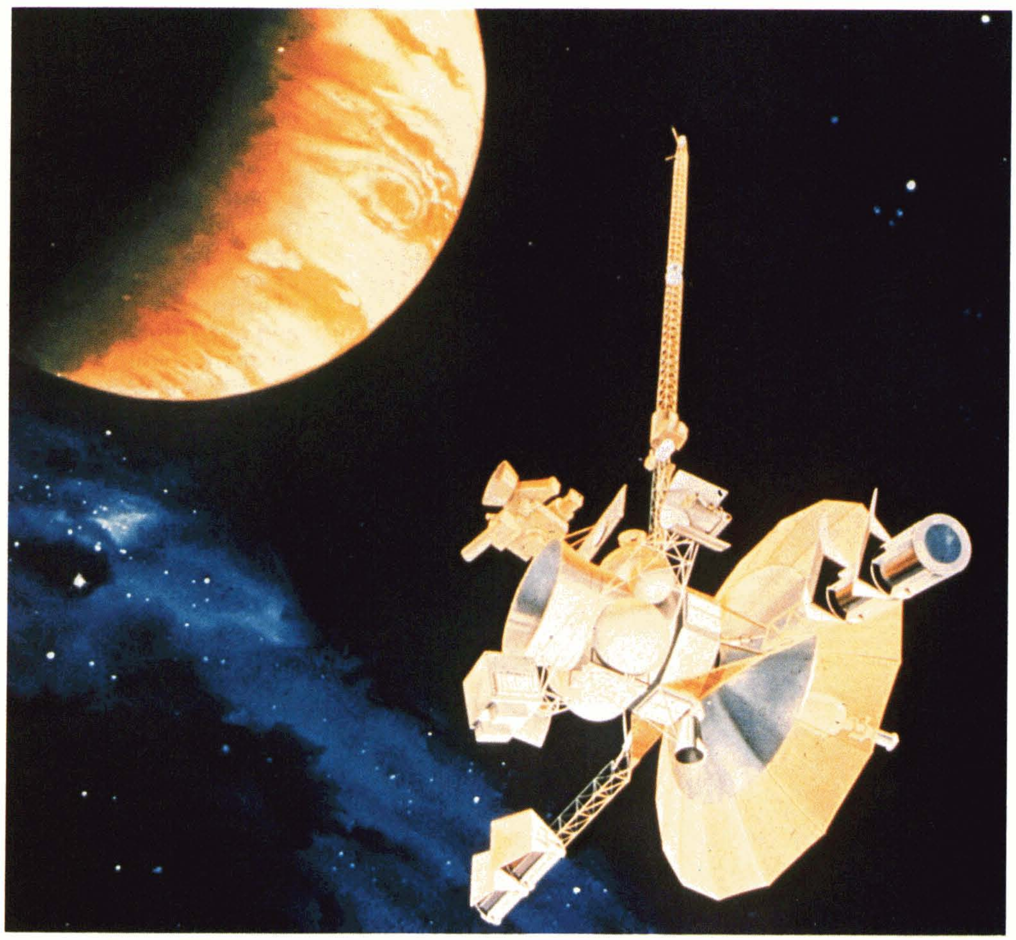
Also in development, in cooperation with the Federal Republic of Germany, is a spacecraft designed to meet a need for long-term detailed studies of Jupiter, amplifying the information acquired by the Voyagers in their brief fly-bys. Called Galileo and scheduled for Shuttle launch in 1986, the spacecraft is a two-element system that includes a Jupiter-orbiting observatory (below right) and an entry probe. Below left, the probe is shown undergoing a 1982 test in which it was carried to high altitude by a balloon, then released to descend to Earth by parachute; these tests continued in 1983. The probe will descend into Jupiter's atmosphere, protected by a heat shield from temperatures expected to reach 14,000 degrees

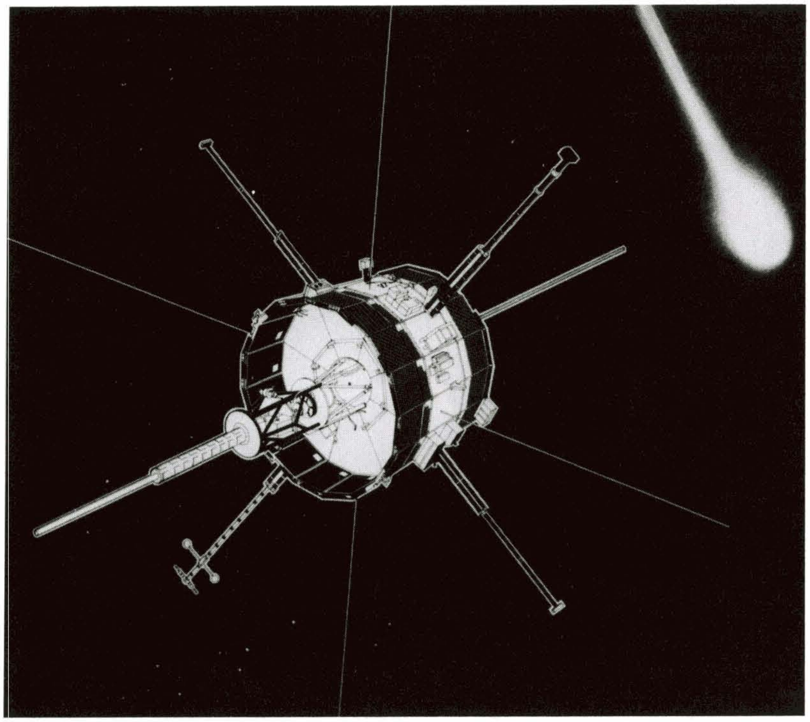


Fahrenheit; its instruments, lowered by parachute, will provide readings on the pressure, temperature and composition of the atmosphere for about an hour.

The observatory element of Galileo will swing into orbit around the giant gas planet, a man-made moon of Jupiter providing long-term imagery and instrument data on the planet and its natural moons. JPL is Galileo project manager and builder of the orbiter; Ames has responsibility for the probe, which is being built by Hughes Aircraft Company and General Electric Company.



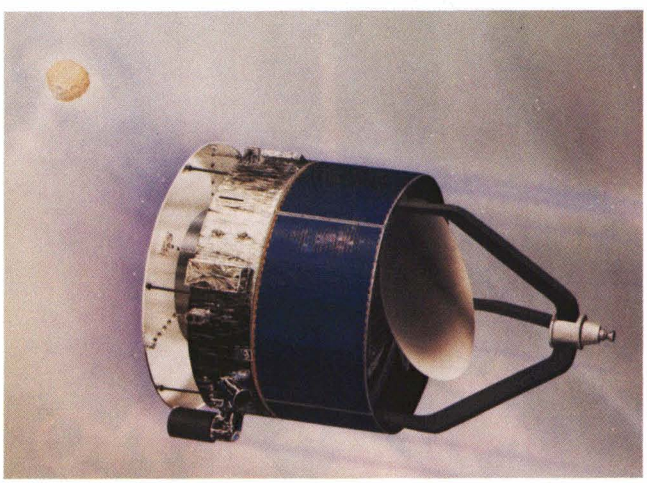




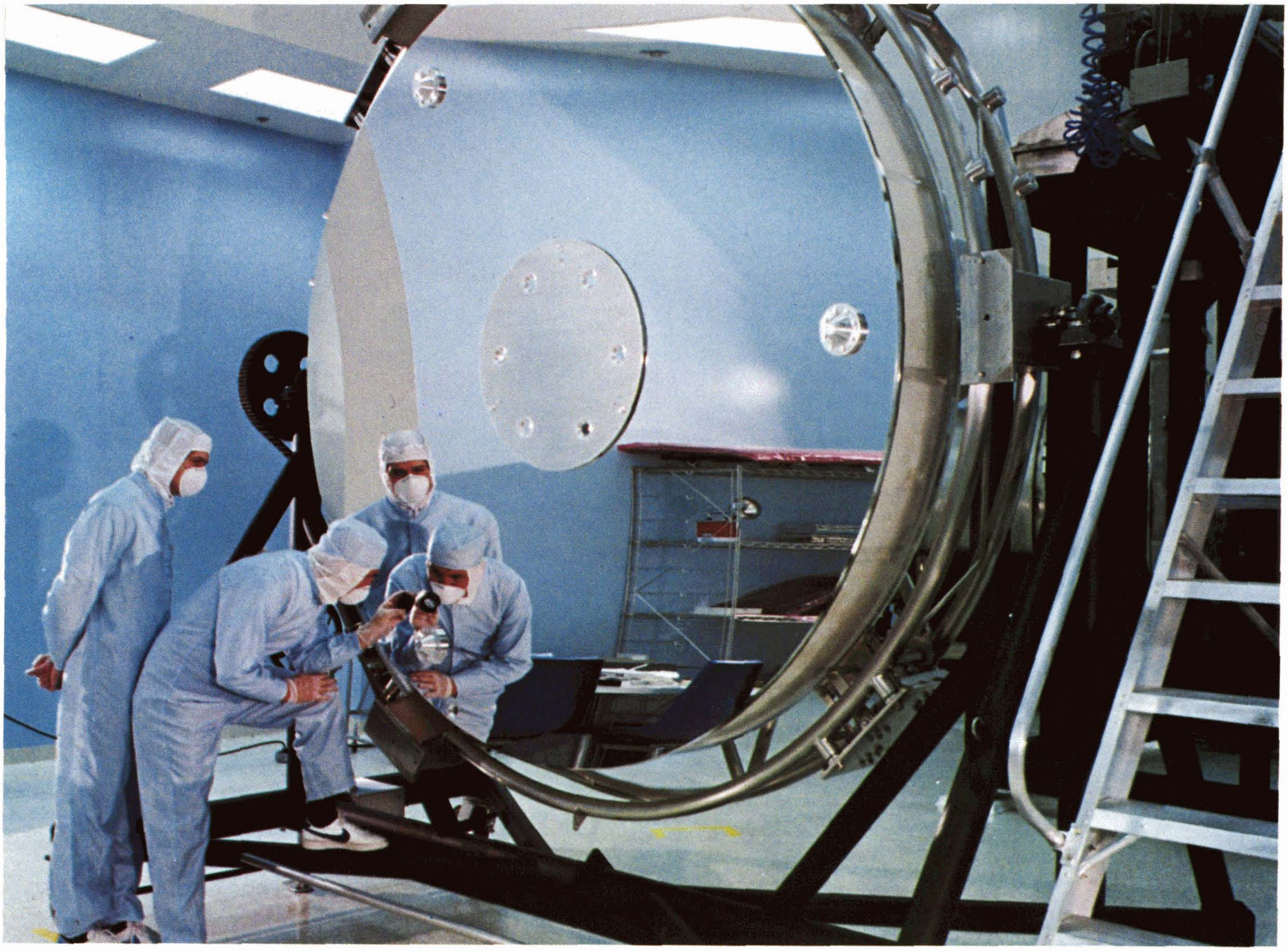
COMET STUDIES

Comets represent a particularly important area of space science research because they are believed to contain material relatively unchanged by time, hence offer clues to the earliest physical and chemical make-up of the solar system. Last summer, NASA's International Ultraviolet Explorer took ultraviolet images of the newly discovered Comet Austin as it approached Earth and the Sun. Also in 1982, NASA initiated a new comet investigation that will utilize a satellite already in orbit—ISEE-3 (left), one of three International Sun-Earth Explorers. Controllers at Goddard Space Flight Center, which designed and built the spacecraft, fired ISEE-3's propulsion system to nudge it out of its Sun-monitoring orbit into a new path that—after additional course corrections—will take it to a September 1985 rendezvous with Comet Giacobini-Zinner; then the spacecraft will fly directly into the comet's tail. Although ISEE-3 has no imaging equipment to take close-up pictures, its instruments can provide valuable data on temperatures, gases, particles and magnetic forces within the tail. When Comet Halley makes its once-every-76-years close encounter with the Sun six months later, ISEE-3 will provide solar wind data complementing direct observations of Halley by other spacecraft.

The Halley encounter will be the best documented event in the history of comet studies and NASA will play an important role in coordinating the flow of information. In 1982, NASA sponsored establishment of an International Halley Watch (IHW); composed of scientists all over the world, it will conduct one of the most comprehensive scientific investigations ever undertaken. The scientists will make observations, analyze data and monitor the operation of many types of instruments aboard spacecraft, balloons and aircraft and at Earth-based facilities. All of this information will be channeled to a central Halley Archive. Co-leaders of the IHW are NASA's Jet Propulsion Laboratory and the Remeis Observatory of the University of Erlangen-Nurnberg.



Japan, the Soviet Union and the European Space Agency (ESA) will each send a spacecraft to intercept Halley and study it at close range. The U.S. will participate in the ESA mission, named Giotto; the U.S. will have co-investigators for nine of the 10 instruments that make up the Giotto payload. Giotto will take color images of the comet's nucleus and its instruments will provide data on the chemical composition of the coma—a hazy, luminous region surrounding the nucleus—and the multimillion-mile-long tail. At lower left, the artist's rendering shows Giotto en route to an intercept with Halley, depicted in nucleus form (the long tail does not materialize until the comet gets close to the Sun and the pressure of solar radiation initiates the buildup).

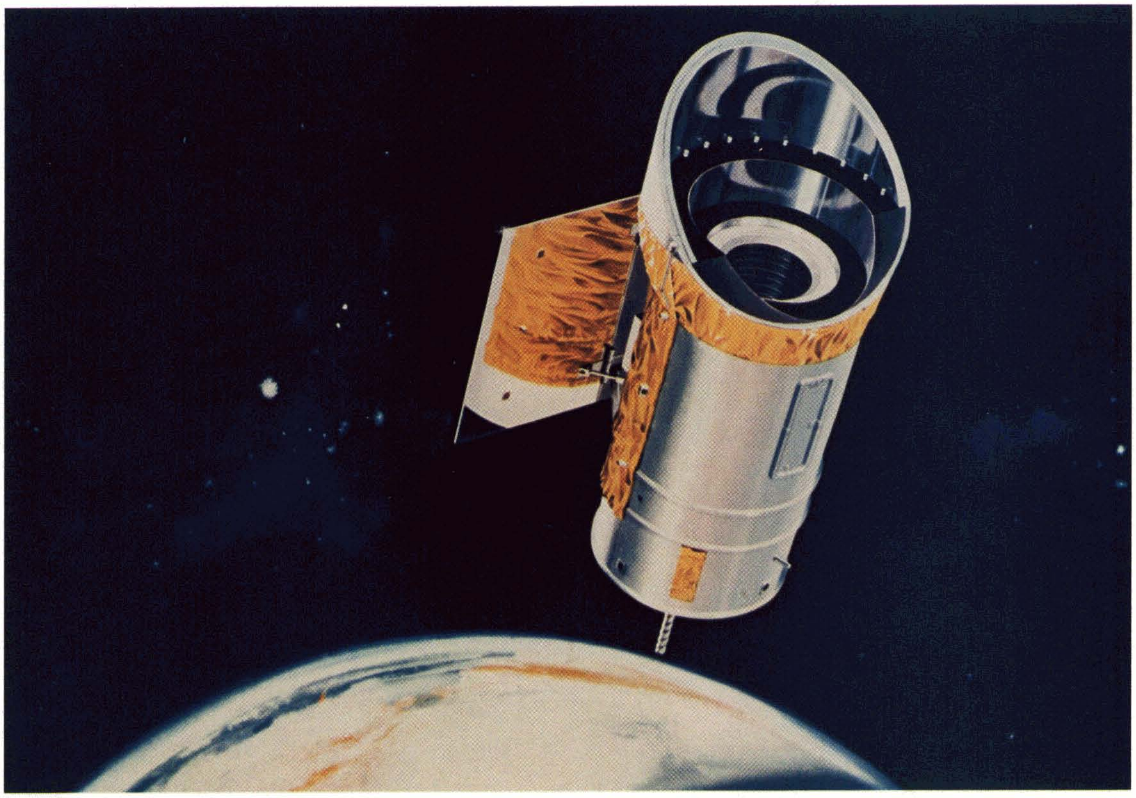


SPACE TELESCOPE

Operating above Earth's atmosphere, which blurs observations from the ground, NASA's Space Telescope will peer seven times farther into space than the largest ground-based telescopes and provide images of celestial bodies with at least 10 times better clarity of detail, opening up an entirely new view of the universe. To be Shuttle-launched in 1986, it will detect objects 50 times fainter than can be picked up by Earth-based observatories. Because light from distant galaxies takes so long to reach Earth, the Space Telescope will literally allow scientists to look back in time billions of years. Some of the light the telescope will capture was generated before our solar system existed; astronomers may be able to see to the very edge of the universe.

The Space Telescope passed a major milestone early in 1982, when its eight-foot-diameter primary mirror was successfully coated in a vacuum chamber. The coating process involved application of a layer of vaporized aluminum to enhance the mirror's reflectivity (above), plus a layer of magnesium fluoride to protect the exquisitely polished surface; the combined coatings are less than three-millionths of an inch thick. The primary mirror is the key element of the Optical Telescope Assembly (OTA), being produced by Perkin-Elmer Corporation. Lockheed Missiles and Space Company is building the other major element of the Space Telescope—the Support Systems Module, which houses the OTA and associated scientific instruments and also provides electrical power, communications and data management. The European Space Agency is furnishing the solar array and one of the five scientific instruments.

Next year, Lockheed will start assembling the complete 43-foot-long, 12-ton spacecraft. Marshall Space Flight Center is managing Space Telescope development. When the system becomes operational, it will be controlled by Goddard Space Flight Center. Images and data from the telescope will be transmitted to Goddard, thence to a new Space Telescope Science Institute at Johns Hopkins University in Baltimore, Maryland, where astronomers will view the images, inspect the data and get printed or taped readouts for further analysis at their home institutions. The Institute will be operated by a 16-university consortium known as the Association of Universities for Research in Astronomy.



ORBITING OBSERVATORIES

Starlight represents only a small portion of the radiation coming from distant space. Much of this energy—x-rays, ultraviolet and infrared radiation, for example—never reaches Earth; it is absorbed or filtered by Earth's atmosphere, hence is largely invisible to ground observatories. The dawn of the Space Age made it possible to view these non-visible radiations from *above* the atmosphere with specially-designed telescopes and other instruments. Over the past two decades, a number of spacecraft have made observations in the gamma ray, x-ray, ultraviolet and infrared regions of the spectrum and uncovered a wealth of important information. This work has made it clear that further and more comprehensive investigation of radiations not visible from Earth holds enormous promise for unraveling the secrets of the universe. Fields such as x-ray astronomy have moved into a central position along with the more traditional fields of optical and radio astronomy.

NASA is developing a series of advanced astronomy systems to complement visible light observations by ground and space-based optical telescopes. Launched in January of this year, the first (above) is the Infrared Astronomical Satellite (IRAS), a three-nation project in which the U.S. (NASA) provided the telescope and launch services, The Netherlands the spacecraft and the United Kingdom the control center. IRAS' sensitive equipment opened up a new frontier of astronomy by detecting cool and cold celestial objects that do not shine in visible light but emit radiation in the infrared wavelengths. IRAS has, for example, detected stars being born, stars in their death throes, and a score or more of distant galaxies never before mapped. It will map as many as a million infrared sources for future study, charting the universe in an entirely new perspective. Jet Propulsion Laboratory is NASA's manager for the IRAS project; Ames Research Center

managed development of the 24-inch telescope, which was built by Ball Aerospace Systems.

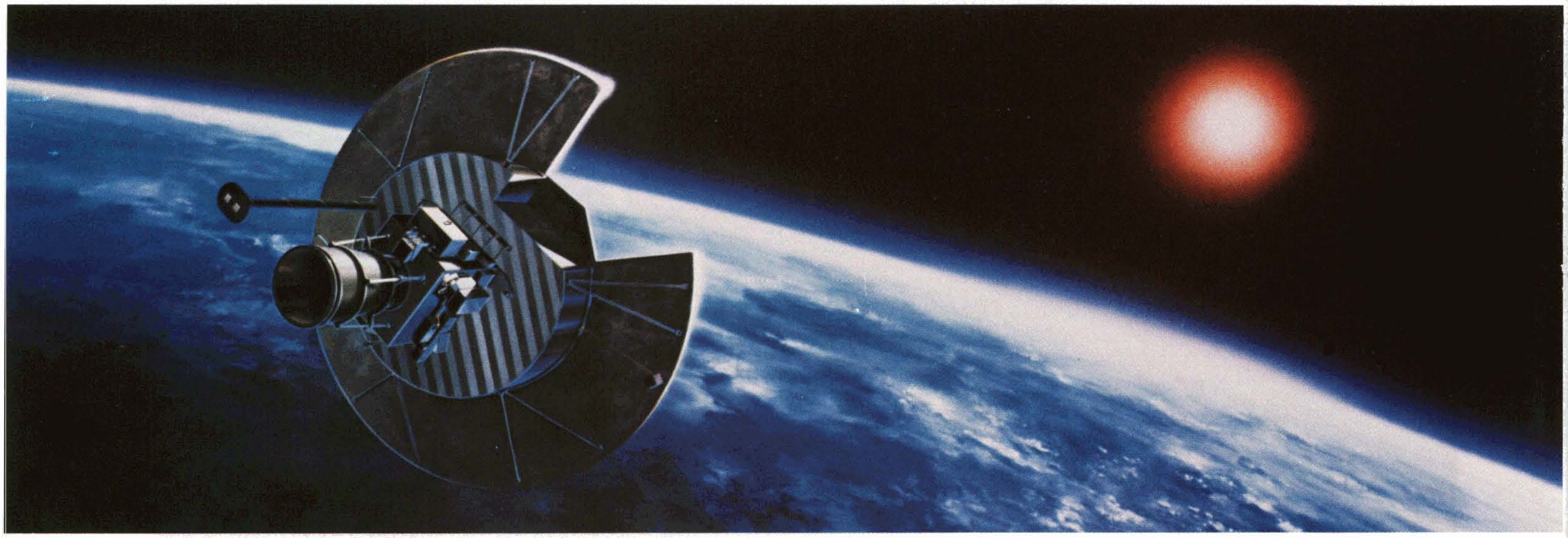
A follow-on to IRAS, planned for service late in this decade, is the Shuttle Infrared Telescope Facility (SIRTF), a system to be flown aboard the Shuttle Orbiter. Like IRAS, but with even greater detection sensitivity, SIRTF will study the cool regions of space, such as the planets, asteroids and comets of the solar system, and dust and gas clouds where stars are forming.

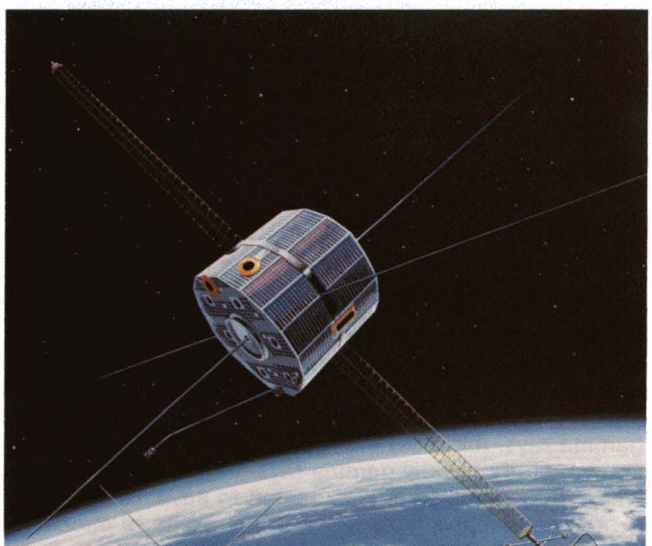
Among other new astronomy projects are the Cosmic Background Explorer (COBE) and the Gamma Ray Observatory (GRO) to be launched in the latter 1980s. COBE will be the first satellite designed specifically to observe details of the "Big Bang," the monumental explosion believed to have marked the beginning of the universe. Operating far from the influence of Earth's atmosphere, COBE's instruments will map radiation at a large number of different wavelengths, seeking clues as to how the first galaxies were formed and the nature of the Big Bang itself. The GRO spacecraft (left), managed by Goddard Space Flight Center, will investigate gamma rays, the most energetic form of radiation known; study of how gamma rays are produced and where they come from is expected to advance significantly man's knowledge of the origin of chemical elements and the evolution of the universe.

To meet a need for an advanced imaging telescope to explore x-ray sources in space, NASA plans development of a 43-foot, 11-ton observatory known as the Advanced X-ray Astrophysics Facility (AXAF). With instruments that will have about 100 times the sensitivity of those in prior x-ray spacecraft, AXAF (above) will provide information on the forces involved in the creation of stars, galaxies, quasars and black holes. The project is to be managed by Marshall Space Flight Center.

GLOBAL ENVIRONMENT

A most important area of space science research seeks knowledge of how energy from the Sun is transported to Earth, how it drives Earth's environment and how man's activities may influence the physical and chemical reactions that take place in a buffer zone between Earth and space. Coursing through this buffer zone at more than a million miles per hour is an

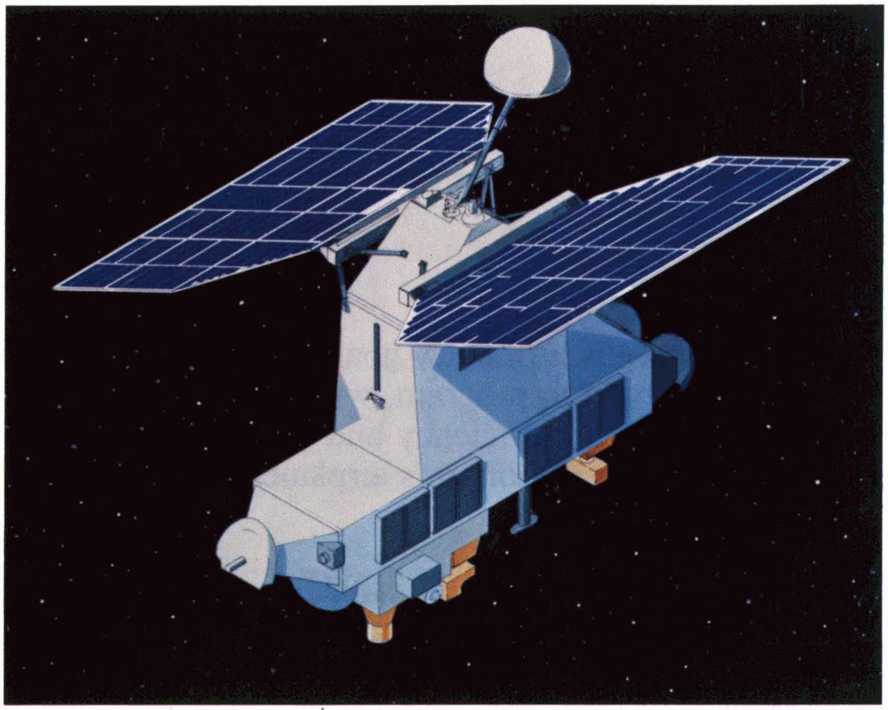




electrified gas emitted by the Sun; known as the solar wind, it transfers energy from the Sun to the Earth through a chain of complex reactions with Earth's magnetic fields, its ionosphere and its upper atmosphere. This energy transfer sometimes produces marked effect on Earth's atmosphere, weather, communications and power transmissions.

A first requisite toward protecting Earth's environment is learning a great deal more about the little understood physical processes that link Earth and the Sun. NASA is conducting an integrated program of research, involving a number of satellites, to study Earth's "total environment" from the region where the solar wind begins to interact with Earth's magnetic fields (magnetosphere) all the way down to the lower atmosphere.

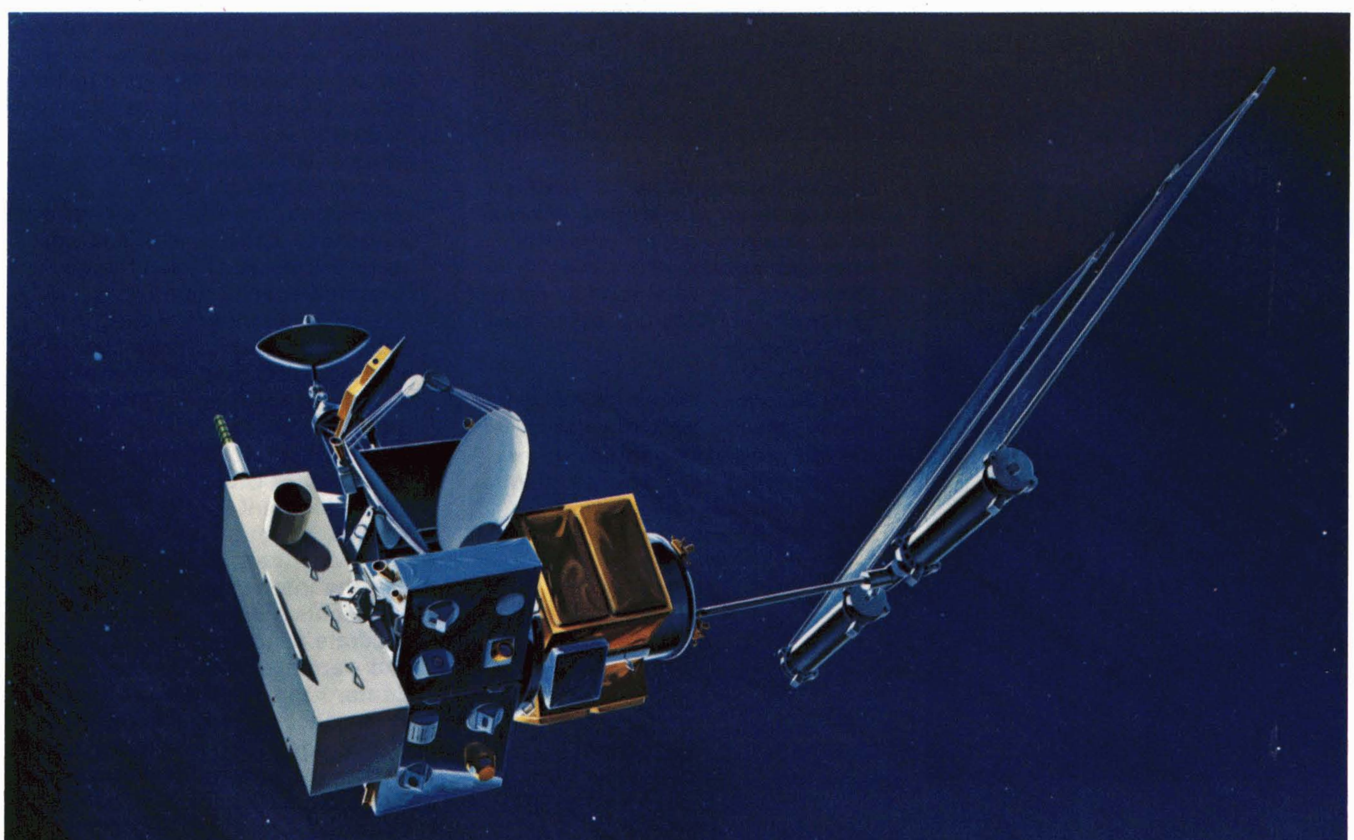
Among currently operational members of the satellite family are the Solar Mesosphere Explorer (SME) and two Dynamics Explorers, all launched in 1981. The SME (top) is investigating how Earth's ozone layer is influenced by solar energy transfer or by man-made and natural contaminants; reduced ozone concentration would increase the amount of ultraviolet radiation that reaches Earth with possible adverse effect on life. The two Dynamics Explorers (left), working as a team, are studying the massive transfer of solar energy into the magnetosphere, thence to the ionosphere and eventually to Earth's upper atmosphere.



The SME project is managed by Jet Propulsion Laboratory; Ball Aerospace Systems built the spacecraft. The Dynamics Explorers were built by RCA Astro-Electronics; Goddard Space Flight Center is project manager.

A pair of spacecraft known as Active Magnetospheric Tracer Explorers, one supplied by NASA and the other by the Federal Republic of Germany, will be launched next year to study how plasma—the electrified gas in the solar wind—is transported in the magnetosphere.

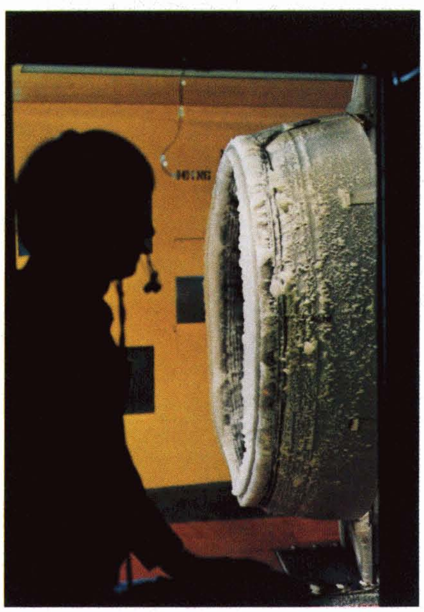
Also slated for launch next year is NASA's Earth Radiation Budget Explorer (ERBE), being developed by Ball Aerospace Systems under Goddard management. Shown above, ERBE will investigate how energy from the Sun is distributed throughout Earth's environment, a step toward understanding the mechanisms that determine Earth's climate; the long range goal is to develop a capability for anticipating climate trends that influence planning in such areas as agriculture, energy and natural resources. For launch late in this decade, NASA is planning an advanced Upper Atmosphere Research Satellite (below) to make global observations of the chemical composition and energy transfer mechanisms in the upper atmosphere. A major objective of this project is to expand the knowledge provided by the Solar Mesosphere Explorer as to how human activities affect the ozone layer.



FLIGHT PLAN FOR THE FUTURE

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

Can lightning strike the same object twice? It certainly can. In fact, at Langley Research Center there is an "object" that has been struck more than 170 times. It is a specially protected F-106B fighter instrumented as a "storm penetrator." The job of the pilots who fly it is to penetrate thunderstorms at various altitudes and collect data on direct lightning strikes, turbulence, wind forces, x-rays and the atmospheric chemistry of severe storm conditions. The Langley work focuses on learning more about how lightning affects aircraft in flight and how future aircraft may be protected.



Langley Research Center's F-106B is a lightning seeker in a program aimed at providing aircraft greater protection from lightning and other storm phenomena. The white scars on the blue background are lightning strikes, more than 170 of them.

Lewis Research Center's Icing Research Tunnel simulates ice accumulations on airplane components—in this case an engine cowling—as part of an effort to develop technology for advanced ice protection systems.

The F-106B flights are part of a broader program of meteorological hazard research in which NASA is cooperating with the Federal Aviation Administration (FAA), the Department of Defense, the National Oceanic and Atmospheric Administration and other agencies. A principal area of investigation is low level windshear, a sudden change in wind direction or velocity that is a reported cause of many aircraft accidents. The goal of this research is technology development for better ways to detect and warn pilots of windshear conditions.

Ames Research Center is conducting research on an airborne windshear detector with a range up to five miles. Dryden Flight Research Facility operates a specially instrumented B-57 airplane for storm flying. Last year it participated in a comprehensive windshear study—in cooperation with the FAA, the National Center for Atmospheric Research and the University of Chicago—known as JAWS, for Joint Airport Weather studies. Although JAWS data is still being analyzed, researchers feel that the information acquired represents a big step toward accurate windshear measurement and warning. Ames Research Center is also flying a C-141 aircraft in investigations of clear air turbulence (CAT), which can cause passenger/crew injuries, possibly airplane damage or partial loss of control; CAT cannot yet be predicted with the precision needed to guarantee avoidance. The Ames C-141 flights are evaluations of a new type of CAT detector developed by Jet Propulsion Laboratory (JPL).

With all-weather flying on the increase in both civil and military operations, icing research has taken on new importance. Lewis Research Center operates a unique Icing Research Tunnel for simulation of ice accumulations on airfoils, engine intakes and other parts of aircraft. The aim is development of technology for ice protection systems that are more effective yet require less weight and power than contemporary systems.

To improve occupant survivability in post-crash fires, Ames Research Center and Johnson Space Center are developing fire-resistant cabin interior materials in cooperation with the FAA. Johnson and Ames sponsored development of lightweight seat cushions that demonstrated, in full-scale fire simulations, dramatic improvement in fire resistance. Development of lightweight ceiling, wall and floor panels, including composite panels that do not produce toxic gases when subjected to fire, is in progress. Ames, Lewis and JPL are all supporting the FAA in evaluations of a British-developed anti-misting safety fuel designed to eliminate a fire propagation source by preventing the jet fuel mist cloud that develops when a wing tank is ruptured. In a related effort, NASA is developing technology for new structures intended to absorb a good part of the energy of a crash impact and thereby reduce the crash forces transmitted to passengers. As part of a NASA/FAA program to improve transport aircraft crashworthiness, NASA is preparing instrumentation and data collection systems to record what happens during a full-scale crash test of a Boeing 720 jetliner next year.

Among other NASA safety programs are human factors research toward better understanding of aircrew capabilities and limitations; flight simulations to provide guidelines for airlines in developing training programs; evaluations of anti-skid devices on wet runways; development of new braking systems and research on advanced blowout-resistant tires; and flight tests toward finding new ways of preventing accident-causing stalls and spins in light aircraft.

Safety investigations constitute one facet of NASA's broad aeronautical research program, which also embraces research toward improving the performance, efficiency and environmental acceptability of general aviation planes, rotary wing aircraft, small transports, advanced jetliners and high-performance military aircraft. While most of the program's objectives relate to the design of future aircraft and systems, much of the technology generated is also applicable to current problems.

NASA, together with industry and other government agencies, is making a special effort to assure that certain technologies important to the U.S. transportation system—for example, safety improvements, short-haul transports, tilt-rotor aircraft, aircraft noise reduction, environmental improvements and new considerations for passenger comfort—are brought more rapidly to operational service.

This comprehensive effort pays dividends to the nation in several ways. It strengthens the position of American plane builders in the international marketplace at a time when they are meeting greater-than-ever competition from abroad, with many thousands of jobs at stake; it provides important technological input to national defense; it contributes to lower airline operating costs, to the advantage of passengers, shippers and operators; it helps make flight safer for all who fly; and it benefits everyone by improving the environmental characteristics of the airplane.

In this structure at Langley Research Center (left), NASA crashes full-size aircraft as part of a program to improve the crashworthiness of airplane structures; the result of one test is shown below.

HIGH-SPEED AIRCRAFT

NASA's High-speed Aircraft Technology program is concentrated on exploration of concepts applicable to future military vehicles, including advanced tactical aircraft, powered-lift vertical takeoff and landing aircraft, air-breathing and rocket-propelled missiles and hypersonic vehicles. Most of these activities are cooperative programs with industry and Department of Defense agencies such as the Air Force, Navy and the Defense Advanced Research Projects Agency.

NASA is teaming with the USAF and Navy on the Advanced Fighter Technology Integration (AFTI) program. The first project is the AFTI F-16, a modification of the General Dynamics F-16 fighter in service with the USAF and NATO. The AFTI F-16 (left), flown for the first time in July 1982, incorporates a number of advanced technologies, chief among them a digital "fly-by-wire" control system in which the controls are actuated by electronic signals rather than the conventional complex of rods and linkages. Langley Research Center conducted wind tunnel tests of the AFTI F-16 (below) and the Ames/Dryden Flight Research Facility (DFRF) is responsible for the joint flight tests and data analyses. The test program consists of some 270 flights to be completed in 1984.

Scheduled for first flights in 1983 is the AFTI F-111, also known as the Mission Adaptive Wing project. Boeing Aerospace Company modified a General Dynamics F-111 fighter to incorporate a wing design in which the camber—the fore-aft curve of the airfoil—can be changed in flight, a major aerodynamic "first." The design employs a number of actuators to deflect the wing's leading and trailing edges, allowing the wing

to assume many different shapes for optimum performance over a wide range of flight modes: maneuvering, moderate-speed cruise or high-speed penetration. NASA's role in the AFTI F-111 project includes wind tunnel testing at Langley and flight testing at Dryden.

Another major project involves the X-29A (right), a flight demonstrator for an innovative design in which the wing is swept forward rather than rearward. This is a concept first studied more than 40 years ago but rejected because of structural problems induced by the enormous bending stresses encountered by a foreswept wing; advances in composite material technology have made it possible to overcome the "structural divergence" problem and to build a low drag, high-performance vehicle that is considerably lighter than equivalent performance aircraft with aft-swept metal wings. NASA wind tunnel tests at Ames and Langley Research Centers indicate that the X-29A will have greater maneuverability at transonic speed, superior low-speed flying qualities, short takeoff and landing characteristics and greater range than comparable fighters. The demonstrator is being built by Grumman Aerospace Corporation under funding by the Defense Advanced Research Projects Agency; the project is managed by the Air Force Flight Dynamics Laboratory. After initial flights at the Grumman plant, NASA will conduct a comprehensive flight test program at Dryden.

Another example of high-speed aircraft technology effort is one in which NASA teamed with General Dynamics Corporation on a company-funded modification of the F-16 fighter known as F-16XL (below). In this program, NASA applied technology originally developed for advanced supersonic civil transports to produce a new "arrow wing" for the F-16XL. The arrow wing has more than twice the area of the standard F-16 wing and it permits the XL to carry 80 percent more fuel internally. In addition to significantly increased range, the design promises a balance of excellent flying qualities at high and low speeds, shorter runway requirements, high penetration speeds and better overall combat performance. Ames and Langley supported development of the F-16XL with wind tunnel and simulator tests. The first of two XLs—a single-seater—made its initial flight in July 1982; the two-seat version flew in October.

HiMAT

The uniquely shaped airplane pictured is one of two unmanned test craft in the joint NASA/Air Force Highly Maneuverable Aircraft Technology (HiMAT) program, in which a number of advanced technologies for future high performance military planes have been tested in flight. The HiMAT vehicle has a forward "canard" surface in addition to its primary wing, a combination that offers exceptional maneuverability; HiMAT can make very tight turns at supersonic speeds and has a maneuvering capability substantially greater than that of today's operational fighters.

Built by Rockwell International and flown at Dryden Flight Research Facility, HiMAT is a remotely-piloted research vehicle that is air-dropped from a B-52 carrier plane, then operated by a pilot in a ground-based cockpit. This concept, developed by NASA Dryden, permits high-risk testing without hazard to the pilot and reduces the cost of the test vehicle by avoiding the expensive systems normally required for pilot occupancy and safety.

First flown in 1979, HiMAT began supersonic flights in 1982, gradually increasing speed until it reached the design point of Mach 1.4, more than 900 miles per hour at 40,000 feet. This completed the flight test portion of the program. NASA and the Air Force are now analyzing the extensive data acquired in the areas of stability, flight controls, structures and propulsion.

QUIET SHORT-HAUL JET

The Quiet Short-haul Research Aircraft (QSRA) is an experimental pathfinder for future short-haul transports operating from short runways at close-to-city airports with minimal noise impact on the surrounding community. The principal research aim of the QSRA program, which is managed by AMES Research Center, is validation of the technology known as "propulsive lift"—use of engine exhaust as an auxiliary lifting force. In this installation, the propulsive lift technique involves deflection of the exhaust from the QSRA's four turbofan engines across the upper surfaces of the specially-designed wing and flaps, then downward; this creates very high lift that allows steeper climbout and approach paths and low-speed, short-roll landings. The extra lift enables the QSRA to operate from runways measuring 1,500 to 4,000 feet, compared with the mile or more needed by conventional jetliners.

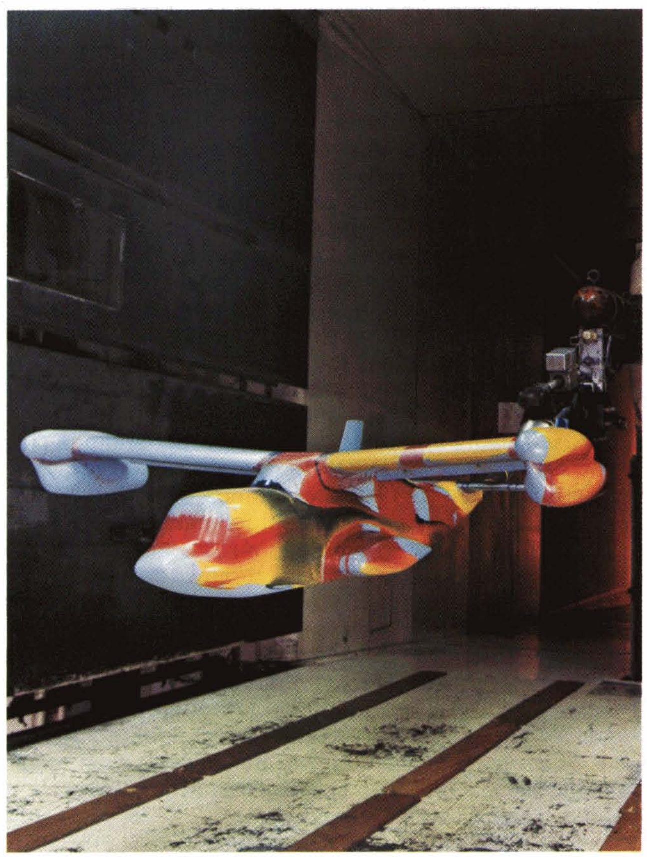
The QSRA's engines are soundproofed to muffle internal noise. External noise is reduced by the fact that the engines are mounted above the wing; the wing blocks the sound of engine exhaust and diverts it upward, away from listeners on the ground. The plane's steep climbout and descent characteristics further reduce the overall noise impact. Although it is a relatively large airplane—in the 50,000 pound class—the QSRA can operate at lower noise levels than most small business jets. The craft was built by Boeing Commercial Aircraft Company.

TILT ROTOR AIRCRAFT

The XV-15 Tilt Rotor Research Aircraft pictured is an experimental forerunner of a new type of vehicle that affords significant advantages in both civil and military air transportation. Built by Bell Helicopter Textron under the joint sponsorship of NASA and the U.S. Army Research and Technology Laboratories, the XV-15 is a convertible rotorcraft that combines the unique flight capabilities of the helicopter with the greater forward speed of a fixed-wing airplane. It has helicopter-like rotors for vertical takeoff, hovering and landing; for cruise flight, its rotors tilt forward to become propellers that drive the craft at speeds up to 350 miles per hour.

One of the two XV-15s is shown landing (above) on the Navy aircraft carrier *USS Tripoli* during sea trials last year. This was one of a series of operational demonstrations to the military services during 1982; proof-of-concept flight testing also continued in a program jointly managed by Ames Research Center and the Army Aviation Research and Development Command.

Bell Helicopter Textron has teamed with Boeing Vertol Company for further development and marketing of both military and commercial tilt rotor applications. At right, a military version is undergoing test in the Boeing wind tunnel; the rainbow effect results from injection of varicolored oils into the airstream to get a visual impression of how air flows over the model's surfaces at different simulated speeds.



ROTARY WING RESEARCH

To build a technology base for coming generations of helicopters and other rotor-driven vehicles, NASA and the U.S. Army are conducting a multi-year flight program with two Rotor Systems Research Aircraft (RSRA), heavily-instrumented airborne laboratories for study, under actual flight conditions, of a wide variety of rotors and supporting systems. The RSRA is shown right in its basic helicopter configuration. It becomes a compound helicopter (below) by the addition of short fixed wings and two auxiliary jet engines; the extra lift and power thus provided allow testing of smaller rotor systems that could not by themselves support the RSRA. The two aircraft were built by Sikorsky Aircraft, a division of United Technologies, under the direction of Langley Research Center and the U.S. Army Research and Technology Laboratories; Ames Research Center manages the flight program.

In 1982, the RSRA completed the initial phase of the research effort, involving detailed measurements of aerodynamic loads on the rotors and fuselage in hovering and low-speed forward flight. In advanced tests, the aircraft will check out different rotor systems over a wider range of operating conditions. The aim is to develop technology toward increasing the speed, performance, reliability and safety of rotary wing aircraft and reducing noise, vibration and maintenance.

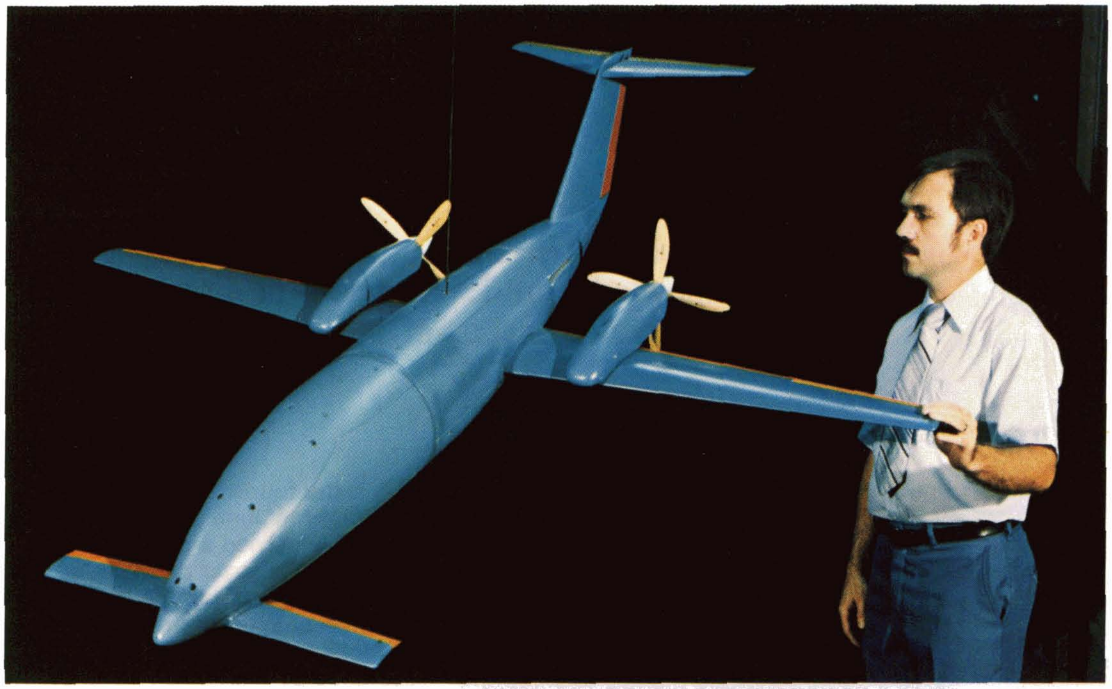
ADVANCED TURBOPROP

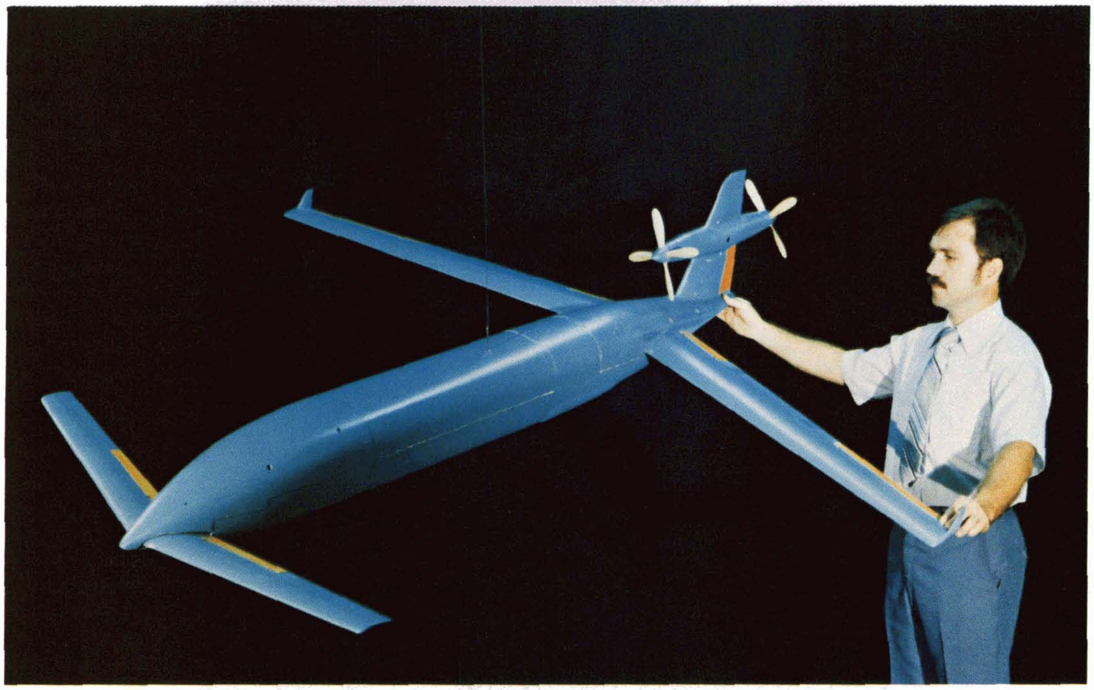
'spite a moderation in jet fuel prices last year, ' remains a pressing problem for the airline and operators of business jets. NASA has for ears conducted an Aircraft Energy Efficiency rogram that has produced a number of innovations, some of which have already porated in operational aircraft. ACEE with investigations of new ways to improve aerodynamic efficiency, along with ways of rcraft weight for reduced fuel consumption. most promising projects is the Advanced 'rogram.

rop engine has inherently better fuel n the jet engine, but when jets made their debut in commercial service a quarter-century ago the turboprop lost favor because propeller tip speed limitations restricted airplane speed. Now, however, researchers have found that advanced technology multi-bladed swept-tip propellers could provide jetlike speeds with sharply reduced fuel consumption. Wind tunnel tests of model propeller assemblies have indicated that turboprops offer fuel savings of 15–20 percent over equally advanced turbofan engines and perhaps 40 percent or more over some older jet engines still in service.

Lewis Research Center, in cooperation with NASA's principal contractor in the program—United Technologies' Hamilton Standard division—continued ground and flight tests of small-scale propellers in 1982 and established a concept for a large-scale, nine foot diameter propeller assembly for further research.

There has been concern that high inside-the-cabin noise levels would be an obstacle to development of a fuel efficient high-speed turboprop airliner. One phase of the NASA research addresses that problem; it involves propeller noise tests in acoustic chambers and flight tests of a small-scale multi-bladed propeller assembly to measure noise levels impinging on fuselage surfaces. At left is an in-flight view of the test system mounted atop a Lockheed JetStar; below is a closeup of the test installation. More than a score of microphones on the JetStar's fuselage and wing record noise levels at various distances from the test assembly; this data will be used in design of acoustic treatment to bring the cabin noise level of a turboprop aircraft down to the level of a turbofan airplane.





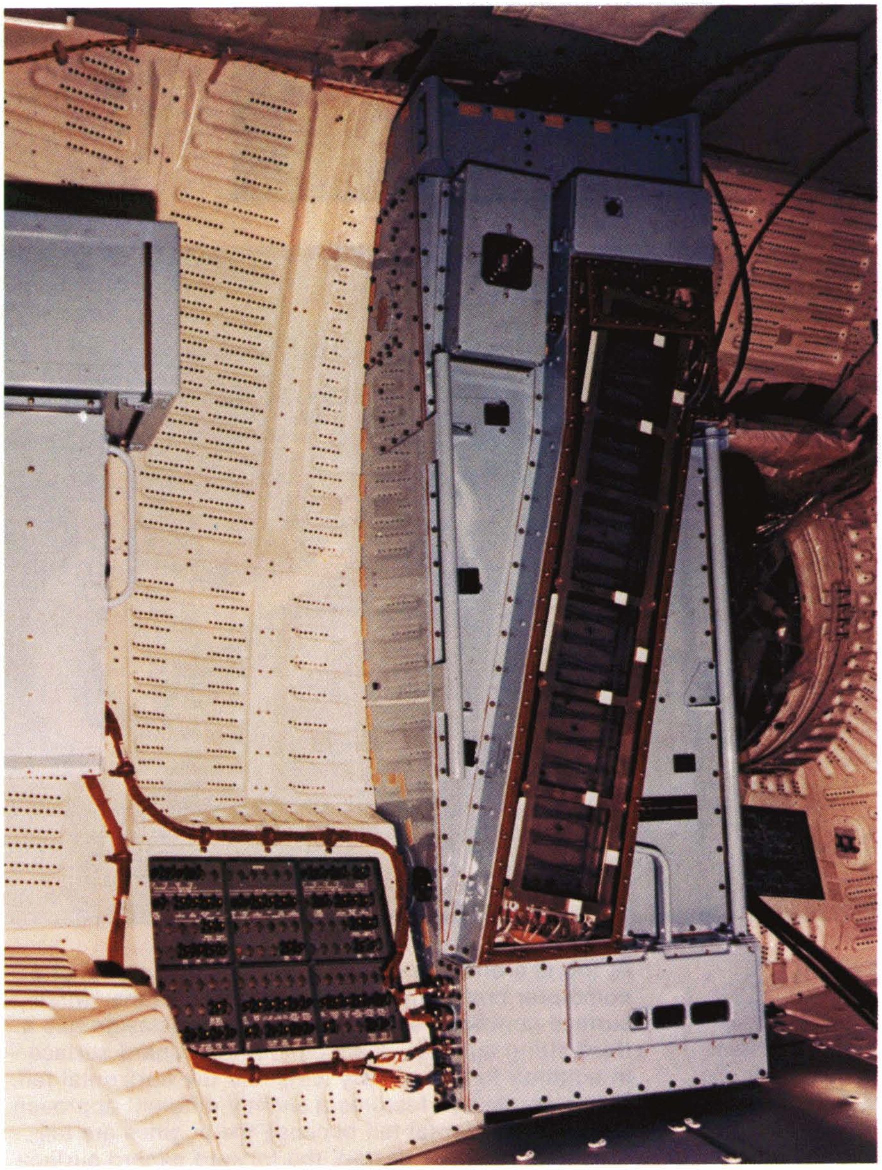
COMMUTERLINER STUDIES

Short-haul commuter service is one of the fastest growing segments of the air transportation industry and there are indications that it will grow at an even faster pace in the coming decade. To give U.S. aircraft manufacturers a technological headstart on the next generation of commuter airliners, NASA is conducting computer design analyses, wind tunnel testing and other research in aerodynamics, propulsion, materials, controls and guidance systems. These efforts focus on the technology needed for efficient 20–60 passenger commuterliners that will be larger, faster, longer ranging and more cost-effective than current types.

The accompanying photos show two of many designs being investigated at Langley Research Center. At top is a one-seventh scale wind tunnel model of a commuter craft utilizing what is known as the "three surface concept," so called because the design has a third lifting surface—a nose-mounted canard surface—in addition to the primary wing and the horizontal tail. The lower design features a slightly different approach; it has no horizontal tail because the engines are tail-mounted. In either design, the forward canard surface enhances low speed stability and control and the long, slender wing provides greater lift efficiency for an airplane that would spend much of its time climbing or descending. The rear-mounted engines, whether on the tail or on either side of the fuselage, promise lower cabin noise levels. The narrow wing, extensive use of lightweight composite materials and computerized electronic controls would all combine to make the commuterliner exceptionally fuel efficient.

TECHNOLOGY FOR EARTH BENEFIT

NASA is applying aerospace technology and scientific knowledge in development of direct benefit systems to serve the needs of industry and the public



The "gray box" above, installed on the mid-deck of the Orbiter **Columbia** *for the fourth Space Shuttle flight, housed a historic payload called EOS, the first commercial experiment in orbital processing of materials. At right, the EOS system—an experiment in gravity-free pharmaceutical processing—is undergoing a laboratory test at McDonnell Douglas Astronautics Company. Manufacturing in the airless, weightless space environment holds promise for a broad range of superior products not producible on Earth due to the negative influences of atmosphere and gravity.*

On the fourth Space Shuttle flight in June 1982, the Orbiter *Columbia* carried a payload that may in future years be regarded as a historic milestone, the initial step in a new chapter of the industrial revolution. Called EOS and designed by McDonnell Douglas Astronautics Company, it was the first commercially sponsored experiment in orbital processing of materials, a burgeoning technology that promises Earth benefits of extraordinary magnitude.

EOS stands for Electrophoresis Operations in Space; not exactly a household word but a familiar term among medical personnel, electrophoresis is a widely used process involving electrical stimulation of a biological substance to separate the constituents of a mixture so that they can be analyzed—the blood test is an example. Electrophoresis provides good separation, but it has a drawback: Earth's gravity exerts a negative influence on the process, so that only a tiny amount of sample can be extracted at one time. That's why electrophoresis is used only for analysis, not for pharmaceutical production.

McDonnell Douglas and its partner in EOS—Ortho Corporation, a division of Johnson and Johnson—are conducting the program to find out how electrophoresis works in the gravity free environment of orbital space. The results of the first experiment were dramatically encouraging: the automatic EOS equipment aboard the Shuttle Orbiter produced more than 450 times as much biological material as could be expected from a similar process on Earth. Since gravity also affects the purity of the pharmaceutical product, the EOS team expects to demonstrate, on later Shuttleborne tests, that purity can be increased as much as five times by processing in weightless space. The combination of greatly expanded output and much improved purity suggests the possibility of a whole new line of space-processed pharmaceuticals for more effective treatment of many diseases, perhaps entirely new curatives that do not exist today.

The exciting potential of orbital processing is by no means limited to pharmaceuticals. Gravity and atmosphere adversely affect many other material processes—alloying metals, for example. Certain combinations of metals will not mix at all in the presence of gravity; others will combine, but not uniformly. Processing in space, with gravitational effects eliminated, offers the possibility of producing a wide range of materials with properties vastly superior to those made on Earth—for example, metallic superalloys much lighter yet far stronger and far more temperature-resistant than existing alloys.

Both gravity and air combine to hamper Earth production of silicon crystals that are sliced into wafers, then made into semiconductors. Orbital processing could allow growth of large, perfect crystals with enormously better electrical properties, greatly improving the end products in which crystals are used—computer memories, lasers, solar cells, optical communications and a multitude of industrial and scientific instruments.

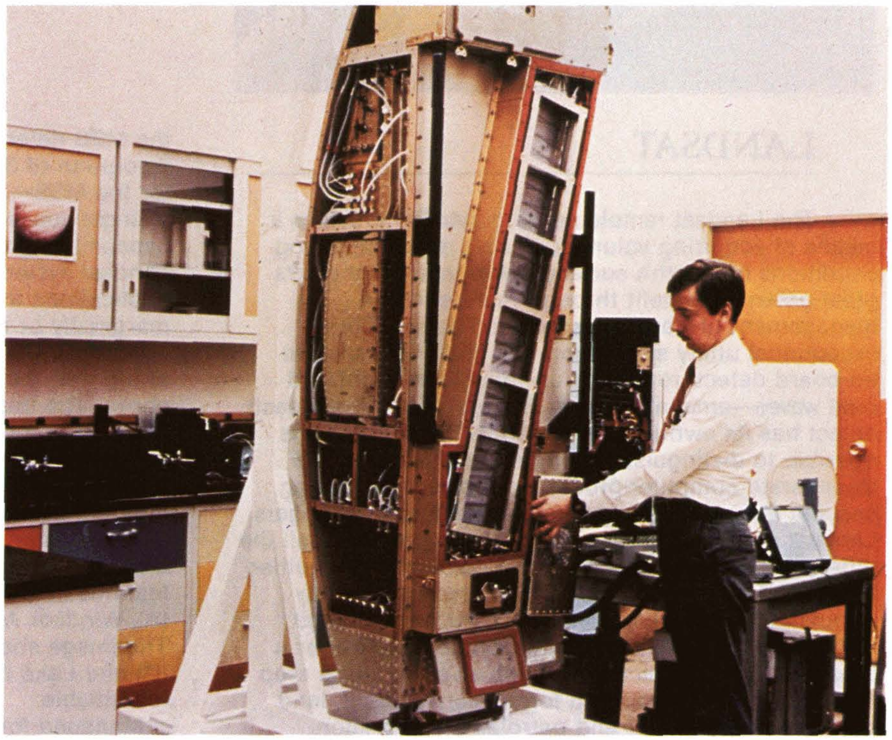
Aside from drugs, high purity is very important in many other types of material processing—for example, glass for laser and optical systems or tungsten for x-ray tubes. But it is impossible to get total purity because these materials are contaminated by the containers in which they are processed. Although it is difficult to envision, space processing offers the interesting posibility of *containerless* processing—melting, shaping and solidifying materials while they float freely in near-zero gravity.

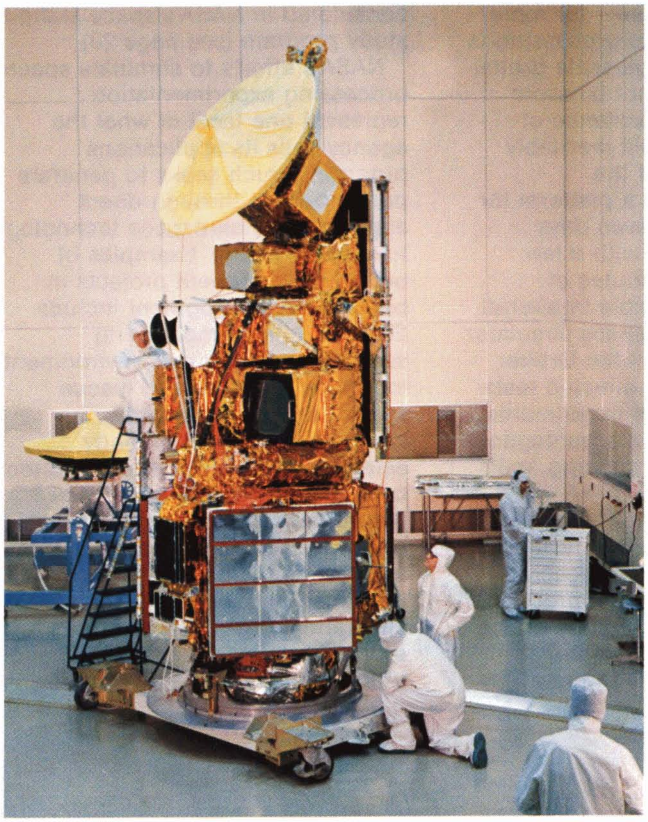
NASA and industry studies have identified some 500 materials that could be advantageously processed in orbit to create a wide range of superproducts of particular benefit to medicine, metallurgy and electronics. A 1982 survey showed that more than 250 companies are seriously interested in space processing. So far most have limited their interest to cautious study of the potential and the requisite cash outlays, but a pioneering few have committed to investment in experiments.

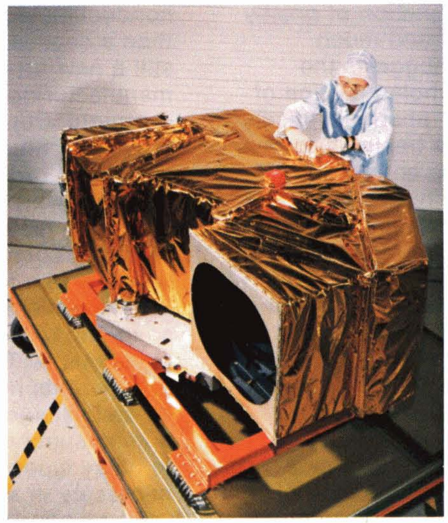
Although NASA has been conducting experiments for more than a decade, space processing is still a new art and full-scale orbital manufacturing will not blossom overnight. But the existence of the Space Shuttle will inevitably accelerate growth of the technology; it offers a platform for long-term tests of seven days duration, compared with a few seconds to a few minutes of weightlessness possible in aircraft, sounding rocket or space simulator experiments. The Shuttle Orbiter also permits human-directed tests as well as automated experiments; human supervision is advantageous in many types of processing and necessary in some.

Eventually, there will be a need for a manufacturing facility. It could be a large unmanned spacecraft housing several different production lines, periodically visited by Space Shuttle crews to retrieve the product and resupply the raw materials. The more efficient way of doing the job, however, is in a human-habitable space processing module in a permanent space station. That would put man into the cycle and allow regularly scheduled servicing of the facility on the Shuttle's routine visits to the space station. In time, the initial facility could be expanded to a full-fledged multi-module manned space factory operating independently of the space station and serviced by its own Shuttle. These possibilities are being considered in NASA's space station study program (see page 29).

NASA's efforts to stimulate space processing experimentation represent one facet of what the agency calls its applications program, which seeks to generate public benefit through direct application of aerospace technology to societal needs. Examples of orbital direct benefit projects in being or in development include Earth resources monitoring satellites, weather and environment monitors, a search and rescue system and an advanced communications technology satellite. NASA also conducts direct benefit projects of a non-space nature, in particular development of Earth-use energy systems. This applications effort has already produced public benefits of substantial order and promises even greater dividends to the nation in future years.







LANDSAT

The Landsat remote sensing satellite provides a means of acquiring voluminous data about changing conditions on Earth's surface, information that offers great potential benefit through more effective management of Earth's resources. The satellite's exceptional utility stems from the ability of sensitive on-board detectors to pick up radiations—light and heat waves—emanating from Earth objects. Since each object has its own unique radiation "signature," it is possible to distinguish among surface features and to generate computer-processed imagery identifying specific features of importance to resources managers. Landsat data can, for example, be interpreted to tell the difference between one type of vegetation and another, between densely populated urban areas and lightly populated farmland, or between clear and polluted water. Such capabilities offer practical benefit over a broad range of applications, such as agricultural crop forecasting, rangeland and forest management, land use planning, mineral and petroleum exploration, mapmaking, water quality evaluation and disaster assessment.

The first Landsat was launched in 1972, a second in 1975 and a third in 1978. Landsats 1 and 2 are no longer in service; Landsat 3 is still capable of providing data but it was placed on standby status after successful checkout of the new Landsat 4. Launched in July 1982, Landsat 4 is the most advanced member of the Landsat family of satellites built by General Electric Space Systems Division. Like its predecessors, Landsat 4 has a highly sophisticated multispectral scanner (MSS) with an Earth-viewing telescope and bands of radiation detectors. It also has a new scanning instrument called a thematic mapper (TM). Developed by Hughes Aircraft Company, the TM collects radiometric data in seven bands of the spectrum, where the MSS detects in four bands, and it has a ground resolution of 30 meters, compared with 80 meters for the MSS—meaning more data and more detail in a single space-viewed scene. Thus, the added TM capability significantly advances the value of the Landsat system and opens up a new range of applications that could be accomplished only marginally or not at all with predecessor Landsats.

Landsat 4 is shown undergoing pre-launch checkout at top left; the thematic mapper segment is pictured above. The image at right exemplifies the greater clarity of detail in a thematic mapper scene. The first TM image produced, it shows an area around Detroit, Michigan and Windsor, Ontario. Red and pink represent different densities of vegetation; urban areas are shown in gray; water is black and the blue tones in water areas indicate turbidity. Clearly identifiable are such features as Detroit Metropolitan/Wayne County Airport (A), Windsor Airport (B), and Willow Run Airport (C). The image shows distinctive turbidity in Lake St. Clair (D) and Lake Erie (E); even a small ship (circled) is identifiable.

Managed for NASA by Goddard Space Flight Center, Landsat 4 was turned over to the National Oceanic and Atmospheric Administration (NOAA) on January 31, 1983, when it officially became the first interim operational remote sensing satellite. NOAA controls the spacecraft and schedules the use of its sensors. Distribution of Landsat data is handled by the Department of the Interior's Earth Resources Observation System (EROS) in Sioux Falls, South Dakota. An identical backup satellite known as Landsat D Prime is in storage; it will be launched if Landsat 4's performance degrades. The Landsat program has become increasingly popular with both domestic and foreign users; more than 100 nations make some use of Landsat data in resources management and 11 nations have their own capabilities for receiving and processing data directly from the satellite.

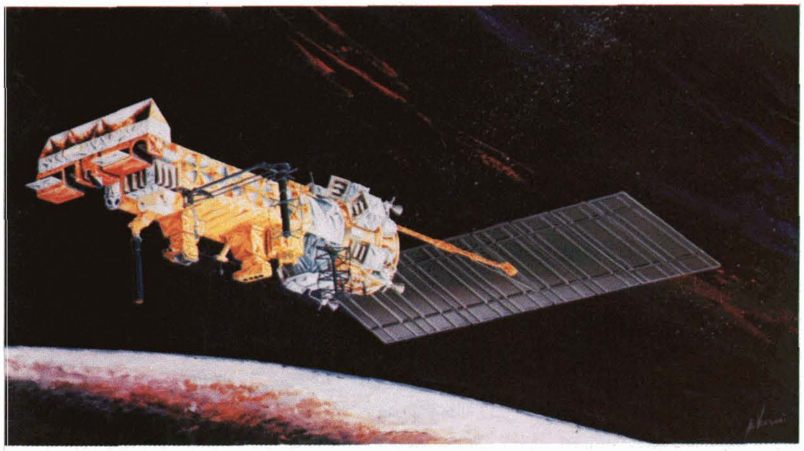
D
B
C
A
E

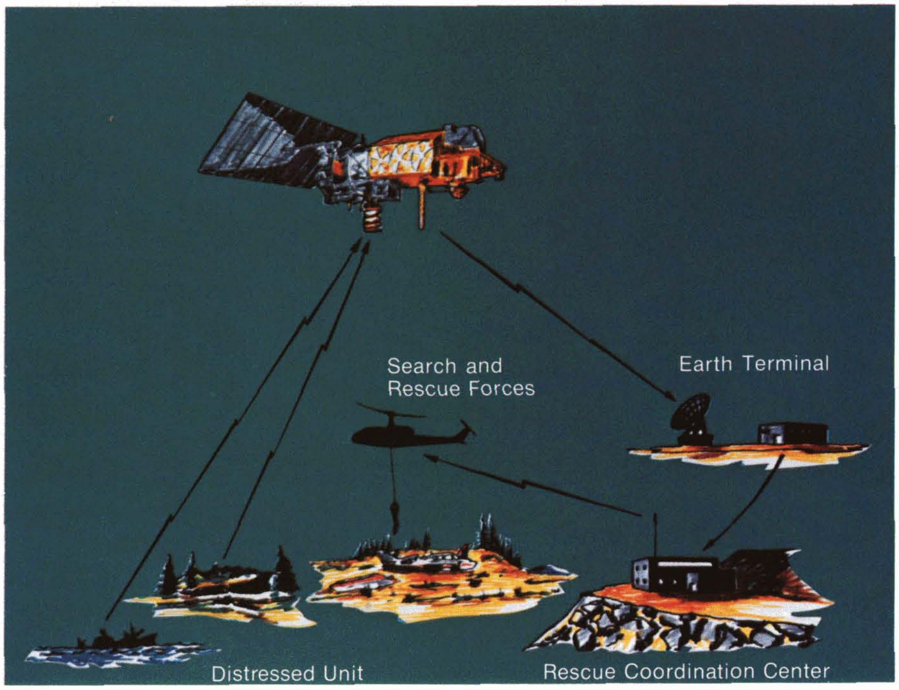
SEARCH AND RESCUE

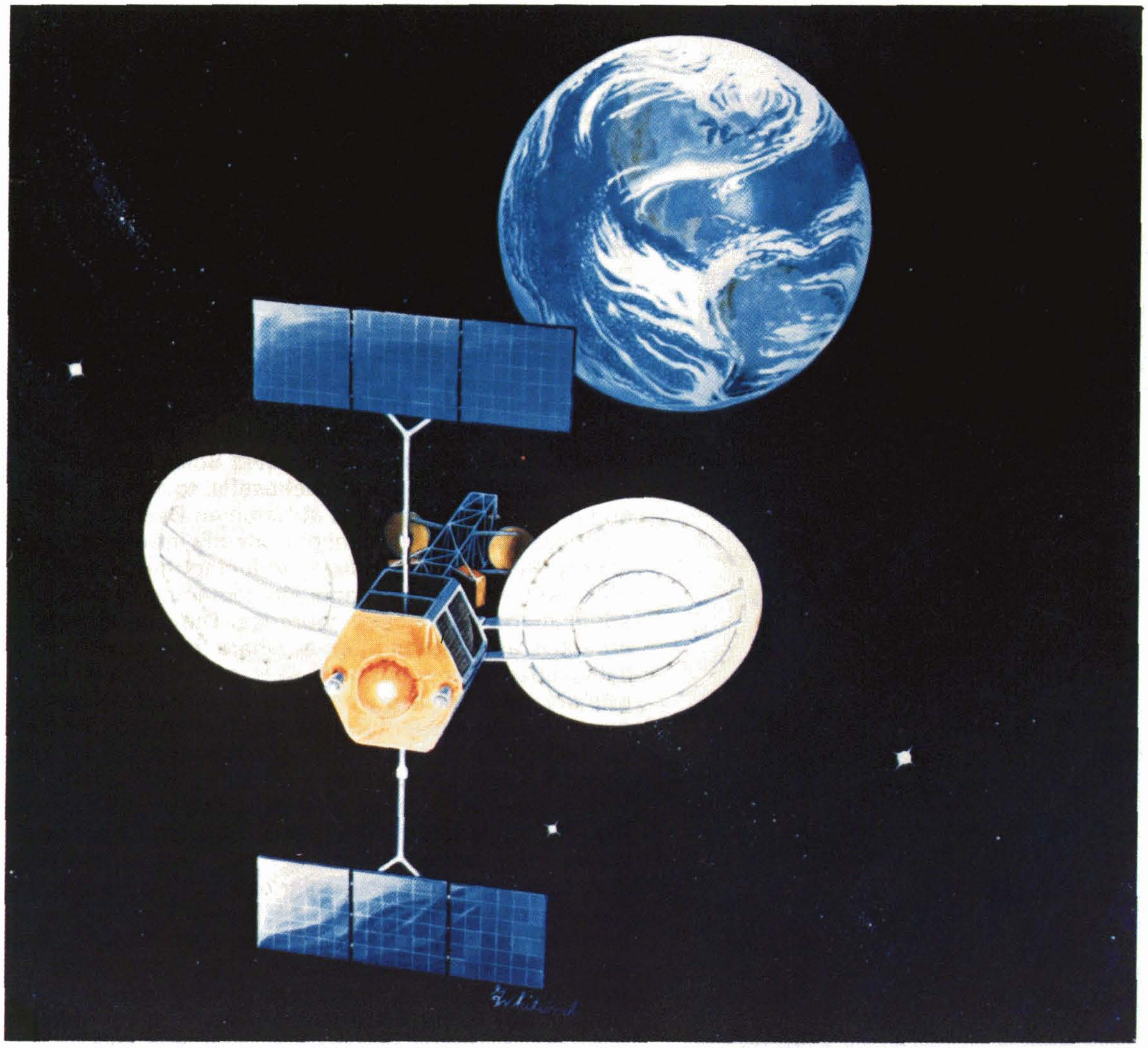
Shown below is NOAA-8, basically a weather satellite operated by the National Oceanic and Atmospheric Administration (NOAA). Built by RCA Astro-Electronics and launched in February of this year, NOAA-8 carries a secondary payload called SARSAT, an electronic equipment package that acquires emergency signals from downed aircraft or troubled ships and relays them to search and rescue centers on Earth. Three additional SARSAT systems are being built in a joint development project involving NASA, NOAA, the U.S. Air Force and the U.S. Coast Guard, in collaboration with French and Canadian agencies. The Soviet Union independently developed a similar monitor known as COSPAS and the two elements are combined in a global search and rescue system known as COSPAS/SARSAT, now undergoing evaluation.

COSPAS/SARSAT started operating last September 1 after orbital checkout of the first COSPAS satellite, and only a week later it demonstrated its effectiveness when a lightplane crashed in a remote area of British Columbia, seriously injuring three men aboard. Fortunately, the crash impact set off the plane's emergency locator beacon, whose signal was picked up by COSPAS 1 and relayed to Canadian rescue authorities. The morning after the accident a rescue transport reached the site pinpointed by the satellite and found the three airmen; all recovered. In its first month of operation, the system was credited with saving seven lives on four rescue assists and it has since provided vital location data on many occasions.

COSPAS/SARSAT fills an important need. Most ships and aircraft carry radio beacons to signal emergencies and provide a homing beam for locating the position of the craft in distress, but the effectiveness of the beacons is limited by lack of *continuous* signal monitoring. COSPAS/SARSAT solves that problem by providing an orbital monitoring platform equipped with advanced electronics compatible with computerized locating equipment at ground stations all over the world. The satellites "listen" continuously on emergency frequencies used by ships and aircraft. When the spaceborne equipment picks up an alert, it relays the information to a ground-based local user station as shown below. Within minutes, the station's computer produces a position fix, locating the distressed craft within 12 miles if it is equipped with existing types of beacons, three miles if it has a new, specially-designed beacon being developed. Search and rescue centers are notified that an emergency has occurred and advised of the whereabouts. If successful, COSPAS/SARSAT could lead to establishment of a permanent international operational system, which, in addition to its life-saving potential, would allow substantial reduction in the costs of search and rescue work. The first rescue in British Columbia offers an excellent example of the cost-reduction potential. Just prior to that incident, the Canadian government had spent more than $3 million in an unsuccessful multi-sortie search for a downed plane in the same general area; by virtually eliminating the "search." phase, COSPAS/SARSAT held costs down to $2,000 an hour for the six flight hours of a single rescue plane.







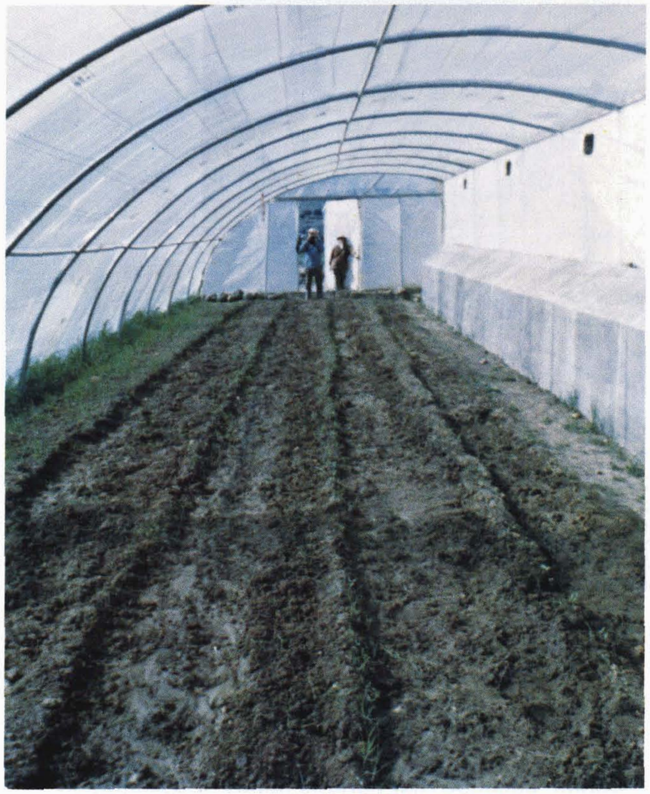
SPACE COMMUNICATIONS

Twenty years ago, NASA pioneered development of communications satellites and provided a technology base for commercial use of such systems. Commercial operations began in 1965 and the growth of satellite systems since that time has been startling. More than two-thirds of all overseas communications traffic is now relayed by satellite and a number of domestic satellite systems are in operation. There are more than 80 "satcoms" in service and it is estimated that traffic demand will require launch of 350 more by the end of the century. And therein lies a problem.

Commercial satcoms operate at an altitude of roughly 22,300 miles in geosynchronous orbit, an orbit in which the satellite's velocity is synchronized with Earth's rotational speed; thus, the satellite remains stationary with respect to a point on Earth. That enables positioning satcoms so that each "views"—or beams its signals to—a particular geographical area. The problem is that many satellites are viewing the same area from the same altitude and proximity can cause one satellite's signals to interfere with another's. The segment of synchronous orbit occupied by satcoms relaying communications to North America is already crowded and other areas are becoming congested; similarly, one of two radio frequency ranges used by satcoms is already saturated and the other is expected to become so within this decade.

In cooperation with several U.S. space equipment manufacturers, NASA is developing technology to ease what could be a space communications logjam. One approach is to open up a new frequency range—known as Ka-band—not yet in use. That's not as simple as it sounds, because that band is highly susceptible to weather-caused interference and the technology for its employment without degrading signal quality does not yet exist. Another approach is to make more efficient use of the spectrum through techniques enabling simultaneous transmission of multiple messages in the same frequency band.

These two approaches demand extensive technology development—for example, greater transmission power on board the satellite and new types of antennas in space and on Earth. NASA hopes to demonstrate these and other new technologies in the latter 1980s on the Advanced Communications Technology Satellite pictured. Looking further into the future, NASA is studying the potential of large unmanned platforms in geosynchronous orbit, each providing power, antennas and other functions for a number of advanced technology satcoms capable of sharing the platform without signal interference; that would ease orbital congestion by replacing many individual satellites with a few platforms.



SOLAR CELLS

At left is the Tunisian village of Hamman Biadha. In the foreground is a solar cell array that is now the primary power source for a community that has never had electricity. Located about 90 miles southwest of the capital city of Tunis, Hamman Biadha is the site of a program jointly sponsored by the government of Tunisia and the U.S. Agency for International Development (AID) to study the feasibility of using photovoltaic (PV) systems as power sources for remote villages that have no connecting lines to the national power grid. To manage the project, AID selected Lewis Research Center, which supports the Department of Energy's photovoltaic program by conducting demonstrations of the advantages of this type of power generation. Lewis, in turn, selected Solar Power Corporation, Woburn, Massachusetts, to design, build and install the PV systems at Hamman Biadha.

PV systems convert sunlight directly into electrical energy. Research is gradually reducing the cost of PV power and such systems are beginning to find application in developed countries. They are already attractive alternatives in areas where there is no established energy network. At Hamman Biadha, the primary solar cell array provides 30 kilowatts of peak power for the residential area, population 120; for the commercial area, two stores, a barber shop and a cafe; and the public area, which includes street lighting, a well, a mosque, a clinic, a meeting house and a school that accommodates 300 students from the village and surrounding farms.

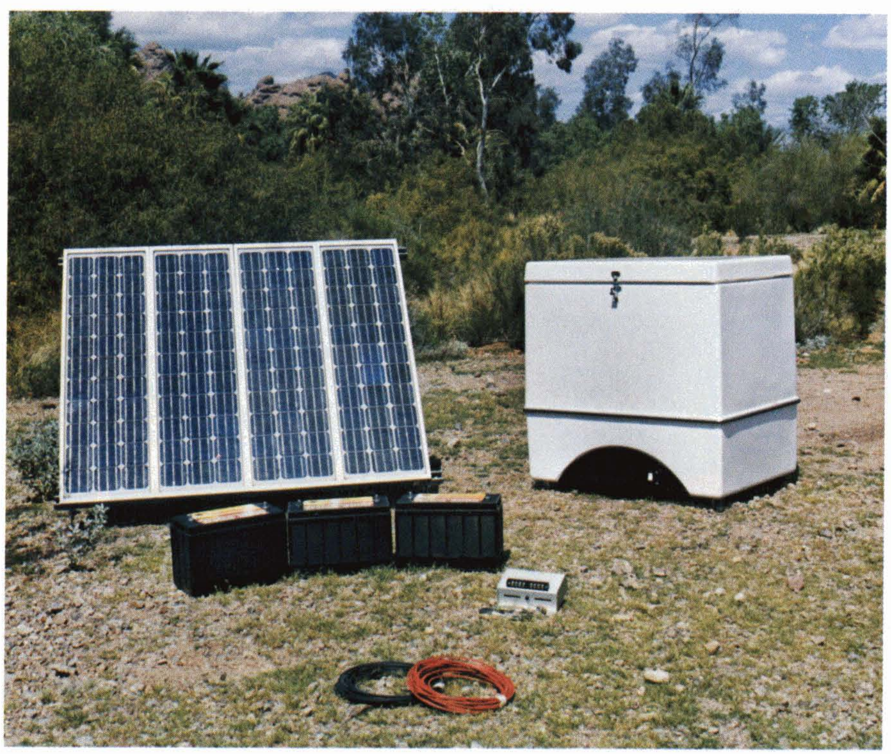
In addition to the main solar cell array, there are three smaller PV systems of 1.5 kilowatts each. One provides electricity to farms outside the village for their lights, television and refrigeration. Another pumps water to irrigate an orchard. The third powers a greenhouse pump. Wind power systems pump water for two other greenhouses, used to grow vegetables in the off season. One of the greenhouses and its solar array are shown at left and below.

Lewis Research Center is active in a number of other solar energy applications. Last year, NASA-developed standard solar cell packages began providing electricity to rural health clinics in Ecuador, Guyana, Kenya and Zimbabwe. This year, Lewis will supervise

installation of solar cell power systems for four villages in the West African nation of Gabon. Lewis is also managing installation of 28 PV-powered refrigerator systems at a number of sites around the world. A typical installation is one at Anse a Veau, Haiti; the photo above shows the photovoltaic array, which is connected by cable to the refrigerator (upper right). Designed to determine the effectiveness of using PV systems for preserving vaccines in developing nations, the project is jointly sponsored by AID, the Department of Energy and the Centers for Disease Control of the Department of Health and Human Services.

Vaccines are used extensively to control such communicable diseases as polio, diphtheria and measles, but lack of refrigeration can cause the vaccines to lose their potency. Conventional electric service in rural areas of developing countries is often unreliable or non-existent. In some cases where there is no electricity, refrigerators fueled by kerosene or gas are used. However, they have proved unsatisfactory for a number of reasons, including high maintenance requirements and unreliable fuel supplies. It is estimated that three-fourths of the people in developing countries do not have adequate refrigeration, a fact that seriously hampers disease control by vaccination. Thus, if the initial 28 solar-powered refrigerators—now operating in Asia, Africa, the Caribbean, South America and Central America—prove successful, and if their costs can be reduced by further research, they may be the forerunners of a great many more PV systems in medical storage applications.

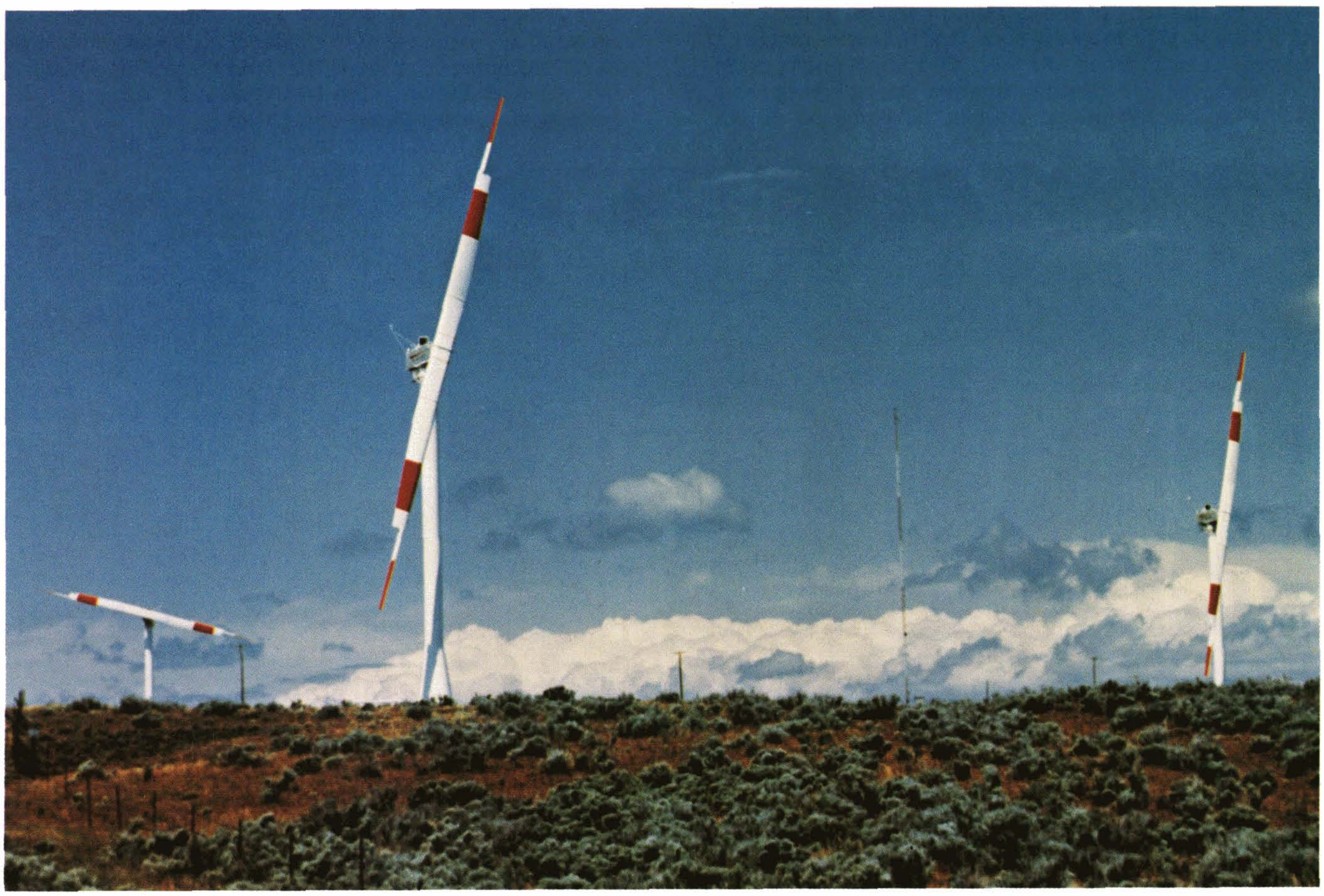
Prime contractors for the PV-powered refrigerator systems are Solar Power Corporation, builder of the first 20 systems, and Solavolt International, Phoenix, Arizona. An example of the type of equipment installed in developing countries is the Solavolt system shown below which includes the refrigerator, PV array, a voltage regulator, wiring and batteries.



WIND TURBINES

At right is the world's most powerful wind turbine, which went into operation last year near Medicine Bow, Wyoming. Designated WTS-4, the system employs a 256-foot-diameter rotor blade to convert wind force into 4,000 kilowatts of electrical energy, enough to meet the electrical needs of about 1,000 homes. The WTS-4 was developed by Hamilton Standard Division of United Technologies Corporation under NASA technical direction and Department of the Interior sponsorship. Along with a 2,500 kilowatt MOD-2 wind turbine at the same site, the WTS-4 is undergoing a two-year evaluation that could lead to construction at Medicine Bow of a "wind farm" with as many as 40 machines.

Shown below is the world's highest capacity wind turbine installation, a cluster of three MOD-2 systems—each with a 300-foot-diameter blade—that collectively generate 7,500 kilowatts. The cluster is operated by the Bonneville Power Administration, which feeds the electricity produced into the northwest power grid for use by regional utilities. These turbines were built by Boeing Engineering and Construction Company in a NASA/Department of Energy program aimed at development of advanced technology wind systems as alternative power sources. Managed by Lewis Research Center, the program involves development and test of a number of differently-sized turbines in different geographical locations under varying wind conditions. NASA has acquired more than 40,000 hours of large wind turbine experience since the first intermediate size (200 kilowatts) machine started operating in 1977. In design status is the most powerful wind turbine yet, a MOD-5 system that will generate 7,000 kilowatts in a single unit.



SPINOFF FROM SPACE ASTRONOMY

A line of sophisticated X-ray systems accents the scope and value of aerospace technology transfer

Producer of space-spawned commercial x-ray systems, American Science and Engineering, Inc. (AS&E) occupies this headquarters and manufacturing facility in Cambridge, Massachusetts adjacent to the site of American Revolution citadel Fort Washington.

One of several spinoff products is AS&E's Model 100 x-ray inspection system for examining baggage at airports and other high-volume security areas. Called MICRO-DOSE, the system features exceptionally low radiation exposure—100 times less than the standard set by the Federal Aviation Administration.

In 1895, Germany's Dr. Wilhelm Conrad Roentgen discovered what he called x-rays, a form of radiation that could pass through solid matter and provide a photographic image of the solid's interior. Before the turn of the century, manufacturers were producing systems to generate x-rays and physicians were using them, initially to set broken bones. Over the years, x-ray use expanded to scores of applications in medicine, dentistry and biology, and in such commercial functions as examining manufactured products to insure quality, inspecting gems to detect flaws, or scrutinizing paintings to establish authenticity. But while there was enormous growth in the body of knowledge about terrestrial x-radiation, virtually nothing was known in the first half of the 20th century about cosmic x-rays. Some suspected their existence but—as was later learned—x-rays from stars and galaxies are absorbed by Earth's atmosphere, hence are not detectable on Earth's surface.

After World War II, scientific rockets capable of climbing above the atmosphere confirmed that the Sun emits x-rays, arousing curiosity as to whether other stars did, too. In 1962, an Air Force-sponsored sounding rocket found an x-ray source in the Constellation Scorpio; that marked the genesis of x-ray astronomy.

NASA became the primary proponent of this new field. In 1967, Goddard Space Flight Center flew an x-ray telescope aboard OSO-4, the fourth Orbiting Solar Observatory, and performed the first long-term study of x-ray emissions from the Sun's corona. Goddard also sponsored development of the first satellite devoted entirely to study of cosmic x-ray sources; called the Small Astronomy Satellite (SAS-1), it was launched in December 1970.

The data returned by SAS-1 completely changed man's view of the universe. The satellite's x-ray telescope—not a telescope in the conventional sense but an array of radiation detectors—found 161 x-ray sources, many of them in areas where there was nothing visible to optical telescopes; this indicated the presence of a new class of non-luminous objects in space whose existence had not been anticipated. SAS-1 discovered the first black hole, x-ray emissions from galaxies, and pulsars emitting x-rays in evenly timed sequences.

TECHNOLOGY TWICE USED

Much of the technology generated by NASA's mainline programs is being adapted by private firms and public sector organizations for use in a broad range of new products and processes, providing important economic and social benefits

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

This experiment heightened world scientific interest in cosmic x-rays; it also inspired NASA development of a series of x-ray explorers of ever-increasing capability.

The company whose detectors found the first cosmic x-ray source more than 20 years ago is American Science and Engineering, Inc. (AS&E)®, Cambridge, Massachusetts. Not surprisingly, the same company built NASA's first x-ray telescope flown on OSO-4, and it also developed the x-ray detectors that operated flawlessly for four years aboard SAS-1. There were AS&E instruments on NASA's Skylab interim space station (1973–74), the High Energy Astronomical Observatories 1 and 2 (1977–81) and the Solar Maximum Mission spacecraft (1980–81). AS&E has become synonymous with x-ray astronomy, thanks to the success record achieved by more than 100 rocket and satellite, payloads.

The experience AS&E acquired in detecting and processing cosmic x-rays gave the company a broad technology base—and some attractive competitive features—for commercial applications. To capture faint x-ray signals from distant space, AS&E had to develop exquisitely sensitive radiation detectors. Such detection sensitivity, along with a novel method for precisely controlling the applied radiation beam, allows the use of exceptionally low levels of radiation exposure in the company's commercial systems. In many instances, irradiations of one hundredth to one thousandth that of conventional techniques are sufficient for excellent images. The system is so efficient and so well shielded that radiation exposure to personnel operating the equipment is well below natural background levels. AS&E commercial systems do not use film; they are digital and computer-compatible, allowing the full gamut of image enhancement applications where that is necessary or desirable.

Among the commercial products that stemmed from AS&E's space technology are:

• MICRO-DOSE® x-ray inspection systems, which come in many models. The two most commonly used are for high-volume screening of baggage at airports, mail rooms and similar facilities, and for parcel scanning in lower-volume security areas, such as office buildings. Both employ advanced scanning beam technology that provides high-quality images at extremely low radiation dosages. AS&E also produces larger and more powerful systems used to scan whole automobiles, buses and cargo containers for contraband.

• A computerized tomography scanner for medical use, considered one of the most advanced machines available. The system employs 600 radiation detectors, connected to two separate computers, to produce a high-quality image representing a plane or "slice" of the patient's head or body.

• A digital radiography system, based on the MICRO-DOSE technology, for medical diagnosis. Its exceptional clarity of detail, coupled with a patient radiation exposure about 100 times less than that of conventional medical x-ray systems, permits digital radiography in applications not feasible in the past, such as pediatrics and obstetrics.

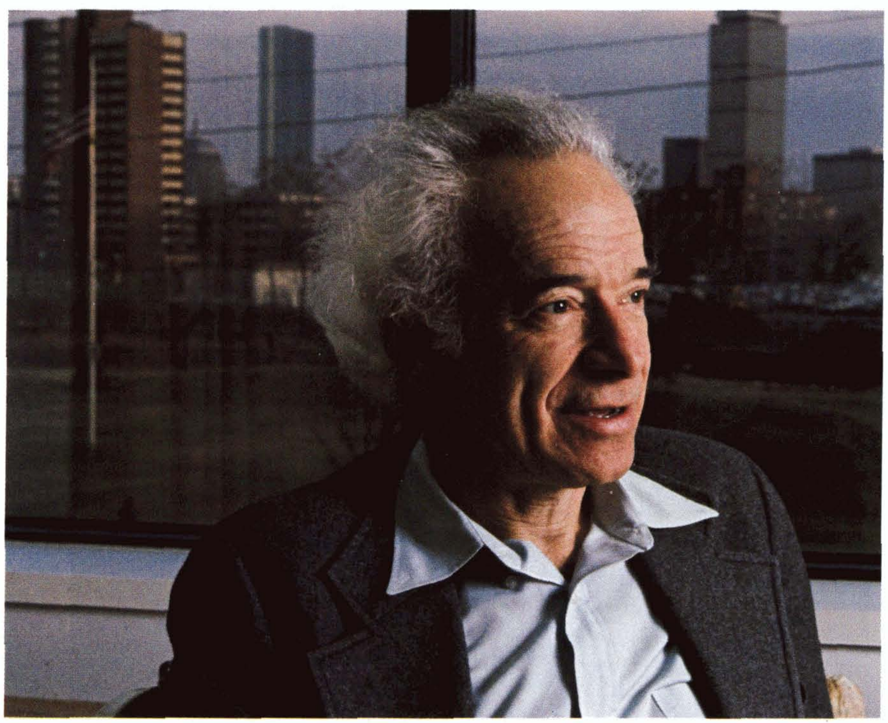
• A system for non-destructive testing of manufactured products. The first application was in the inspection—by x-ray imagery—of auto and truck tires to detect flaws.

• A system of load management for electric utilities designed to optimize use of energy and provide savings to the utility and its consumers. It is not an x-ray system but a spinoff nonetheless, because the technology derives from AS&E's electronics and general science know-how acquired in space work.

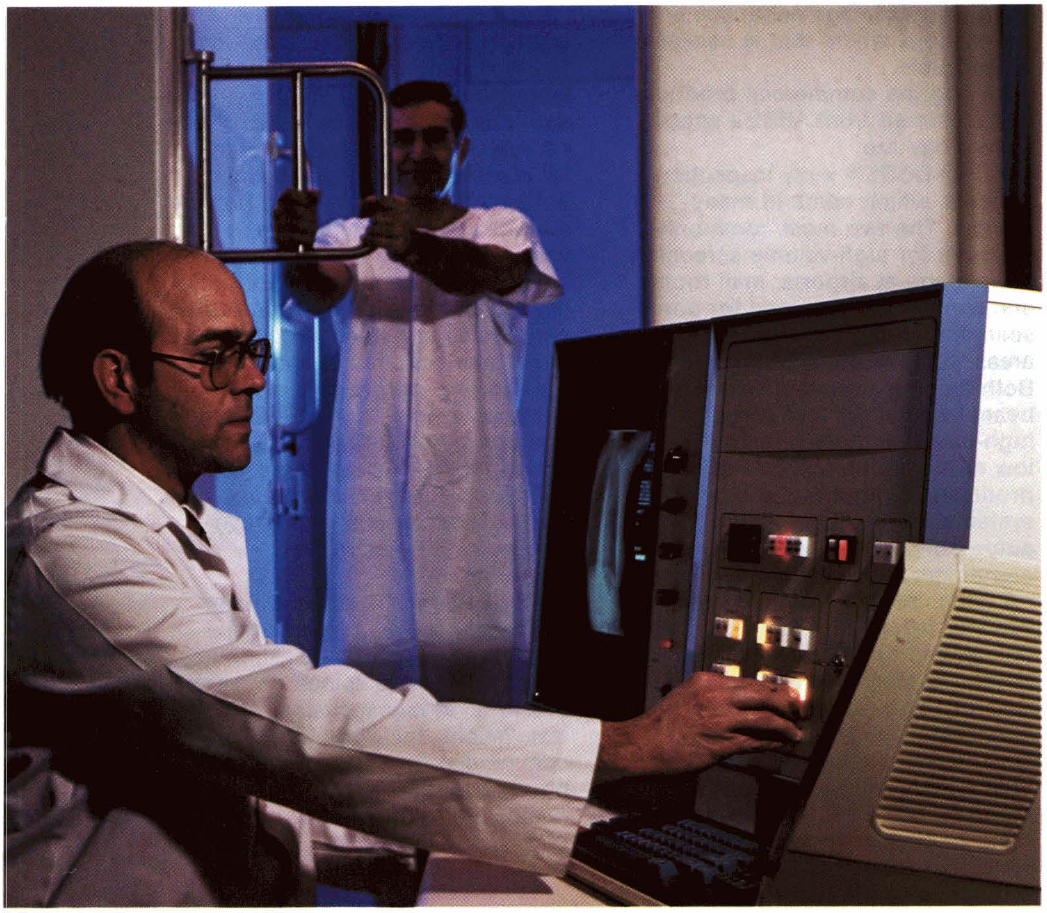
Additional outgrowths of the company's work for NASA include a number of specialized instruments, for example, an x-ray microscope for fusion energy research and an x-ray optical system to improve fabrication of electronic microcircuits.

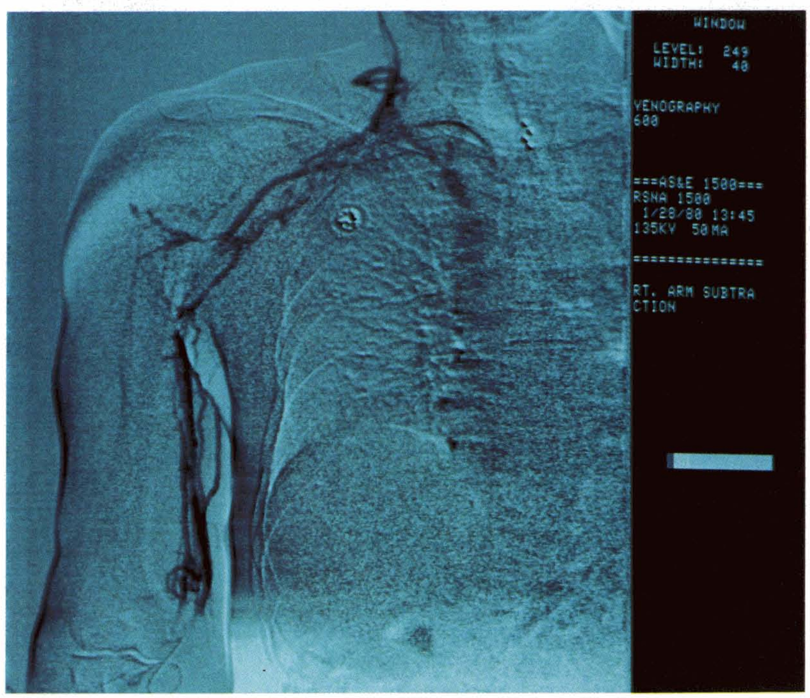
AS&E's Space Systems Division is still very active in developing equipment for advanced astronomy missions, but two spinoff divisions—one for load management installations, the other for commercial x-ray instrumentation—now account for much of the company's sales volume.

®AS&E and MICRO-DOSE are registered trademarks of American Science and Engineering, Inc.



Dr. Martin Annis, chairman of AS&E: "Our work for NASA gave us an education in handling x-rays and it gave us the confidence to expand into commercial applications. Now our business is 85 percent commercial."





The latest of AS&E's MICRO-DOSE medical x-ray systems, introduced in 1982, is a digital radiography system for diagnostic use. The unit pictured above is at Massachusetts General Hospital in Boston. A patient (in background) is being scanned by equipment in the adjacent cabinets; the physician is monitoring the results on the video screen, images such as those shown at right.

Using computerized data from a single x-ray exposure of the patient, the physician can vary the image electronically to concentrate on bone, muscle or soft tissue while simultaneously varying the amount of contrast. The MICRO-DOSE system offers exceptional image clarity and extremely low radiation dosage, permitting use of digital radiography in applications once considered impracticable—pediatrics and obstetrics, for example.

SHUTTLE NET, TUNA NET

Among a sampling of spinoffs that contribute to industrial efficiency and productivity is an innovative netting designed to boost fishing yield

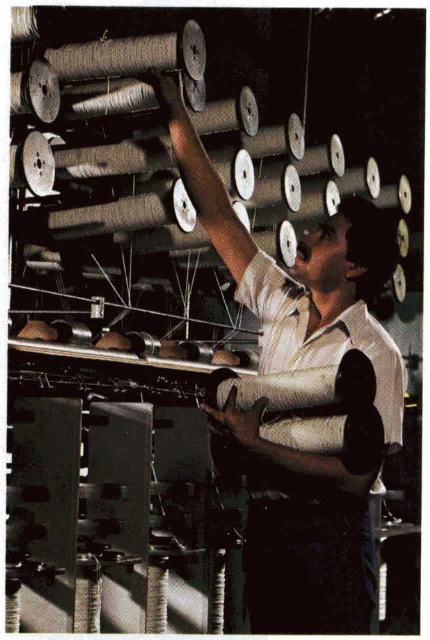
Last summer, the newly christened *Ocean Pearl*, a 1,200-ton San Diego-based commercial fishing vessel, sailed the western Pacific on a dual mission. Skipper Harold Medina was looking for tuna, but he was also conducting sea trials of a giant new net that could revolutionize deep sea fishing by sharply reducing the time needed for a full catch. Called the Hyperester™ Seine, the net is manufactured by West Coast Netting Inc. (WCN), Rancho Cucamonga, California; its development stemmed from the company's work for NASA in the Space Shuttle program.

The *Ocean Pearl's* $500,000 net is more than a mile long, weighs 60 tons and covers 86 acres. "It represents," says WCN president Bill L. Kirkland, "the first major innovation in seine fishing—tuna, anchovy, menhaden, herring, salmon—in more than 20 years. It offers a productivity gain of 30 percent."

A prime advantage of the Hyperester Seine is that it sinks faster and arrives at its fishing depth in one-third of the time it takes conventional nets, thus making it possible to trap tons of fish that would otherwise scatter free. Hyperester also fishes deeper and covers a larger area than nets in general use. These factors add up to big monetary gains.

Kirkland cites fuel costs as an example. Large tuna seiners like the *Ocean Pearl* burn $3,000–5,000 worth of fuel a day, so if a ship can reduce the time necessary to make its catch, the savings would be significant. It would also allow more trips annually, hence more fish. The Hyperester net could prove a real boon to a hard-pressed fishing industry whose operational costs have escalated enormously.

The *Ocean Pearl's* Harold Medina feels the net has great promise for improving productivity, based on his initial test of Hyperester, wherein he recorded daily catch tonnages well above the norm. "I personally believe the (tonnages) were, to a great extent, the result of the speed and depth at which Hyperester fishes," he reported. "With the costs of tuna and other fishing operations today, Hyperester is being proven to be a tool of major significance. If it sounds like I believe in Hyperester, you're right. This is the net of the future."



At left, an employee of West Coast Netting Inc. is loading fiber spindles onto a machine that will twist three fiber strands together to produce an exceptionally strong twine. This is the first step in manufacturing a Hyperester Seine, a new type of fish netting that promises substantial productivity improvement. In the lower photo is a high-speed machine that ties 1,400 knots a minute and weaves the twine into netting; the end product is at right.

™Hyperester is a trademark of West Coast Netting Inc.

Though not an x-ray system, AS&E's load management concept for electric utilities also traces its origin to the company's space work, which advanced AS&E's competence in electronics and communications. This competence attracted the interest of a public utility that sought improved control of its electric output. With no prior experience in the field AS&E developed the ASEP® system for managing peak electric loads by remotely controlling residential electrical equipment. The prototype system made its debut only a decade ago, but today ASEP is used by more utilities than any other system.

A two-way communications system allows the utility to "shave" peak loads by temporarily cutting off—with customers' consent—such home equipment as water heaters, space heaters and air conditioners; this can save big money for the utility, and the customer gets a share of the savings as a credit on his monthly bill.

Control measures are taken when electricity demand is high or when the company's generating capacity is reduced. A computer generates the commands that turn off home equipment. The top photo shows the computer room at Duke Power Company, Charlotte, North Carolina, an ASEP-equipped utility. The computer communicates over telephone lines to substation control units, such as the one shown at right. The substations then relay the control signals over power distribution lines to load control receivers (bottom right) located at customers' homes. The communications system also makes possible automatic meter reading.

®ASEP is a registered trademark of American Science and Engineering, Inc.

Hyperester had its origin in 1979. WCN was then already an established firm with almost 30 years experience, providing nets for sports and circus performers, hospital nets for patients who must be immobilized, capture nets for law enforcement use, and projectile-catching nets for the Department of Defense. Rockwell International, NASA's prime contractor for the Space Shuttle, asked WCN to develop a safety net for personnel working on the Shuttle Orbiter; several such nets would be used to prevent a worker's falling through an open engine cavity a long way to the ground. NASA/Rockwell wanted something more than an ordinary net. It would be relatively small, 100 inches in diameter, yet had to have a tensile strength twice the government standard for safety nets; it also had to be fire resistant and ultraviolet resistant. It posed a difficult development job.

It took WCN six months just to find a fiber that had the requisite temperature resistance and could be treated to resist deterioration from ultraviolet rays; it is a polyester-like material called Nomex.® The next step was to develop a "twine" made of multiple strands of the fiber twisted together. This, too, proved troublesome; using conventional methods of twisting the strands, WCN could not get anything approaching the specified breaking strength. So the company was forced to invent a more sophisticated twisting process in which exactly the same tension is maintained on each of three strands as they are machine-twisted into a three-ply twine. This resulted in a supertwine that met the NASA specifications; a net made of it can sustain a load of 800 pounds falling 25 feet or, to put it another way, a relatively small net could support an average size automobile.

The Space Shuttle nets were proof tested, accepted by NASA and are now in service. But the technology that created them—the combination of Nomex fiber and the innovative twisting technique—offered obvious application in the fishing industry. Twines of various fibers manufactured in this manner have a 30 percent smaller diameter than conventional nylon cords used in other nets; that means less hydrodynamic resistance, allowing the net to move faster in the water. The twine is very dense and

absorbs less water; that's why it sinks faster and fishes deeper. A patented treatment for ultraviolet protection and greater abrasion resistance makes Hyperester nets last longer, and the net's no-shrink feature is an economic bonus.

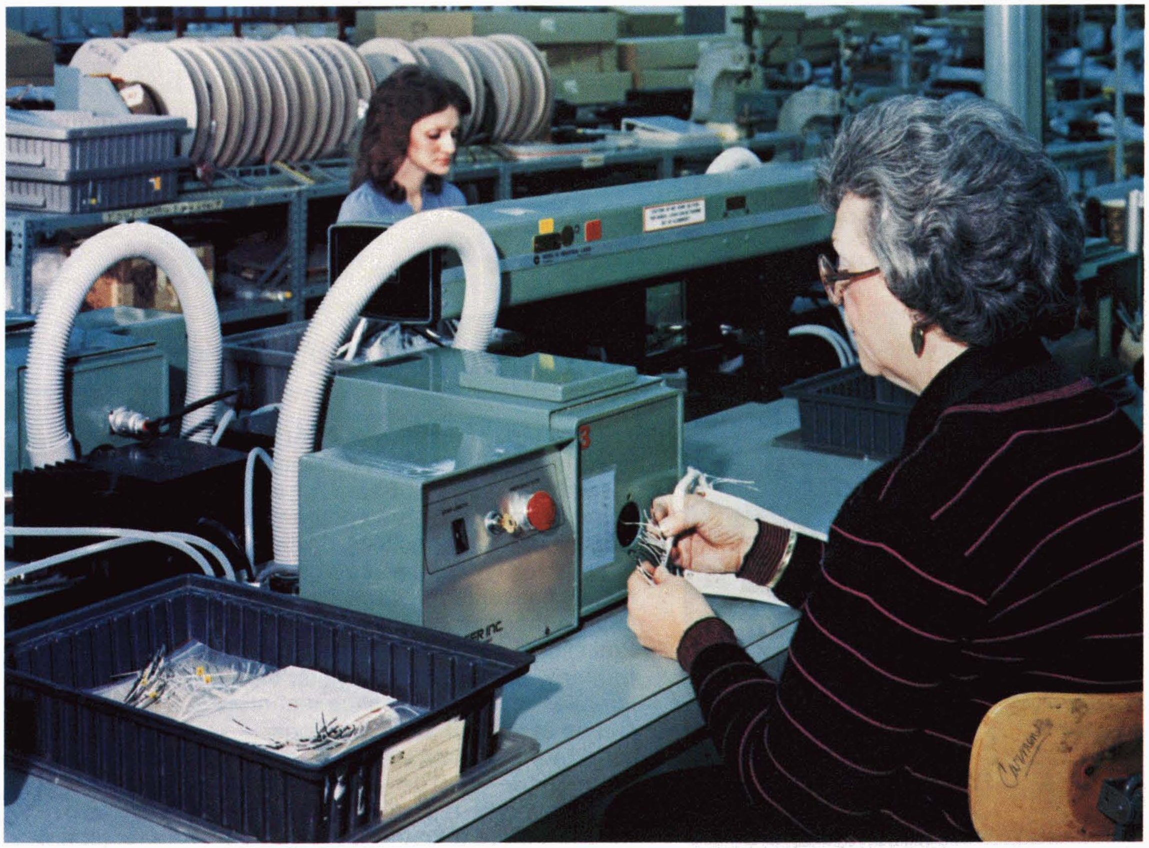
These advantages, WCN feels, should prove attractive to fishing fleets and it is preparing for large-scale business; it has licensed two facilities in Pennsylvania and Michigan that, along with the Rancho Cucamonga plant, will give the company a total annual production capacity of 3.5 million pounds of Hyperester netting. Bill Kirkland points out an international competition factor: Japan has almost totally dominated the market for a long time and Hyperester is the first American-built net in more than 15 years; it could provide a foundation for American competition in the $500–600 million a year netting industry.

®Nomex is a registered trademark of DuPont Company.

LASER WIRE STRIPPER

Aircraft and spacecraft have miles of wiring, so a small reduction in wire weight can add up to a total vehicle saving of hundreds of pounds. For that reason, the aerospace industry adopted a type of electrical wiring with very light plastic insulation. But the weight saving created a problem in stripping the insulation to make connections: some of the insulating films are so thin and so tough it was difficult to get the required precision with mechanical wire cutters. The result was frequent cutting or nicking some of the wire strands, unacceptable under rigid aerospace quality control standards.

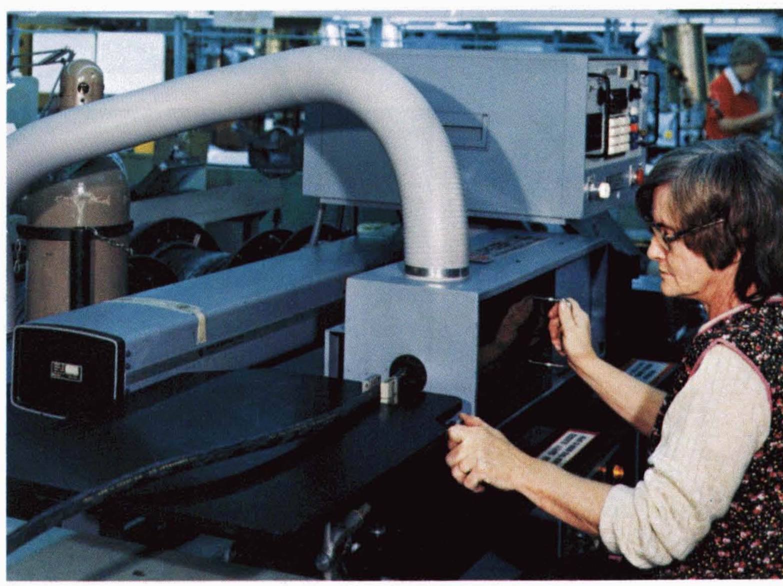
The need for flawless wiring in the Space Shuttle prompted NASA to start a program to develop a better way to strip insulation. An effort involving Shuttle prime contractor Rockwell International, Johnson Space Center and NASA's Manufacturing Applications Team at IIT Research Institute, Chicago, Illinois resulted in successful development of both hand-held and bench-mounted laser wire strippers. A laser beam can cut through the insulation on a wire without damaging the conductive metal, because the laser radiation that melts the plastic insulation is merely reflected by the metal. The laser process is fast, clean, precise and



repeatable; it eliminates the quality control problems and the expense of rejected wiring. Several aerospace firms are now using the NASA developed technology in systems manufactured by Lincoln Machine Company, Milwaukee, Wisconsin and Photon Sources, Livonia, Michigan.

Raytheon Company's Missile Systems Division, West Andover, Massachusetts has adapted the NASA technology to laser systems of its own design. The West Andover plant originally stripped wire manually for missile harnesses, then introduced an automatic system in which thermal heads removed the insulation. Edward J. Cenik, a section manager in the company's Product Development Department, had the job of proving and "debugging" the machine, which generally worked well but had a major flaw: the high temperature needed for stripping degraded the thermal head, necessitating frequent replacement.

Looking for an alternative, Cenik studied NASA's technical report on its laser wire stripper work, which provided a basis for Raytheon's system. In cooperation with Coherent, Inc., Palo Alto, California manufacturer of industrial lasers, Raytheon designed a laser device to replace the thermal heads in the company's automatic stripping machine. The success of this modification led to design and introduction of other machines for three different types of wiring—shielded wire, jacketed cables and harness terminations; the laser systems were built for Raytheon by Laser Inc., Sturbridge, Massachusetts, a subsidiary of Coherent, Inc. At left is a four-position laser system for stripping harness terminations. An operator simply inserts a wire into the stripping head (above); the rest of the operation is automatic. The machine senses the wire's presence, energizes the carbon dioxide laser, strips to the required length and ejects the stripped wire. At right is a companion system for stripping jacketed cable.

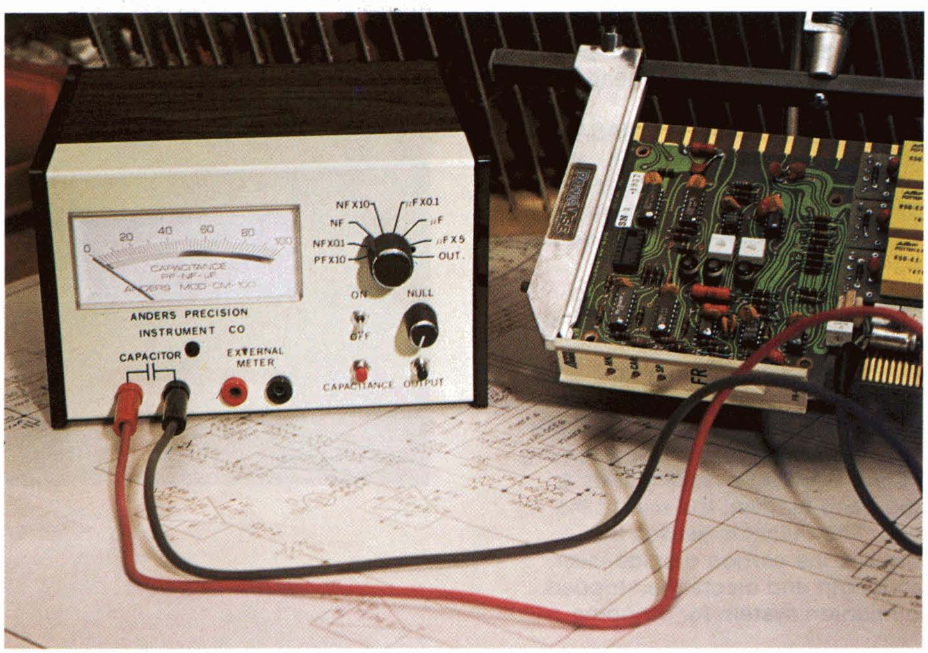


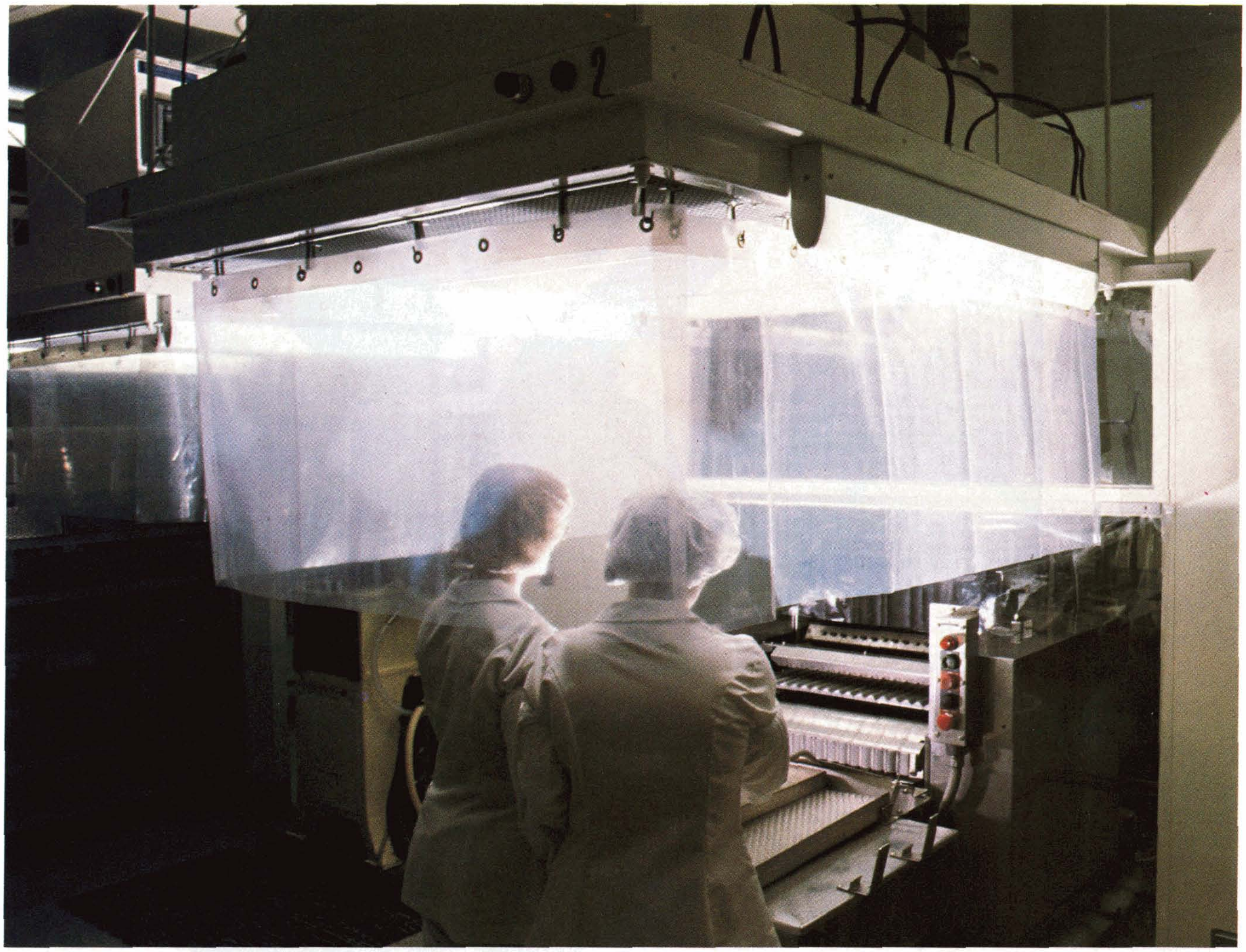
CAPACITANCE METER

At left, an employee of Anders Precision Instruments Company, Willimantic, Connecticut is assembling a circuit board for a new capacitance meter being produced by the company. The meter (below) is used to test capacitors, devices used in electrical circuits for temporary storage of electrical charge; the meter measures the capacitance, or the quantity of charge that can be stored for a given voltage. Anders Precision's customers for capacitance meters are primarily electronic hobbyists; the company also supplies meters for service technicians and for a variety of industrial applications.

Anders Precision's original meter could not measure dissipation—leakage—in a capacitor. Seeking to add that capability, the company planned an advanced model. Before initiating development work, company president Thomas Anderson sought technical assistance from NASA's New England Research Application Center (NERAC) at the University of Connecticut, Storrs, Connecticut. Specifically, he asked for a survey of the status and capabilities of electronic measuring instruments.

NERAC conducted a computerized search of six data bases, including NASA's, and provided a comprehensive report on the state of the art worldwide. Anderson reports that NERAC's assistance saved him considerable research time and capital, provided assurance of the uniqueness and competitiveness of his own design, and contributed to a meter superior to his company's earlier product.



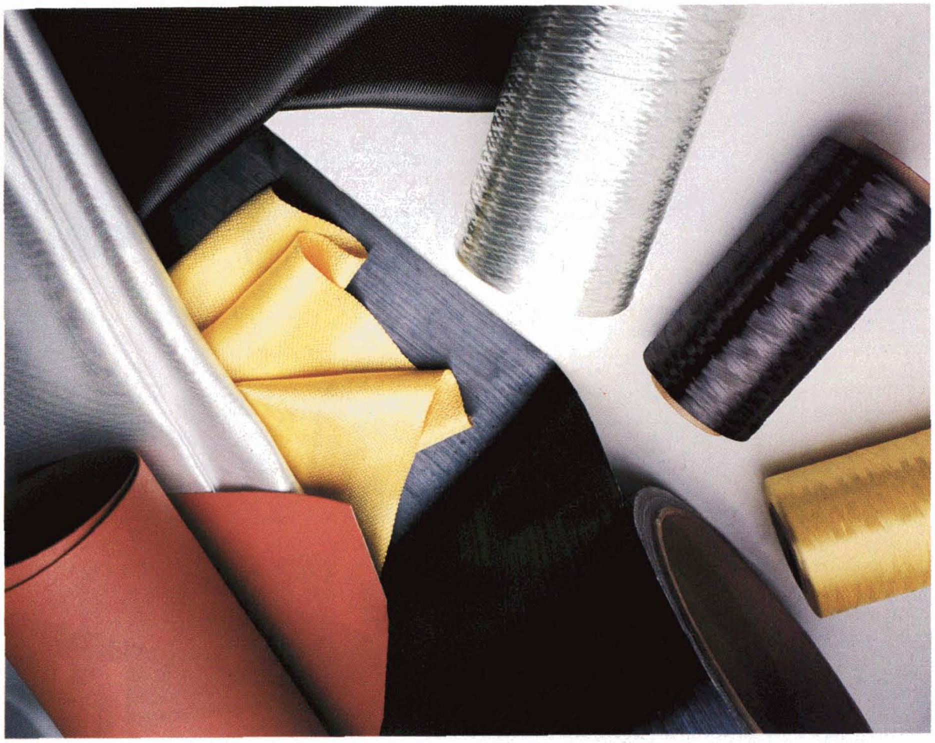


CONTAMINATION CONTROL

One of the largest pharmaceutical producers in the United States, The Upjohn Company, Kalamazoo, Michigan includes among its product lines a variety of sterile injectable drugs. These drugs must be as free of particulate matter—such as dust and pollen—as it is possible to make them. Minimizing contamination is accomplished by controlling air, steam and water services involved in manufacturing operations and by use of air filtration systems in the processing clean rooms (above) where the final product containers are washed before sterilization and filling. Known as High Efficiency Particulate Air (HEPA) filters, these systems remove 99.97 percent of all particles greater than or equal to three-tenths of a micron, an infinitesimal measurement. HEPA systems also produce a laminar—smooth—flow of air over the work area; plastic curtains that hang from the HEPA framework direct the airflow.

In periods of low humidity, company personnel noted that a great deal of static electricity built up and caused dust particles, attracted by the electrical charge, to cling to the curtains. This posed a problem of potential particulate contamination of the final product containers. Seeking a solution, Upjohn found guidance in a NASA *Tech Brief* (see page 137). The *Tech Brief* outlined work performed for Johnson Space Center by Rockwell International Corporation on protecting electronic components of aerospace systems that are highly susceptible to damage by static electricity. Upjohn obtained a Technical Support Package, "Safe Handling Practices for Electrostatic Sensitive Devices," which provided detailed information on the Johnson/Rockwell work, including more than 50 procedures for reducing static electricity, guidelines for setting up static-free work stations, materials and equipment needed to maintain antistatic protection.

Upjohn found that use of antistatic polyethylene in the curtains surrounding the HEPA filter greatly reduced buildup of static electricity and similarly reduced the adherence of particles. The company also learned of a method of grounding stainless steel work tables used in HEPA filtered air environments; this technique, which allows static charge to leak off before it builds up to high levels, further reduced particle adherence in Upjohn's processing areas.



COMPOSITE MATERIALS

Ferro Corporation, Cleveland, Ohio is a leading company in development and production of specialty materials for industrial customers. Among its products is a line of preimpregnated molding materials—or "prepregs"—manufactured by the Composites Division, which has facilities in Culver City, California and Norwalk, Connecticut. Prepregs are reinforced plastics, made by impregnating sheets of fibers—such as glass, graphite or quartz—with chemical compounds including polyimides, a class of plastics resistant to high temperatures. A sampling of Ferro prepregs, including materials in tape, filament and woven fabric form, is shown above. Some of the prepregs manufactured by the Composites Division are based on research conducted by Lewis Research Center on polyimide resins.

To improve certain characteristics of composite materials, which are finding increasing use in aircraft and other aerospace systems, Lewis developed an improved impregnating solution known as PMR-15. Interested in adding to its line of prepregs, Ferro Corporation obtained from Lewis the formula and the procedure for synthesizing PMR-15 and, after a period of company experimentation, used it in developing new composite materials. These Ferropreg® composites, compounded of polyimide/glass and polyimide/graphite, have a variety of applications, such as compressor blades for aircraft engines, radar domes, aircraft structures and other components requiring a material with high temperature resistance.

Ferro Corporation's customers include a number of major aerospace companies, among them The Boeing Company, General Dynamics Corporation, General Electric Company, McDonnell Douglas Corporation, Rockwell International Corporation and Hamilton Standard Division of United Technologies. The latter company is using a Ferro polyimide/graphite material in jet engine nozzle flaps it is producing for the Pratt & Whitney Aircraft division of United Technologies; General Electric is also using Ferro prepregs in jet engines. Hamilton Standard used a Ferro composite in manufacture of 600 compressor blades for an Air Force supersonic wind tunnel at Arnold Engineering Development Center, Tullahoma, Tennessee; the four-foot blades (above) consist of fiberglass/polyimide shells bonded to steel and aluminum spars for operation at temperatures up to 550 degrees Fahrenheit.

®Ferropreg is a registered trademark of Ferro Corporation.

MANUFACTURING AIDS

A contractor's work for Lewis Research Center on "thermal barrier" coatings designed to improve aircraft engine efficiency resulted in two related but separate spinoffs. The Materials & Manufacturing Technology Center of TRW Inc., Cleveland, Ohio invented a robotic system for applying the coating and, in the course of that research, found it necessary to develop a new, exquisitely accurate type of optical gage (right) that offers multiple improvements in controlling the quality of certain manufactured parts.

Thermal barrier coatings, applied to turbine blades, combustors and other parts, act as insulators to protect against corrosion in the extremely hot engine environment. The protection thus afforded allows increasing the operating temperature of an engine by several hundred degrees, a means of increasing overall engine efficiency.

TRW's invention is a computer-aided, fully-automatic system for spraying a very hot plasma onto engine parts. Composed of a gas into which metallic and ceramic powders have been injected, the plasma forms a two-layer insulative coating. The system eliminates the need for extra machining and tooling in production of turbine blades, because the blades are made by an add-on process—adding the sprayed metal or ceramic plasma—rather than by removing metal, as most parts are made. Although the Lewis program focused on aircraft applications, the plasma-spraying system can also be used to coat industrial turbines for greater operational efficiency. NASA has granted TRW a waiver allowing the company to market the system commercially; it is already in operational service with TRW on an Air Force contract for coating aircraft engine blades.

A critical part of the coating operation is controlling the thickness of the plasma deposit, which is measured in thousandths of an inch. To assure exact coating, TRW developed an optical detector that illuminates spots at various locations on the blade, determines thicknesses by measuring reflected light, and monitors the spraying process until precise coating thicknesses are attained. The detector became the basis for the system pictured, a computerized optical gage for measuring and inspecting turbine blades, vanes and other parts with complex shapes. A variable lens focuses light on the part to be measured, then a device measures the intensity of the light reflected back to the lens; the light intensity is a basis for making measurements within a millionth of an inch. The system offers improvements in the quality of manufactured parts and provides savings through elimination of inspection variables that occur in standard methods of inspection. The gage is now in active service with TRW's Aircraft Components Group. Although it is designed specifically for use on aircraft engine blades and vanes, similar equipment could be fabricated for many other complex geometry tools, dies and components.

TECHNOLOGY FOR ICE RINKS

An icemaking system derived from NASA solar heating research highlights spinoffs for home, consumer and recreational use

At the Texas State Fair in Dallas, Ron Urban's International Ice Shows set up a portable rink-stage in a single day, then managed to keep the ice hard through four shows a day for 22 days—despite the fact that temperatures ran 90 to 95 degrees. That was a tough job, but assignments like that are routine to Urban's crew, thanks to a highly efficient icemaking system derived from technology developed under NASA sponsorship.

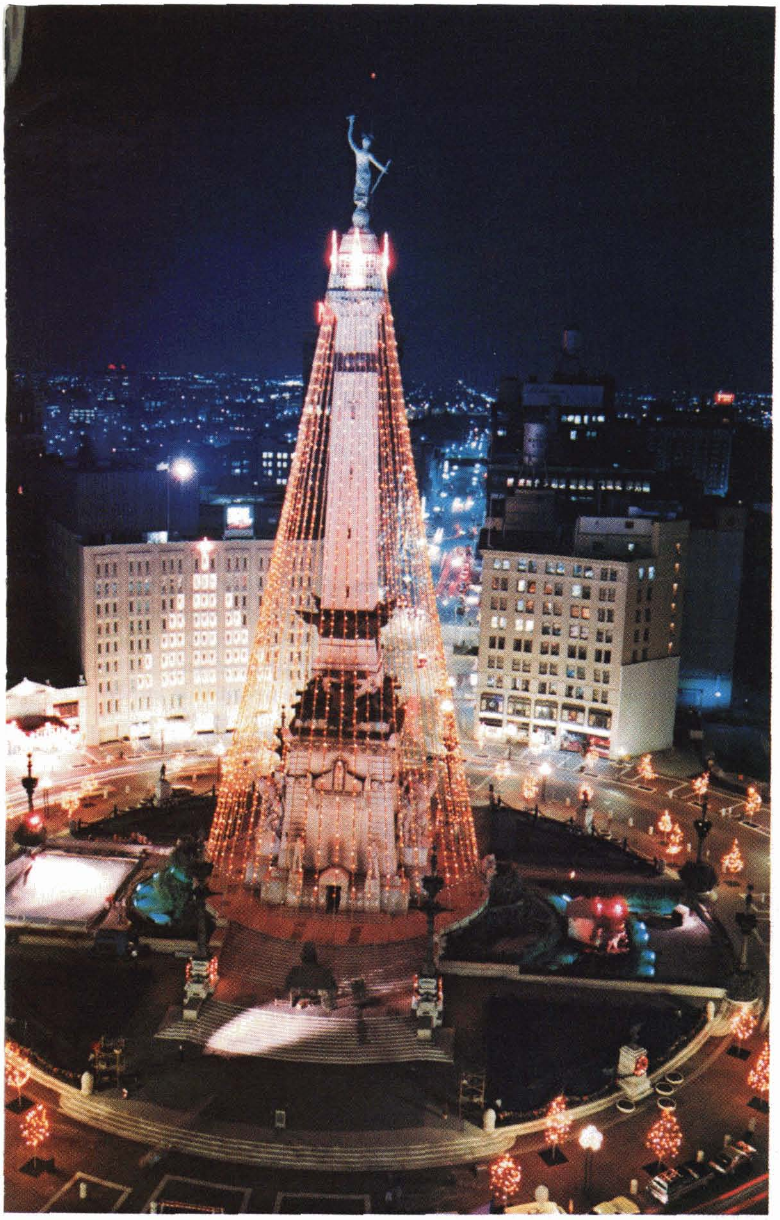
An International Ice Shows troupe performs on a temporary rink built atop a theater stage by means of a spinoff icemaking system called ICEMAT.

Located at Palos Heights, Illinois, International Ice Shows operates several touring troupes performing on temporary rinks at amusement parks, sports arenas, dinner theaters, shopping malls and civic centers; on one occasion they put on a show at the White House. The company also provides completely installed rental ice rinks, offering portable units for indoor or outdoor use ranging from the size of a large room to a hockey rink. It takes as little as one day to set up a small rink, a week for the largest. The key to enhanced rink portability, fast freezing and maintaining ice consistency is a mat of flexible tubing called ICEMAT®, an offshoot of a solar heating system developed by Calmac Manufacturing Corporation, Englewood, New Jersey, under contract with Marshall Space Flight Center. The project was part of the Department of Energy's solar energy program, in which Marshall was responsible for developing advanced technology.

Most solar collectors distribute heat by a network of metal pipes through which Sun-heated water flows. In his work for Marshall, Calmac president Calvin McCracken came up with an innovative energy absorber made of flexible tubing rather than pipes; the tubing is made of synthetic material, a rubber-like elastomer called EPDM.

Called SUNMAT®, the flexible tube system offers a number of advantages. Delivered in rolls four and a half inches wide, the tubing can be cut to any length and zipped together, which allows tailoring a solar collector to any desired size or shape. It is easily spliced for repairs and the formulation of the plasticized rubber eliminates cracking due to ozone attack or the stress of repeated expansion and contraction. Originally designed as a solar collector for home, pool or hot water heating, it can also be used as a heat distribution system for fuel-powered energy sources; it can be employed for radiant floor heating in homes or offices or, in such outdoor installations as driveways, patios and parking lots, for surface heating to prevent ice and snow buildup.

®ICEMAT is a registered trademark of ITT Corporation.
®SUNMAT is a registered trademark of the Besicorp Group.



Based on a mat of flexible tubing for freezing water, the ICEMAT system allows quick freeze and permits rink construction in any size or shape. This one, measuring 50 by 80 feet, is a public skating rink at Indianapolis' Monumemt Circle set up each winter by International Ice Shows.

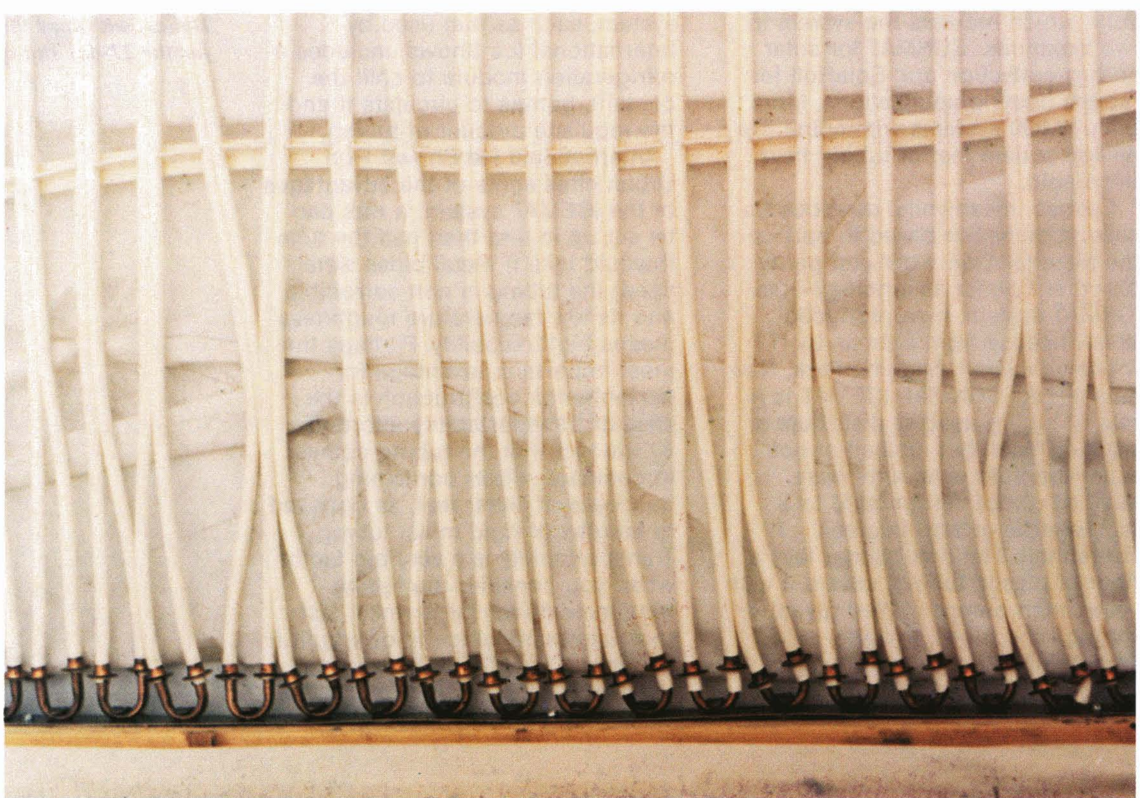
This rink, built by International Ice Shows for the Texas State Fair at Dallas, withstood 90-plus temperatures for the 22-day run of the show.

Calmac sold the SUNMAT line to the Besicorp Group, Ellenville, New York, which markets the system in two variations: SUNMAT for solar energy collection and SolaRoll for radiant heating applications. More than 10,000 systems with some five million square feet of tubing have been sold.

Calmac, meanwhile, developed a second derivative based in part on the Marshall/DoE work and partly on other Calmac technology—the ICEMAT system, now produced under license from Calmac by ITT Marlow Division, Midland Park, New Jersey. Like SUNMAT, ICEMAT is a mat of tubing used to distribute a working fluid, but instead of hot water the fluid is an antifreeze, such as glycol, refrigerated to a temperature of zero degrees Fahrenheit. The rink builder lays a floor of plastic tubing, covers it with water, then pumps chilled glycol through the tubes. It works something like the home refrigerator: the cold glycol draws warmth from the water, thereby freezing it. A complete icemaking system, such as that used by International Ice Shows, includes a refrigeration module to chill the coolant, pumps to circulate it and the requisite amount of tubing.

International Ice Shows' Ron Urban cites some of the advantages of the ICEMAT system: a rink can be set up in less than half the time it would take if metal pipes were used; the tubing is non-corrodible and its low temperature toughness means high reliability. Perhaps the most important advantage for portable rink construction is the ease of transportability afforded by the fact that the tubing comes in compact spools containing hundreds of linear feet, as opposed to lengths of rigid metal tubing. Transportability is a very big factor when you consider the tubing requirements for large rinks: last year International Ice Shows built a 200-foot ICEMAT rink that needed more than 32 *miles* of tubing.

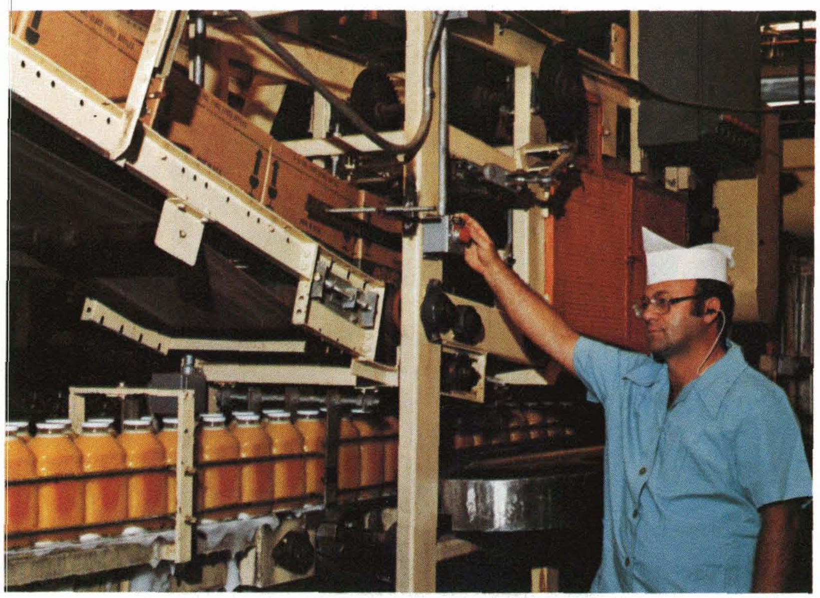
Normally a water-filled reflecting pool, the Royal Fountain (top) at Kings Island amusement park near Cincinnati, Ohio has been drained and covered with a wood base, first step in creating a public skating rink for last year's month-long "Winterfest" at Christmastime. The International Ice Shows' trailer being craned into position contains an icemaking system that includes a refrigeration unit, pumps and spools of flexible tubing, the latter a spinoff of NASA solar heating research. At left, the plastic tubing is rolled out to cover the wooden base; the tubes are shown in closeup below. Next, the field of tubing is covered with water (above right); in this case, several tons of crushed ice were added. Then compressors in the trailer pump glycol chilled to zero Fahrenheit through the 32 miles of tubing; the glycol draws warmth from the water, thus freezing it and (right) the Royal Fountain becomes a 200-foot public skating rink with three inches of solid ice.



INVENTORY MANAGEMENT

In the photo above, a clerk at Tropicana Products, Inc., citrus fruit and juice producer of Bradenton, Florida, is recording receipt of materials in the company's new automated inventory management system. Known as MRO, for Maintenance, Repair and Operating supplies, the Tropicana system is an adaptation of the Shuttle Inventory Management System (SIMS) developed by NASA to assure an adequate supply of every item used in support of the Space Shuttle. The Tropicana version monitors inventory control, purchasing, receiving and departmental costing for eight major areas of the company's operation: the Industrial Glass, Plastics Manufacturing and Fort Pierce Citrus Manufacturing divisions, rail car repair, lift truck maintenance, the auto/truck garage, the machine/sheet metal shop and the main stock room. The company reports that the visibility afforded by MRO enabled identification of more than $1 million in excess and obsolete supplies; that allows cost avoidance of about $100,000 a month.

Originally developed by Kennedy Space Center (KSC), SIMS required software modification for adaptation to company use. Tropicana's own computer technicians handled the adaptation, converting a manual Cardex inventory control system into computer language compatible with SIMS; KSC provided assistance in the form of documentation manuals and adaptation guidance. Additional guidance was provided by the Computer Software Management and Information Center (COSMIC)®, NASA's repository of adaptable computer programs and software expertise.



SPACE CAMERA

The accompanying photos show two versions of the Nikon F3 35-millimeter camera, produced by Nikon, Inc., Garden City, New York. At right is the company's standard F3 consumer product; shown below is a camera specially modified for use by Space Shuttle astronauts. The modification work produced a spinoff lubricant. Because lubricants in space have a tendency to "migrate" within the camera, Nikon conducted extensive development to produce non-migratory lubricants; variations of these lubricants are used in the commercial F3, giving it better performance than it would have with conventional lubricants. Another spinoff is the coreless motor, which allows the F3 to shoot 140 rolls of film on one set of batteries.

Nikon modified two cameras that made their space debuts on STS-3, the third test flight of the Shuttle Orbiter Columbia, in March 1982. On that occasion, the cameras were used only for inside shots or for views of the Orbiter's cargo bay taken from the flight deck.

Beginning with STS-6 in 1983, however, the camera will be used by space-suited astronauts working in the cargo bay or outside the Orbiter; the requirement for extravehicular operation of the cameras demanded most of the modifications.

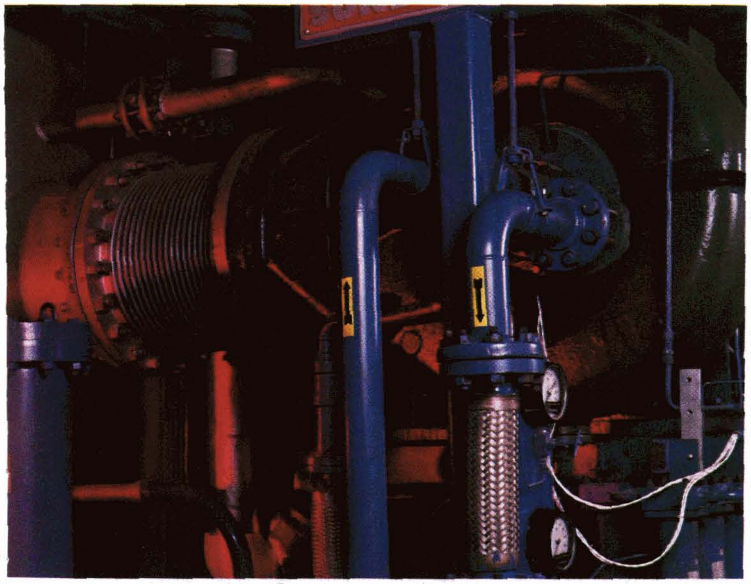
Nikon built a thermal bag to cover most of the F3 and protect it from the extremely harsh environment of low Earth orbit, where temperatures range from 100 degrees to minus 15 degrees Fahrenheit. The normal viewfinder was replaced by a "Long-eye Relief Viewfinder" necessitated by the fact that extravehicular astronauts wear helmets with faceplates; the new viewfinder allows convenient focusing and framing of pictures despite the fact that the operator's eye is some distance from the camera. Nikon added wing tabs—small extensions that stick out from the Nikkor lens—so the astronauts can change focus ring and aperture settings with gloved hands, and an extended shutter release button to allow gloved shutter tripping. In addition to the standard 36-exposure film pack, the space cameras will also have 250-exposure film magazines. For launch, the F3s are packed in special foam containers to protect them from vibration; in orbit, to prevent floating when the cameras are not in use, they can be stuck to any convenient surface by velcro fasteners along their backs.

ENERGY RECOVERY SYSTEM

A "cogeneration" system is one in which the energy ordinarily wasted in an industrial process is recovered and reused to create a second form of energy. The idea has been around for more than 30 years and it saw some industrial application in the 1950s, but usage dwindled thereafter. Today there is a revival of interest due to still-increasing power costs and a number of advanced technology cogeneration systems are being employed in industrial operations. An example is the energy recovery system at Crane Company's plant in Ferguson, Kentucky, which manufactures ceramic bathroom fixtures such as the sinks being conveyed to a kiln (below). Crane's system captures hot stack gases from the company's four ceramic kilns and uses them to produce electrical power for plant operations.

Built by Sundstrand Energy Systems, Rockford, Illinois, the Crane Company installation is the first industrial application in a pilot program jointly sponsored by Sundstrand and the Department of Energy. Key to the system's flexibility, which permits energy recovery from a wide variety of waste heat sources, is an Organic Rankine Cycle (ORC) engine originally developed by Sundstrand for spacecraft electrical power.

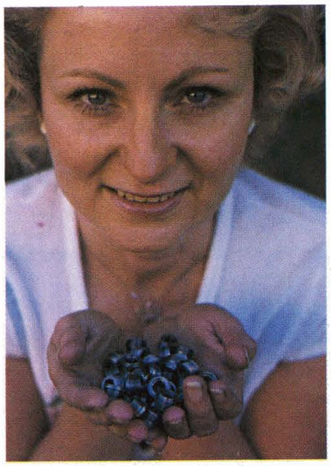
In the Crane installation, an exhaust manifold (right) collects waste heat from one or more of the ceramic kilns and directs it to a central vaporizer. There the heat

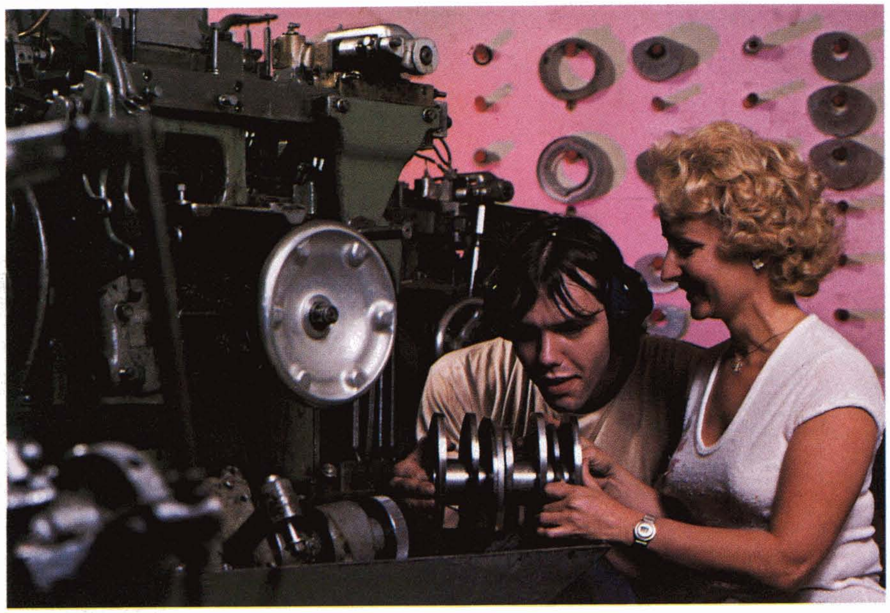


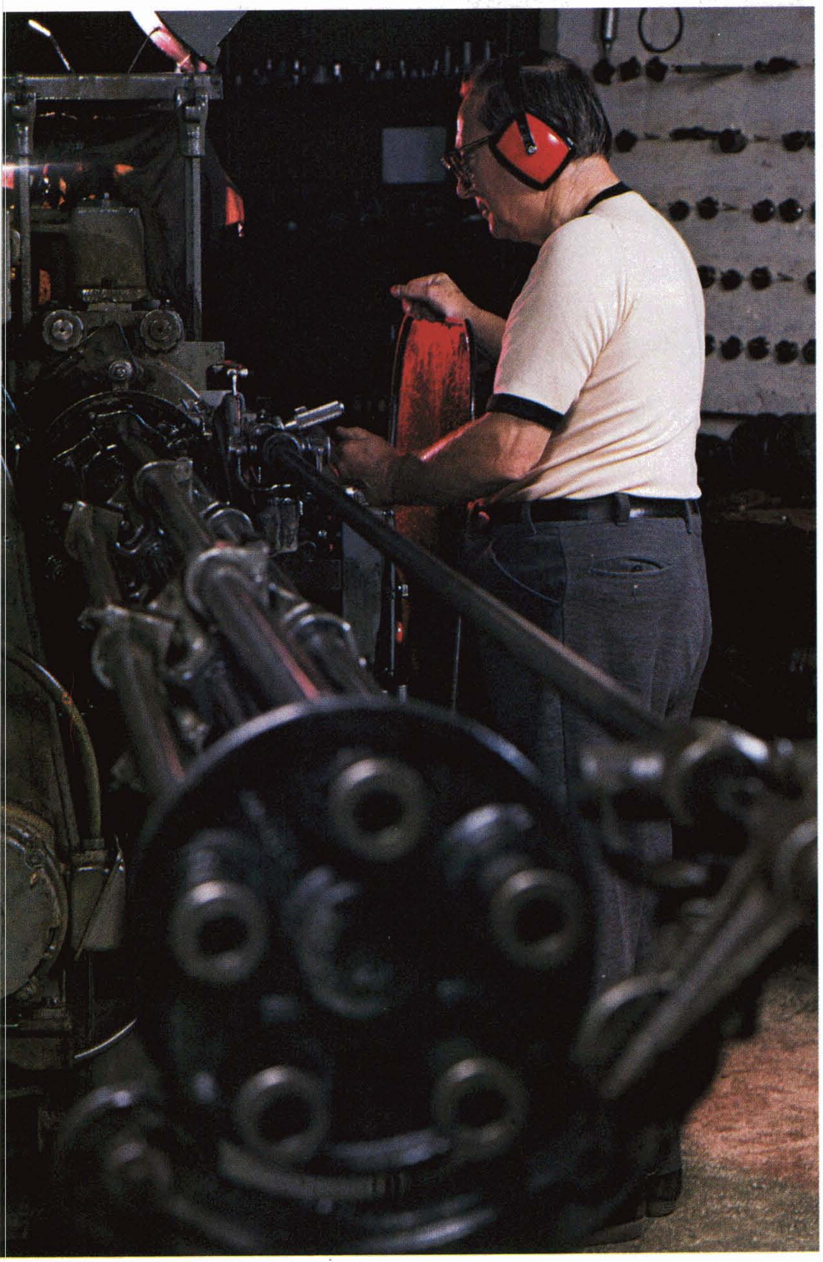
is used to vaporize a working fluid—toluene in this case. The vaporized toluene drives a turbine (above) connected to the 750 kilowatt ORC generator, which produces electricity and feeds it into a plant distribution system, thus reducing the kilowatt demand on the local utility. The toluene vapor, meanwhile, is recondensed to liquid form, cooled and used again. The whole operation is monitored by a control unit (right), which also synchronizes power from the ORC generator with power supplied by the local utility.

In an initial seven-month test, the Crane system produced 20 percent of the plant's total power requirement while operating at only 75 percent capacity. Crane Company expects to produce 30–40 percent of its own electricity and estimates that reduced power cost will pay back the investment in the cogeneration system within three years.

The NASA/University of Kentucky Technology Applications Program (NASA/UK TAP) played a supporting role in the Crane Company installation, in response to the company's request for assistance in developing improved energy conservation and utilization practices. The idea of using an ORC engine as an industrial cogeneration system emerged from NASA/company cooperation. NASA/UK TAP conducted a search of NASA's computerized data bank for relevant information and was able to provide Crane Company with important information used by the firm to evaluate each of the components of the ORC system prior to commitment. NASA/UK TAP's information also contributed to problem solving during the installation and initial operation. NASA/UK TAP is one of 10 NASA-sponsored dissemination centers that provide informational services and technical help to industrial and government clients.







MONEL MACHINING

An example of the technical assistance provided industry and government clients by NASA's Industrial Applications Centers (see page 136) is a research job performed for Castle Industries, Inc., Beacon, New York by the New England Research Application Center (NERAC) at the University of Connecticut.

Castle is a small machine job shop manufacturing replacement plumbing repair parts, such as faucet, tub and ballcock seats. Formed in 1978, Castle is owned and operated by two women—president Therese Castley and vice president Christine Martignetti—in a field of industrial activity where distaff management is unusual. At top left, Castley displays a handful of faucet seats; they are similar to Castle's earlier brass parts but made of a type of metal called R-405 monel. In the photo above, Castley is instructing a machine operator in monel maching technique.

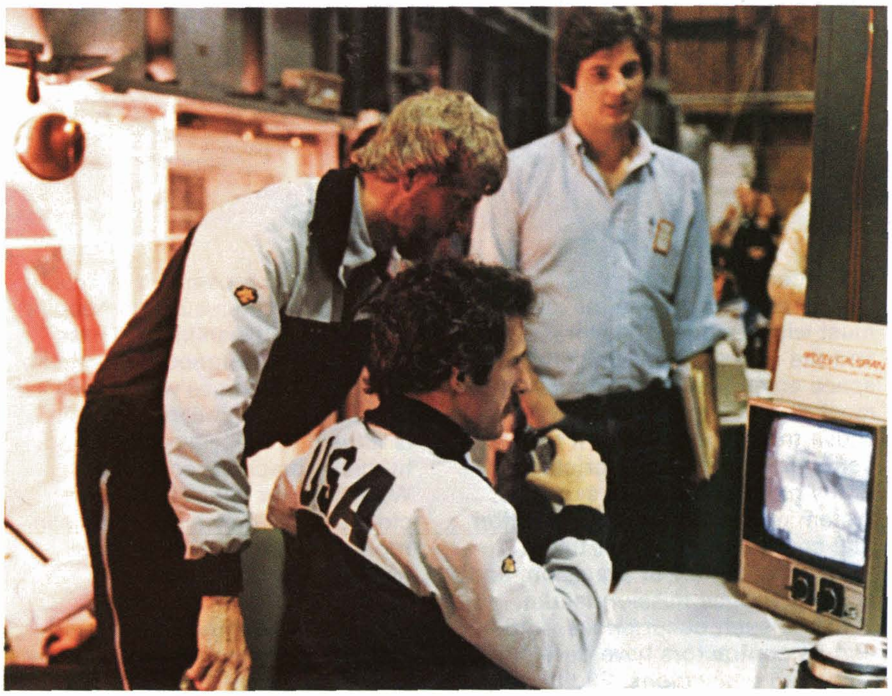
Castley decided to introduce monel because it offered a chance to improve competitiveness and expand the product line. Because of difficulties in machining monel, there is a shortage of replacement parts, hence a good market; also, buyers at most government installations will accept only monel for certain types of replacement parts. Before expanding, Castle Industries sought NERAC assistance on monel technology. NERAC assigned a metals specialist who searched seven computerized data bases and produced an informational package that proved very helpful. NASA's own data base yielded a wealth of information on machining monel with the company's Davenport screw machines (left). Castley estimates that the new monel line will boost sales by more than $1 million over five years.

SKIING SIMULATION

At left, Dr. Michael Holden is preparing a skier for a test in which a wind tunnel simulates the 60-mile-per-hour speeds encountered by a ski jumper. Dr. Holden is an aerodynamicist who normally works on the re-entry characteristics of space vehicles for Calspan Corporation, Buffalo, New York. The low speed wind tunnel, at Arvin/Calspan Advanced Technology Center, is generally used for aerospace research or in a company spinoff program involving the aerodynamic considerations of designing large structures (see page 92). Calspan donated the use of the wind tunnel for a program aimed at improving the performance of members of the U.S. Ski Team; Dr. Holden, a certified ski instructor, offered to apply his aerodynamics expertise to the design and supervision of the tests. Initiated four years ago, wind tunnel simulations have become an annual part of the U.S. Ski Team's training for U.S. and international events.

Dr. Holden realized the advantage of determining, on an individual basis, the optimal aerodynamic body positions at varying speeds in either ski jumping or downhill racing. He designed test equipment, including a computer program to simulate the conditions of actual ski courses, instruments to measure and display lift and drag values, and video screens to show a skier how changes in body position affect lift and drag; in the lower photo, Ski Team members watch on a monitor while a fellow member does a simulated jump.

Downhill racers learn from these simulations which body positions are most effective in maintaining speed through the flats, bumps, sharp turns and long radius turns that make up a downhill course. For ski jump simulations, the skier is supported by cables and counter-balanced so that, when the wind is turned on, he is literally flying and can "lean on the wind" as in an actual jump. In tunnel runs, skiers can learn in a few hours a personalized "tuck"—body position—that many of them have spent years trying to develop on a trial and error basis. U.S. Ski Team members and coaches are enthusiastic about the results.



APPAREL FOR CLEANER CLEAN ROOMS

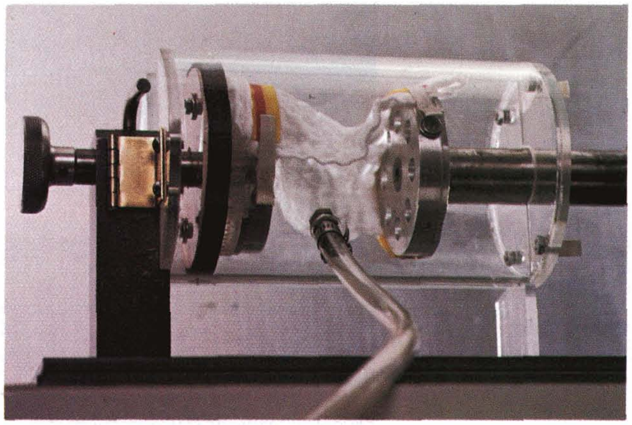
Among spinoff innovations in medicine, pharmaceuticals and medical systems manufacture is a line of garments for improved contamination control

Technicians engaged in production of nuclear diagnostic pharmaceuticals at Medi-Physics, Arlington Heights, Illinois are wearing new Micro-Clean anticontamination garments developed and manufactured by American Hospital Supply Corporation.

Spacecraft equipment is necessarily rugged, because it must withstand launch vibration and the rigors of an inhospitable space environment. But the most rugged equipment can cause trouble in space if it is contaminated during fabrication. A tiny mote of dust in a sensitive system might trigger a malfunction that could at best impair the system's accuracy or precision, and at worst induce mission failure.

To bar such occurrences, NASA and its contractors have developed elaborate precautions. Flight equipment is assembled in "clean rooms" that often surpass hospital standards of cleanliness. These facilities are designed to eliminate nooks and crannies where dust particles might collect, their air is filtered, their temperature and humidity precisely controlled. Workers wear special lint-free clothing and they enter the clean room through an airlock that prevents contamination from outside air.

In the 1960s, NASA pioneered contamination control technology, providing a base from which



The photo at left shows an earlier method of testing the effectiveness of clean room apparel. The apparatus twists woven fabric to release minute particles as air is passed through the fabric and into a particle counter. Micro-Clean garments are made of non-woven material, hence have no "windows" to allow air passage. So project engineer Rem Siekmann devised the new testing apparatus he is using below, a computerized system for counting particles dislodged by abrasion when a metal block is rubbed over the fabric.

aerospace contractors could develop advanced control measures. NASA conducted a number of special courses for clean room technicians and supervisors, and published a series of handbooks with input from Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), Kennedy Space Center, Lewis Research Center and Sandia Laboratories. These handbooks, which represented the most comprehensive body of knowledge on contamination control techniques available at the time, extended aerospace experience to the medical, pharmaceutical, electronics and other industries wherein extreme cleanliness is important.

NASA's work provided an information base for a new contamination control development, the Micro-Clean™ line of garments for hospitals and industrial clean rooms introduced last year by American Convertors Division of American Hospital Supply Corporation (AHSC), Evanston, Illinois. The garments are distributed by another AHSC division, American Scientific Products, in McGaw Park, Illinois.

AHSC researchers—in particular Rem Siekmann, project engineer in American Convertors' Department of Product Development—felt that high technology products with increasingly stringent operating requirements in aerospace, electronics, pharmaceuticals and medical equipment manufacture demanded improvement in some contamination control techniques. In 1980, Siekmann started research on the subject. He began by studying the NASA handbooks, then visited JSC, MSFC's Michoud, Louisiana facility and several industrial clean room operations, acquiring through interviews a wealth of information on current anticontamination technology and problem areas.

The line of clean room garments that emerged from Siekmann's research and subsequent development stemmed from the company's conclusion that the greatest sources of clean room contamination are the people who work in such facilities; they exude infinitesimal body particles that escape through tiny "windows" in the woven garments they wear. American Convertors, therefore, made its Micro-Clean apparel of soft, non-woven material that is capable of blocking well over 99 percent of all particulate matter smaller than half a micron, a millionth of a meter—which compares with about 15 percent for one material commonly used in clean room wear. Micro-Clean garments are disposable, eliminating the costs of repairs and processing associated with reusable garments. The product line includes pullover hoods, caps, coveralls and "high-top" shoe covers that reach all the way to the knee. The apparel offers two-way contamination control, meaning that it not only protects the product from the people but, where pertinent, protects people from the product or from certain chemical hazards.

In experimenting with new fibers and materials to develop non-woven garments, American Convertors had to find new ways of evaluating the apparel. The company thus provided an additional advance in contamination control technology by devising new tests and testing apparatus, for example, a test to determine how effectively a fabric blocks passage of microscopic particles and a technique for counting the particles removed from a fabric. Developed by Rem Siekmann, the tests are being considered for adoption as industry standards by the Institute of Environmental Sciences.

™Micro-Clean is a trademark of American Hospital Supply Corporation.

ANALYTICAL DEVICE

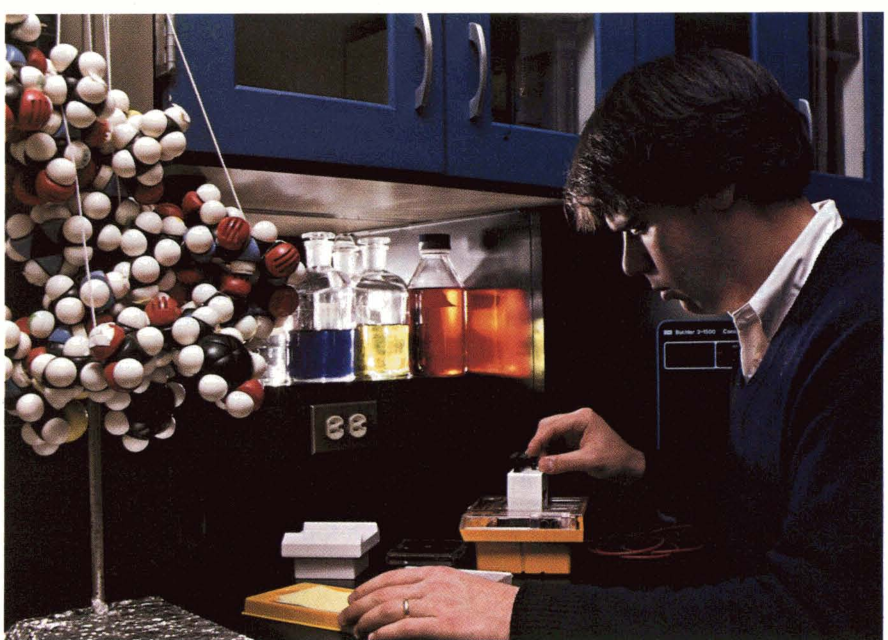
Blood is a complex mixture of particles and organic molecules in solution. In blood analysis—such as the routine blood test—a biochemist must determine the presence and amount of specific blood constituents without interference from other compounds in the mixture. A widely used method of doing that is electrophoresis, a process whereby the components of a fluid are separated by electric current.

In the mid-sixties, Ames Research Center sponsored development of an automated electrophoresis device that would work in the weightless environment of space; it was intended for use in a monkey-carrying spacecraft to provide information on blood behavior in zero gravity, but it did not reach flight status. In 1972, a modified system was planned for use in the Skylab interim space station to study possible changes in astronauts' blood during long-term weightlessness; again it did not fly in space, although it was used in simulated weightlessness studies at Ames. Because the project had produced considerable advanced technology, the device was revived once more in the mid-seventies, this time as a technology utilization project aimed at an automated system for Earth use.

Ames contracted with the investigator who had developed the original device—Dr. Benjamin W. Grunbaum of the University of California at Berkeley—for development of an advanced system that became known as the Grunbaum System for Electrophoresis. It is a versatile, economical assembly for rapid separation of specific blood proteins in very small quantities, permitting their subsequent identification and quantification. The system is capable of handling 10 to 20 samples simultaneously.

The Grunbaum system became a commercial product in 1982, produced under NASA license by Sartorius Filters, Inc., Hayward, California, an international company headquartered in Goettingen, West Germany. Known commercially as the Sartophor® System for Electrophoresis (above), it is both a research instrument and a diagnostic aid, with many applications in medicine, law enforcement science, pathology, biochemistry and other biological sciences; as a system for analyzing substances other than blood, it offers applications in the food, agriculture, cosmetic and pharmaceutical industries. Below, a researcher at Vanderbilt University, Nashville, Tennessee is using the Sartophor system in a study of the functions of proteins.

®Sartophor is a registered trademark of Sartorius GmbH.

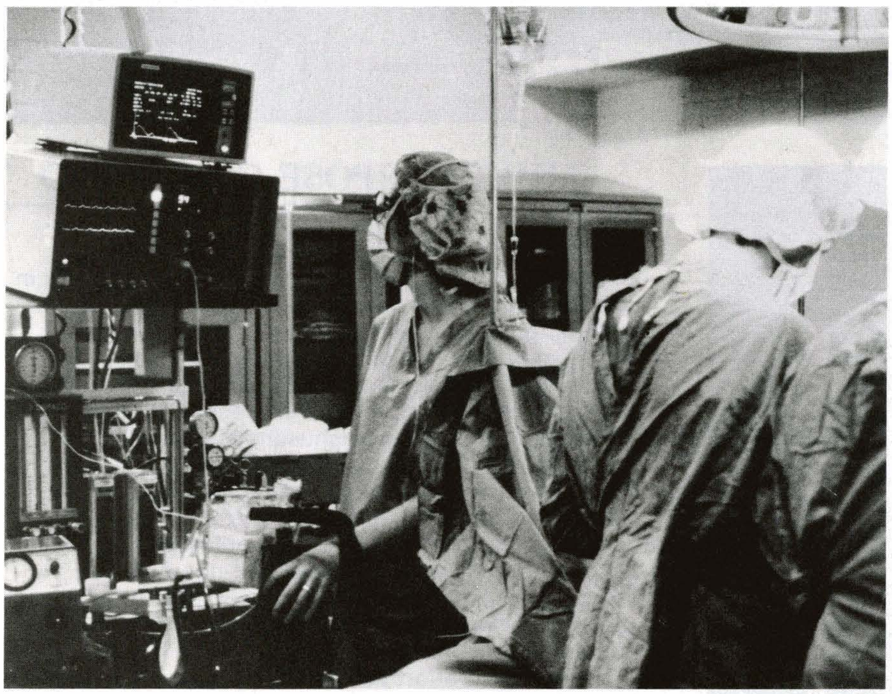


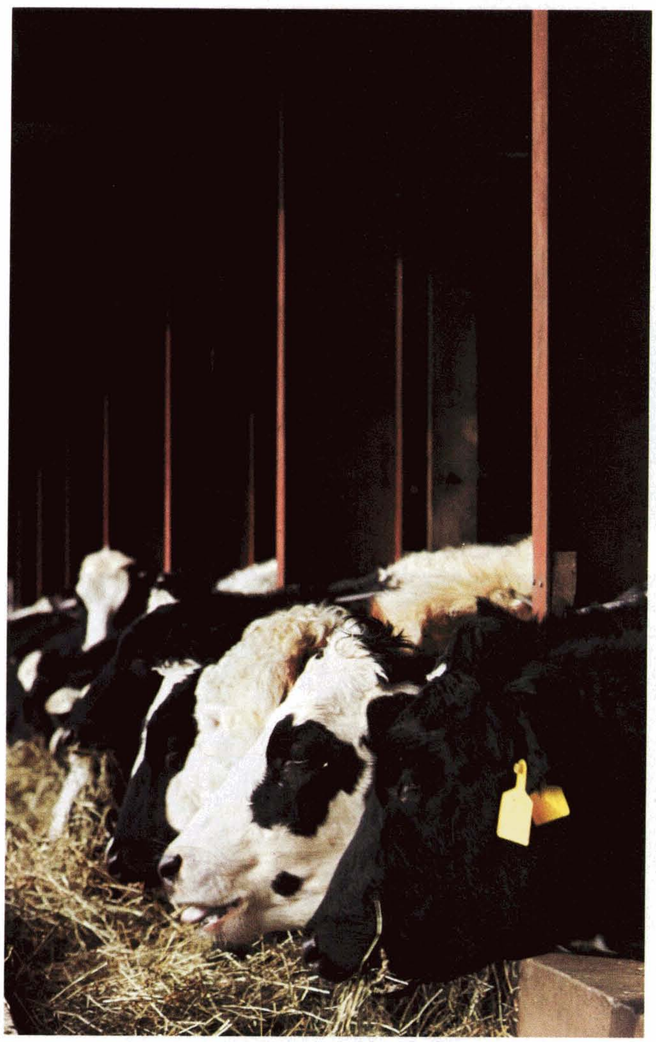
MEDICAL GAS ANALYZER

Below, an anesthiologist is scanning a display of data on the gases inhaled and exhaled by a patient during surgery at Wishard Memorial Hospital, Indianapolis, Indiana. The display unit is part of the hospital's Remote Monitoring System (RMS), whose principal component was originally developed for spacecraft use. The RMS is manufactured by Perkin-Elmer Corporation, Norwalk, Connecticut, a leading NASA contractor for space systems.

At Wishard Memorial, the RMS is used in operating rooms for analysis of anesthetic gases and measurement of oxygen, carbon dioxide and nitrogen concentrations. It assures that a patient undergoing surgery has the proper breathing environment—that he has enough oxygen, that the carbon dioxide is properly removed and that the mixture of oxygen and nitrous oxide is correct. Heart of the system is a fully automatic gas analyzer developed by Perkin-Elmer to monitor astronauts' respiratory gases in NASA's Gemini and Apollo programs. A small amount of gas drawn from the patient's inspired and expired breath is transmitted through a line to an inlet selector valve that delivers the gas to the analyzer. The system can monitor as many as 16 patients, with displays of six gases at a central station and within each operating room. RMS provides an alarm if the concentrations of gases are too high or too low. At Wishard Memorial, the system is not only helping to save lives but it is also providing substantial savings as a replacement for earlier, gas-wasteful monitors.

About 50 hospitals and research facilities are now using RMS for various purposes. The bottom photo illustrates an example: it shows a central control station at Kaiser Foundation Hospital, Los Angeles, California, where the RMS monitors patients in the Intensive Care Unit.





MULTIPURPOSE COMPOUND

Caused by bacteria, bovine mastitis is an inflammation of a cow's mammary gland that results in loss of milk production and, in extreme cases, death. According to the National Mastitis Council, it is the largest cause of financial loss for the U.S. dairy industry, amounting to about $2 billion annually. The University of Massachusetts Department of Animal Sciences, Amherst, Massachusetts is conducting a year-long test of products that might be the answer to effective treatment and prevention of the disease, specially-formulated derivatives of an unusual basic compound known as Alcide™. Manufactured by Alcide Corporation, Westport, Connecticut, the Alcide compound has killed all tested bacteria, virus and fungi shortly after contact, with minimal toxic effect on humans or animals.

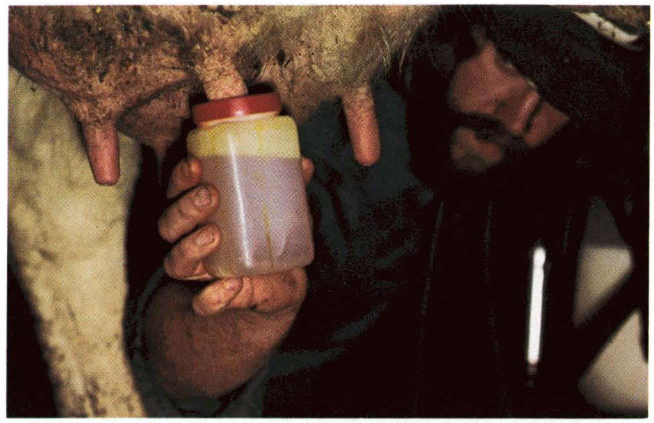
The research effort at the University of Massachusetts' farm involves test of a teat dip version of the Alcide compound as a prevention measure, and intramammary infusions of a related solution designed to treat mastitis. In the upper photo is the farm's milking barn where cows being treated first undergo udder cleansing, then milking and finally teat-dipping in the Alcide preparation (opposite page, top). At right below, a graduate student researcher is taking a milk sample from a cow undergoing treatment. The Massachusetts tests have shown Alcide's teat dip to be effective against a wide range of mastitis-causing organisms; the product has also demonstrated that it is non-toxic and does not irritate the udder.

Alcide Corporation credits the existence of the mastitis treatment/prevention products to assistance provided the company by the New England Research Application Center (NERAC), one of NASA's nine Industrial Application Centers, which provide information retrieval services and technical help to industry and government clients. The story of Alcide Corporation's genesis and product line development is an example of the type of assistance centers like NERAC can provide.

The exceptional properties of the Alcide compound were discovered by Howard Alliger of Heat Systems-Ultrasonics, Plainview, New York. It was originally developed as a fast-acting liquid sterilizer for disinfecting ultrasonic cleaning tanks. On a day in 1978 when he was bothered by a skin irritation on his hands, Alliger nonetheless proceeded with a tank disinfecting job, saturating his hands with Alcide compound. By day's end, he discovered the skin irritation had disappeared. Recognizing the potential of a compound that apparently had uses far beyond tank sterilization, Alliger performed initial experiments to test its efficacy against bacteria, virus and fungi. Results were sufficiently promising that Alliger teamed with fellow inventor Elliott J. Siff to develop, market and license the compound; they are, respectively, chairman and president of the company.

Ready to market certain of their products, Alcide Company requested NERAC's assistance in identifying possible applications and the types of businesses that might use it. NERAC conducted a computer search of more than a dozen data bases and uncovered scores of applications, among them treatment of viral, fungal and bacterial infections in animals; treatment of a variety of human skin diseases; disinfection and sterilization in medical facilities; as a sterilant for food production machinery and food preservation; as a preservative for cutting oils and paints; and as a deodorant/disinfectant for carpets, chemical toilets, public conveyances and meeting places.

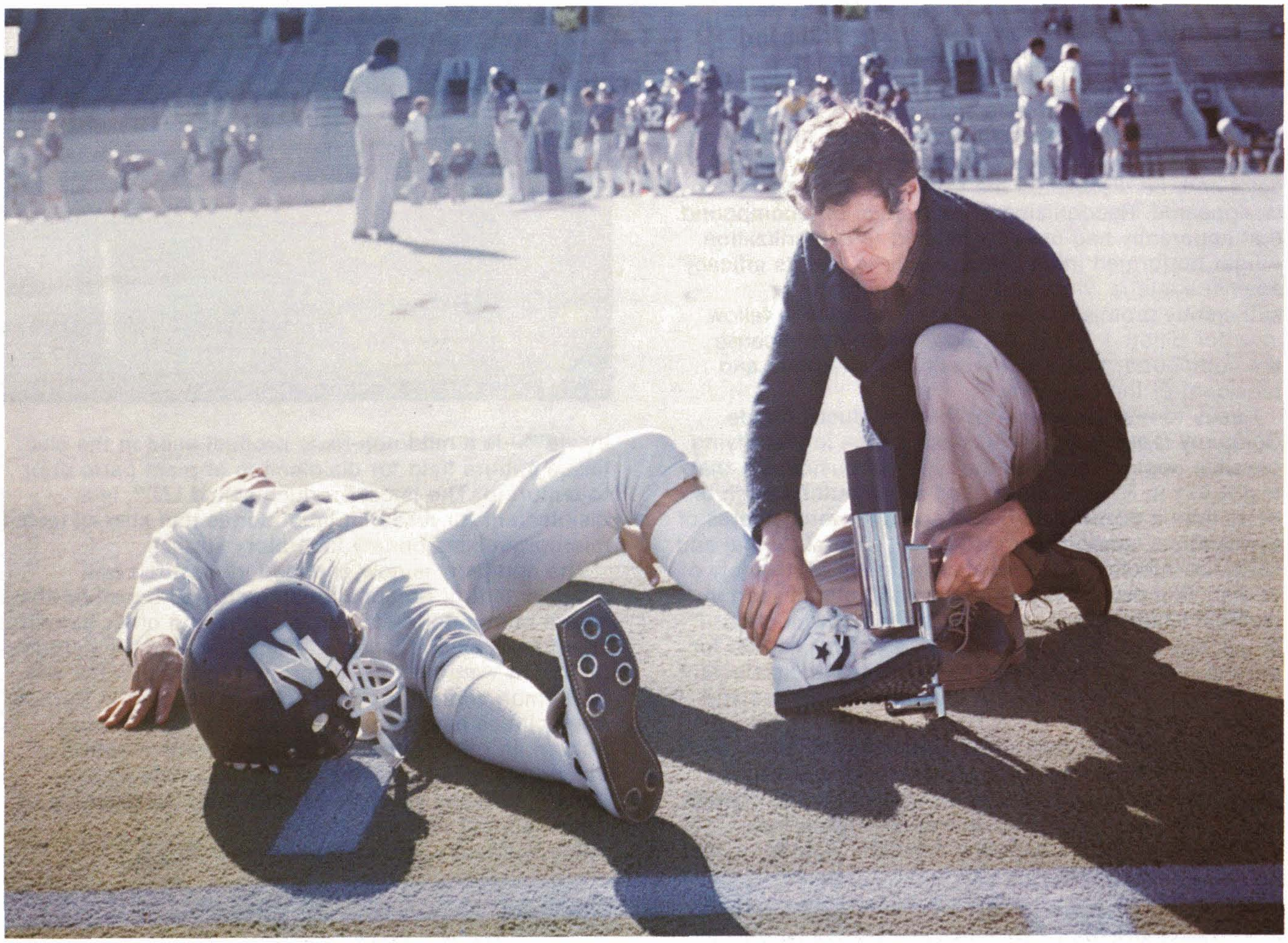
Alcide Company developed experimental compounds for some of these applications and three disinfection products have already reached the commercial market. One, called ABQ™ is used to maintain germ-free conditions in animal breeding quarters. Another—



Incyte™—is a mild non-toxic product used in the plant tissue culture field for disinfection of plant parts prior to culturing. The latest product, called LD™, is a disinfectant for research laboratories that kills all tested microorganisms on any laboratory surface.

The company is now engaged in research and development of potential treatments—all based on the Alcide compound—for herpes, acne and other human viral/fungal skin afflictions. Animal tests of the herpes treatment were sufficiently promising to open the way for human clinical trials, now being initiated in Europe. Acne clinics have begun in the U.S. at Yale Medical School. In other research and development activities, the company is exploring products containing the Alcide compound for use in extending the shelf life of fresh fish and poultry.

™Alcide, ABQ, Incyte and LD are trademarks of Alcide Corporation.

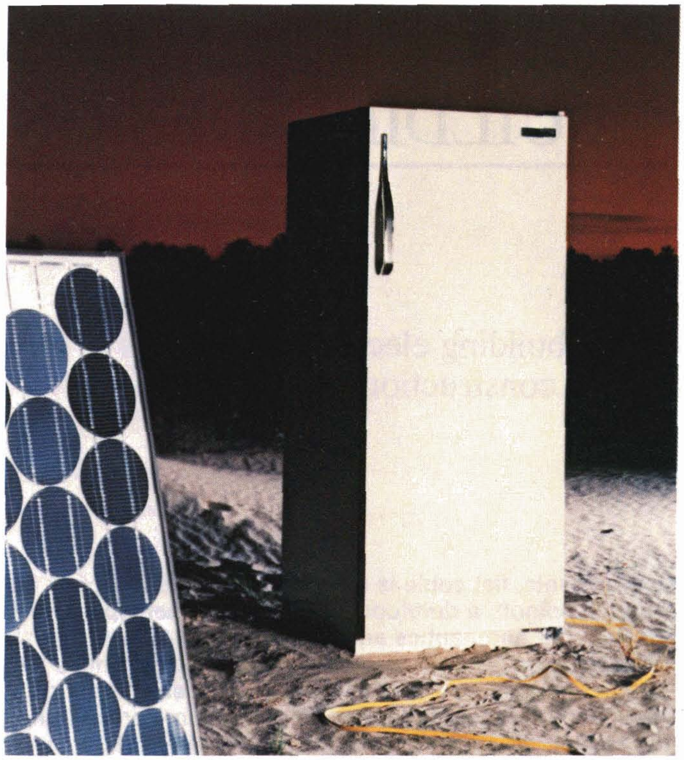


PORTABLE X-RAY DEVICE

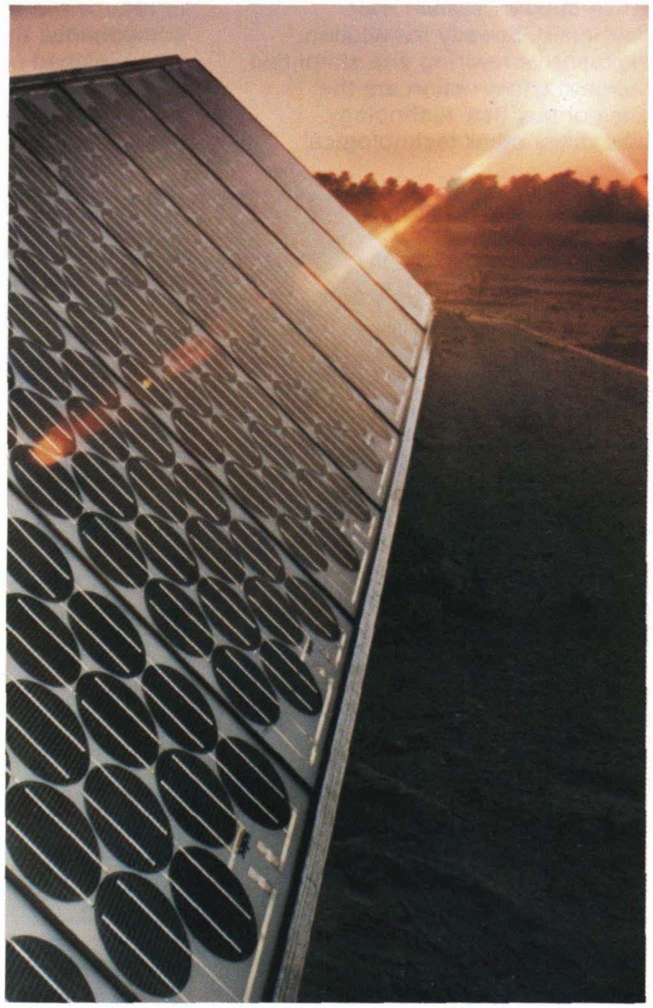
A portable x-ray instrument developed by NASA and now being produced commercially as an industrial tool may soon find further utility as a medical system. The instrument is Lixiscope—Low Intensity X-ray Imaging Scope—a self-contained, battery-powered fluoroscope that produces an instant image through use of a small amount of radioactive isotope; it is designed to utilize less than one percent of the radiation required by conventional x-ray devices. Originally developed by Goddard Space Flight Center, Lixiscope is being produced by Lixi, Inc., Downers Grove, Illinois, which has an exclusive NASA license for one version of the device. Lixi, Inc. has received Food and Drug Administration approval to begin testing the device for medical applications, the first step toward its adoption as a clinical instrument.

The unit's portability allows its emergency use in field situations where immediate fluoroscopic examination is indicated, for example, scanning for possible bone injuries to athletes (above). Lixiscope's small size and low radiation dosage makes it attractive in other medical applications, such as emergency room examination of small children to avoid the necessity for taking them to the x-ray department (below). The instrument also has applications in dentistry and orthopedic surgery.

Lixiscope is finding growing acceptance as an industrial tool in the U.S. and abroad; it is used mostly for rapid non-destructive testing—instant detection of product flaws without waiting for development of x-ray film. It is also used in security applications, such as examining parcels in mail rooms and building entries.



SOLAR EQUIPMENT



In the upper photos are a medical refrigerator and a water pump, both powered by solar cells that convert sunlight directly into electricity. They are representative of a line of solar-powered equipment—manufactured by Independent Utility Systems (IUS), Tulsa, Oklahoma—for use in areas where conventional power is not available. In developing its systems, the company benefited from NASA technology incorporated in the solar panel design and from assistance provided by Kerr Industrial Applications Center (KIAC), Southeastern Oklahoma State University, Durant, Oklahoma. KIAC is one of nine NASA Industrial Applications Centers that provide technical information services to government and industry organizations.

When they were launching their research and development effort, IUS officials sought assistance from KIAC. Most importantly, they were looking for a material that was unbreakable and not affected by ultraviolet light for use as a covering on solar cell panels, such as the one shown at right. A search of the NASA data base disclosed that Jet Propulsion Laboratory had developed, for spacecraft sensor assemblies, a polycarbonate material that was ultraviolet-resistive; it proved ideal for the company's requirement. The data base also provided information about a French company with experience in use of a metal graphite compound; the company is now supplying metal graphite brushes for the DC motors in some IUS systems. These brushes along with permanent magnets, offer long life, an important, feature where spare parts and technical knowledge is in short supply, as they are in the remote areas that constitute IUS' principal market.

IUS states that the data supplied by KIAC would have cost hundreds of thousands of dollars to develop internally and that the center's assistance substantially shortened research and development time. A relatively new company, IUS has sold water pumping systems in Pakistan, Egypt and Thailand. It has also placed refrigeration units, used primarily by remote medical clinics for storage of whole blood and vaccines, in India, South America and North Africa.

INNOVATION IN BUILDING DESIGN

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

"The latest answer to power distribution systems is to sweep them under the carpet," said the trade publication Facilities Design & Management Monthly. "Unknown only a few years ago, flat conductor cable is being highly praised as the best cost-saving office support system ever developed. Speedy installation, inexpensive rewiring and simplified building construction are the lures of this new technology. . . . Like many other technological achievements, flat cable is a space program spinoff, a development of the National Aeronautics and Space Administration."

Flat conductor cable, or FCC, was developed of necessity as aircraft and spacecraft became increasingly complex. In the never-ending battle to reduce the size and weight of components, the use of thin flat wire—instead of the relatively thick and protrusive round cable—provided a dramatic reduction of the space occupied by the many miles of power distribution lines in an aerospace vehicle.

An undercarpet flat cable installation is shown in foreground in this view of the Sun Refining and Marketing Company's offices in Philadelphia; the carpet tiles are produced by Milliken Contract Carpets, LaGrange, Georgia. Flat conductor cable offers cost savings in simplified building construction, reduced installation time and ease of alteration.

NASA recognized that FCC offered similar benefit in design of electrification systems for commercial buildings and, in the latter 1960s, undertook to promote non-aerospace use of FCC. Under the Technology Utilization Program, intended to encourage secondary application of technology in the interests of national productivity, NASA funded a project in which Marshall Space Flight Center developed prototypes for several FCC applications.

Since industry participation was essential to large-scale adoption of flat cable, NASA—in 1975—sponsored formation of a consortium composed of a dozen firms engaged in manufacture of electrical hardware and associated activities. Using Marshall's early work as a departure point, the member companies pooled their resources and technology to develop complete FCC systems. These systems encompass not only the cable but the sheathing, connectors, tools and other equipment necessary to facilitate FCC use by designers and builders. Subsequently, the use of FCC covered by carpet tiles in commercial buildings obtained approval from Underwriters Laboratory and listing in the National Electrical Code established by the National Fire Protection Association.

An example of an undercarpet flat cable system is Versa-Trak®, produced by Thomas & Betts Corporation, Raritan, New Jersey, which has been used in more than 1,500 installations. Versa-Trak cable has three layers: a top copper grounding shield, a bottom plastic abrasion shield, and the conductor

®Versa-Trak is a registered trademark of Thomas & Betts Corporation.

With power and telephone lines out of sight beneath the carpet, and with no floor-to-ceiling wiring enclosures or other ducting, flat cable gives interior designers new latitude in planning attractive "open landscape" office layouts. The photos at right and below are views of the first installation of flat conductor cable, the offices of Facility Management Institute, Ann Arbor, Michigan.

layer sandwiched in between. The cable is covered with protective adhesive steel tape.

The first FCC installation, in 1979, was in the headquarters building of Facility Management Institute (FMI), a division of Herman Miller Research Corporation, Ann Arbor, Michigan. FMI was organized to focus on the research and educational needs of facility managers. Among the Institute's functions is fostering new technologies that enhance office environments and thereby improve employee productivity. After three years experience with undercarpet wiring in its own facility, FMI pronounces flat cable "a great advancement in providing flexibility in office environments."

Only as thick as a credit card, FCC can be installed between floor and carpet tile without evidence of its presence; this makes possible elimination of the ducts—in floors, walls, ceilings or concrete slabs—ordinarily required to accommodate wiring. That offers big savings in new building construction; estimates range from 13 to 40 percent lower than conventional wiring costs. An additional efficiency is the fact that developers can delay decisions on where to put the wiring until they know who will rent the office and what kind of office it will be. When it becomes necessary to relocate work stations, as it frequently does in business operations, FCC significantly reduces the task of changing the electrical system: workers need remove only the carpet squares involved in rewiring, not the whole floor covering—again providing a monetary saving.

There is a bonus in planning office arrangements. Freedom from ducts and other traditional accommodations for wiring offers new latitude in designing airy, "open landscape" office layouts, which are becoming increasingly popular. Under the impetus of these multiple advantages, flat cable is gaining wide acceptance among builders, building managers and interior designers, and sales projections indicate that the fledgling industry is likely to expand rapidly.

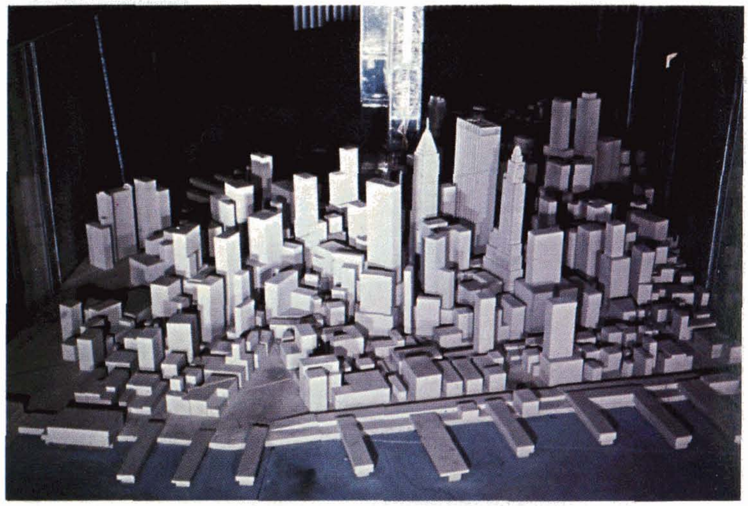
Flat cable allows speedier changing of work stations because workmen need only remove the carpet tiles involved in rewiring. The above photo illustrates minimal disruption of office activities as the technician installs Versa-Trak flat cable manufactured by Thomas & Betts Corporation, Raritan, New Jersey.

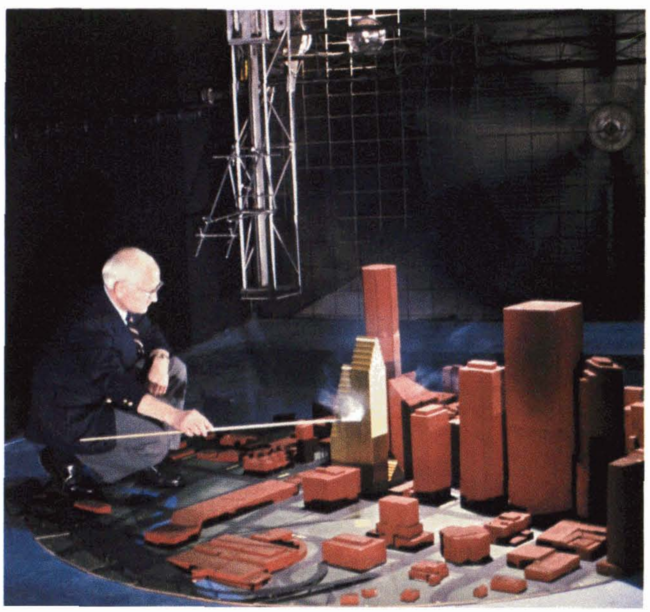
WIND ENGINEERING

Strong winds can cause a lot of problems for buildings, particularly tall buildings—structural damage, glass breakage, excessive sway or inefficient performance of heating, cooling and ventilating systems, to mention just a few of many possible difficulties. Architects can design a building to minimize adverse wind effects and take advantage of beneficial wind motion, if they have detailed information on airflows around the projected structure and neighboring buildings. Such information is provided by wind engineering, a rapidly developing discipline that involves testing models of building designs in wind tunnel facilities that simulate winds, temperatures, pressures and other variables.

Architectural wind engineering was first tried 90 years ago but it did not reach maturity until the mid-1960s, when New York City's World Trade Center (upper right) was in planning status. Project engineers were concerned about wind effect on the 1,350-foot towers, so they consulted several wind engineering experts, among them Dr. Jack E. Cermak, director of the Fluid Dynamics and Diffusion Laboratory at Colorado State University (CSU), Fort Collins, Colorado. A two-year study by Cermak and his design team resulted in important design changes; the group's wind tunnel modeling of the World Trade Center and adjacent structures is shown at right.

Cermak, a 20-year veteran, is one of the leading practitioners of the wind engineering art and the CSU facilities—with four wind tunnels—are among the most comprehensive available. Cermak developed the first wind tunnel to simulate the changing temperatures, directions and velocities of natural winds—as opposed to uniform airflow techniques employed by others. In this work, Cermak benefited from NASA technology related to what is known as the atmospheric boundary layer (ABL), the winds from ground level up to about 2,000 feet. He developed a method of simulating the ABL in a wind tunnel—in order to physically model airflows that cannot be modeled numerically—and sought a method of validating his technique,



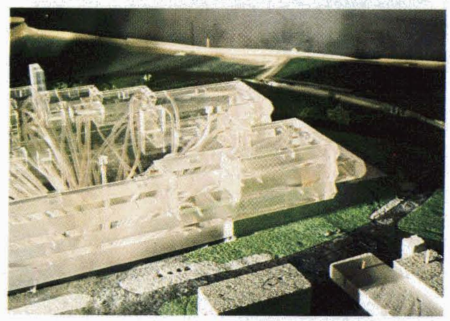


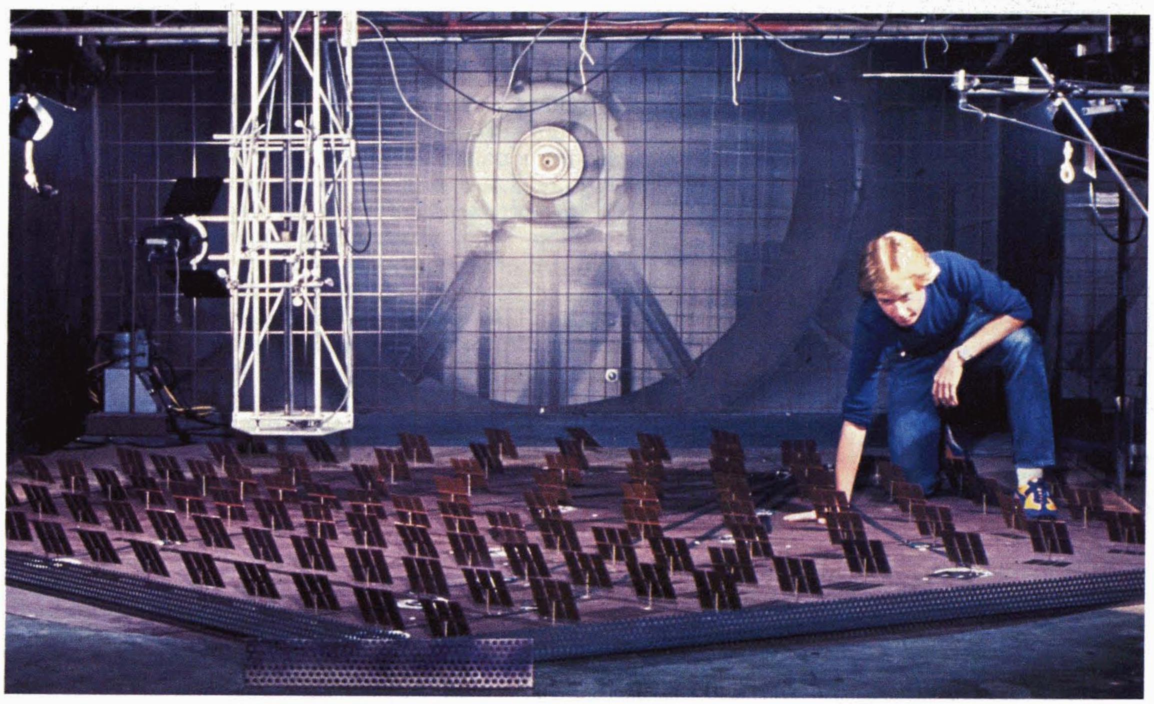
specifically a means of comparing the simulation with actual atmospheric flows. He found it in technical literature describing the results of two NASA studies—one by NASA Headquarters and one by Marshall Space Flight Center—analyzing wind flows around a 500-foot meteorological tower at Kennedy Space Center. Collectively, these studies provided an exhaustive analysis of the boundary layer wind and gave Cermak the comparative data he needed for increased confidence in the accuracy of his modeling technique.

In wind studies, the architect supplies the wind engineer design details of the projected building, along with the heights and shapes of existing buildings within a 2,000-foot radius and a topographic map of the site's terrain. From this information, the wind engineering group first constructs solid scale models of the adjacent buildings that will influence wind effect on the new building. Then they build a hollow model of the planned structure, drill several hundred tiny holes in its surface, and connect the holes by tubing to strain gauge pressure transducers. An example is shown at left, where Jack Cermak is preparing for a test run on a model of the Republic Bank Center in Houston, Texas. The whole area model is on a turntable whose rotation allows simulation of changes in wind direction. In operation, the wind tunnel creates various wind speeds and temperatures, the resulting fluctuating pressures are measured by the ultrasensitive strain gauges and the measurements are reported to a computer, which makes the necessary calculations and supplies a complete pressure distribution analysis of the building's surfaces under varying conditions.

U.S. Steel Realty Development Division

Cermak and his CSU group have conducted hundreds of wind studies, most of them on new building designs. The upper left photo shows three Pittsburgh, Pennsylvania buildings (arrows) on which the group worked, from left, the One Oxford Center building, Pittsburgh Plate Glass headquarters and One Mellon Bank Center; at upper right is the area model of the latter. Wind analyses are made for such other purposes as siting wind energy systems, modeling air pollution dispersion, controlling desert sand and simulating wind effect on Space Shuttle launches. Shown at right is a model of Children's Hospital, Washington, D.C. used in an air quality study designed to reduce entry of polluted air. Below, a technician is preparing a model of a large solar energy farm at Barstow, California for a study of wind effect on the solar reflectors.

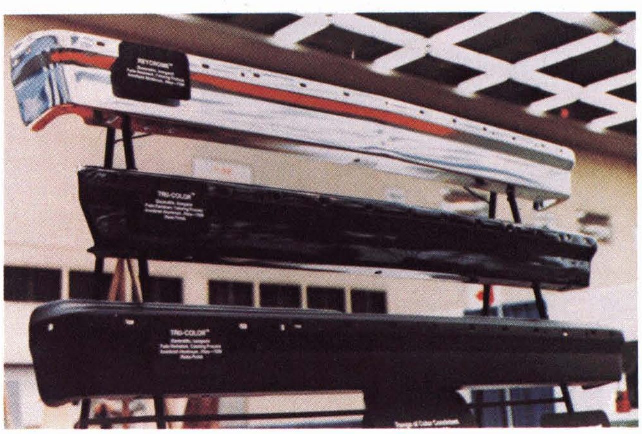




ANODIZING PROCESS

Shown below is the Empire Plaza building in Dallas, Texas, which features an aluminum color finish produced by an anodizing process based in part on NASA technology. Used to produce Tru-Color® products, the process was developed by Reynolds Metals Company and is licensed to industry by Reynolds Aluminum International Services, Inc., Richmond, Virginia. Its principal advantage lies in the considerably reduced time and energy required to produce a color finish; Tru-Color product finishes take about half the time of other anodizing methods and are processed at lower voltages, resulting in energy savings of 60 to 75 percent.

The anodizing process traces its origin to the 1960s, when Reynolds Metals Company, under contract with Goddard Space Flight Center, developed a multipurpose anodizing electrolyte (MAE) process

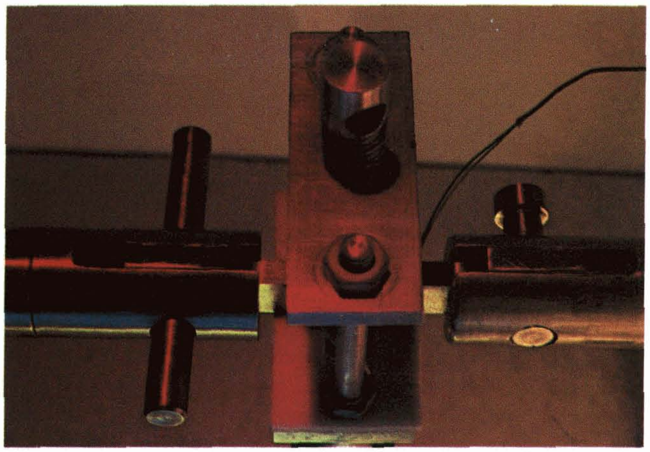


to produce a hard protective finish for spacecraft aluminum surfaces; NASA subsequently granted the company a patent waiver for MAE. In the mid-1970s, rising costs of energy led Reynolds International to look for an alternative to the existing method of color anodizing, which was becoming increasingly expensive. The result of several years of development is a two-step anodizing operation in which the MAE process is the first step; MAE produces a high-density, abrasion-resistant film prior to the coloring step, in which the pores of the film are impregnated with a metallic form of salt.

The process was developed principally for the architectural market and it has found wide acceptance in such Tru-Color product applications as building fronts, railings, curtain walls, doors and windows. It is also being used in automotive applications, primarily for car bumpers (left). Other applications include builders' hardware—such as shower enclosures, light standards, shelving brackets—and a variety of products such as boat masts, signs, belt buckles, picture frames, cookware, camera housings and decorative trim.

®Tru-Color is a registered trademark of Reynolds International, Inc.

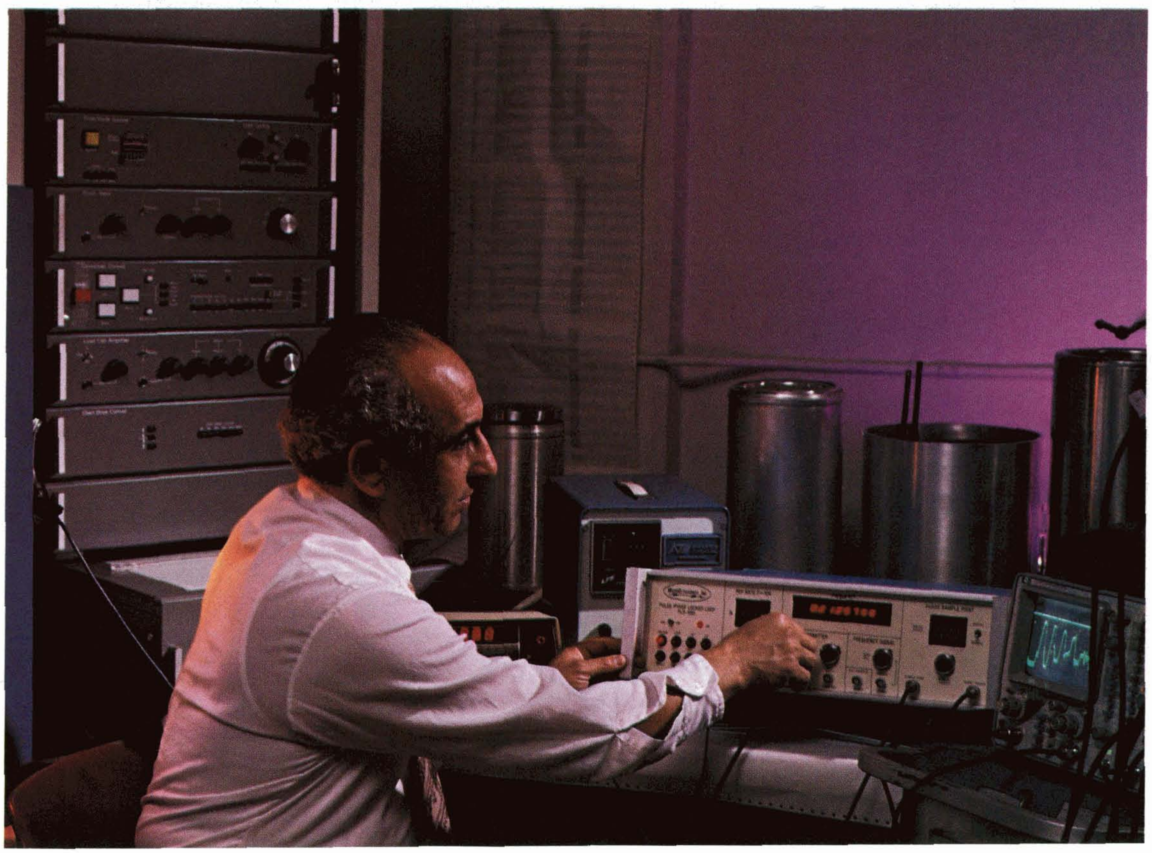
ULTRASONIC MONITOR



Below, Dr. Kamel Salama of the University of Houston's Mechanical Engineering Department is using a NASA-developed stress monitor on a test specimen, which is in the chamber (yellow window) at his back. The instrument is the Model PLR-1000 Ultrasonic Interferometer, manufactured by MicroUltrasonics, Inc., Williamsburg, Virginia. MicroUltrasonics is one of 12 companies licensed by NASA for commercial production of the system originally developed by Langley Research Center and known as the Pulse Phase Locked Loop Bolt Stress Monitor, or P^2L^2.

The system was designed to provide highly precise stress measurement in industrial applications—such as pressure vessels and power plants—where overtightened or undertightened bolts can fail and cause accidents or costly equipment shutdowns. P^2L^2 measures the stress that occurs when a bolt becomes elongated in the process of tightening. The instrument transmits sound waves to the bolt being tightened and receives a return signal indicating changes in bolt stress, changes somewhat analogous to the tone changes in a violin string being tightened. The results are translated into a digital reading of bolt stress. MicroUltrasonics' PLR-1000 is a refined, microprocessor-controlled version of the P^2L^2, usable on bolts, plates, liquids and gases.

Kamel Salama learned, through a colleague, that NASA was using a new monitor to measure stress in fasteners on the Space Shuttle's external fuel tank and on wheel bolts in the Shuttle Orbiter's landing gear. The instrument proved ideal for his own work, which is aimed at development of a new technique for nondestructive measurement of residual stress in various types of structures—for example, nuclear pressure vessels, pipes in nuclear reactors, offshore platforms, bridges, railroad tracks and wheels, aircraft wings and engines. Surface stress can be measured by x-ray devices, but bulk residual stresses—those due to causes other than application of external forces or heat—can only be measured by ultrasonics. Salama is using the PLR-1000 to generate calibrations that will allow measurements of residual stress in the field. The instrument produces sound tone pulses that travel through a test specimen, such as the steel bar shown above. The PLR-1000 precisely measures the phase delay (speed) at which the pulse passes through the specimen; since the speed changes when stress changes, the measurements tell how much stress there is at a specific calibration. The PLR-1000 has a resolution of one part per million, thus enabling Salama to achieve measurements that in the past were difficult if not impossible.




FMC
Link-Belt

CONSTRUCTION EQUIPMENT

At left is a crawler crane; the photo at right shows a tower-mounted gantry crane; and above is a wheeled rope truck crane. These are examples of the Link-Belt® line of cranes, excavators and diesel pile hammers manufactured by FMC Corporation's Construction Equipment Group, Cedar Rapids, Iowa. The company conducts extensive proof lift tests and computerized analysis to insure that the cranes can lift rated capacity loads up to one million pounds in a wide range of applications.

In their analysis work, FMC engineers make use of a computer program supplied by NASA's Computer Software Management and Information Center (COSMIC)®. Called Analysis of Beam Columns, the program is used as part of the required analysis for determining bending moments, deflections and critical loads for latticed crane booms.

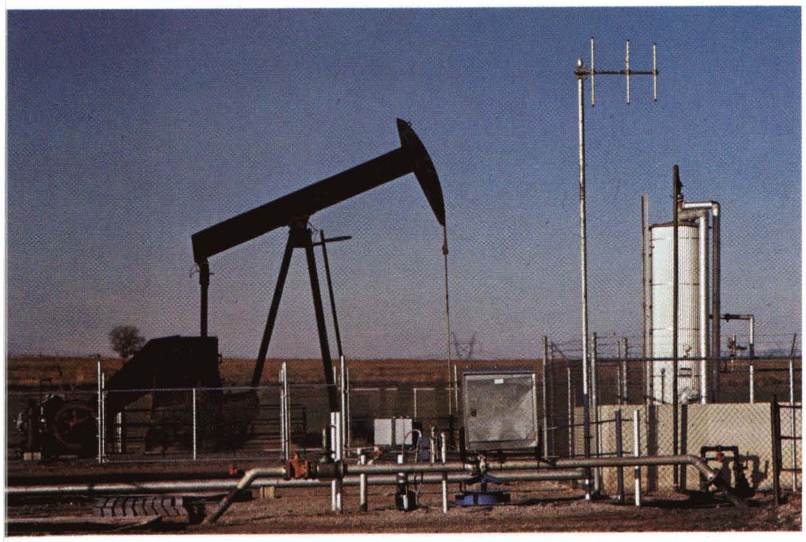
In the interests of national productivity, COSMIC helps U.S. industry reduce automation costs through secondary use of previously developed computer programs. COSMIC maintains a large library of programs originally developed by NASA, the Department of Defense and other technology generating agencies of the government. These programs can be adapted to a broad spectrum of business and industrial applications, enabling users to save time and money by taking advantage of COSMIC's service.

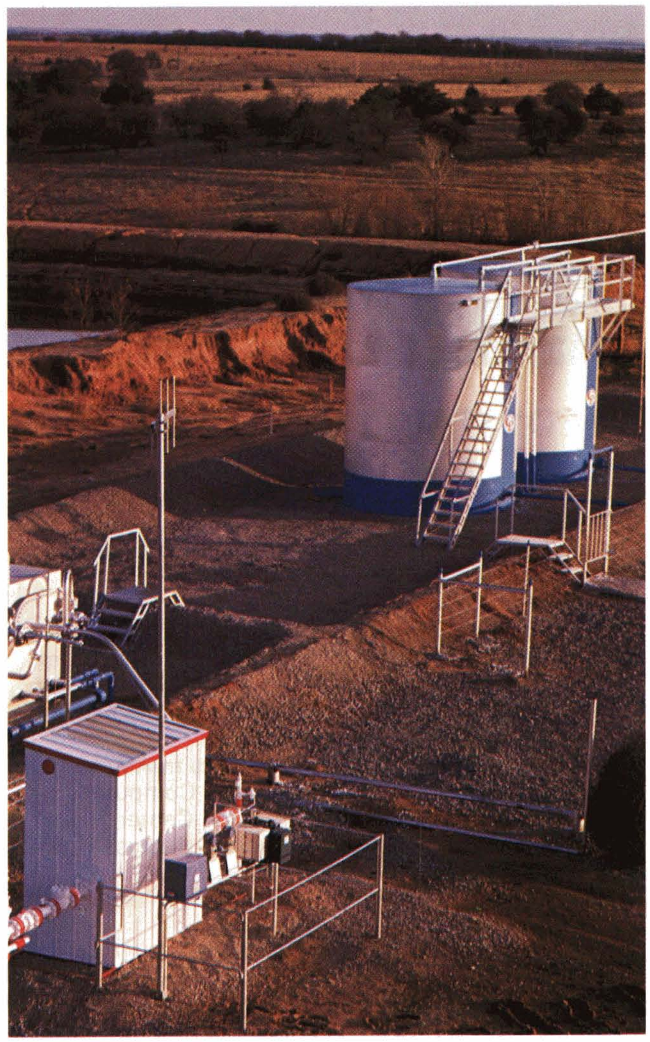
®Link-Belt is a registered trademark of FMC Corporation.
®COSMIC is a registered trademark of the National Aeronautics and Space Administration.

SPACE TELEMETRY FOR THE ENERGY INDUSTRY

An automatic system for monitoring oil and gas flow exemplifies spinoff aids to development, production and conservation of energy

This Oklahoma oil well has an automatic system that measures flow and reports its information to a central computer. The wellhead measurement station consists of the antenna and related equipment in the foreground.





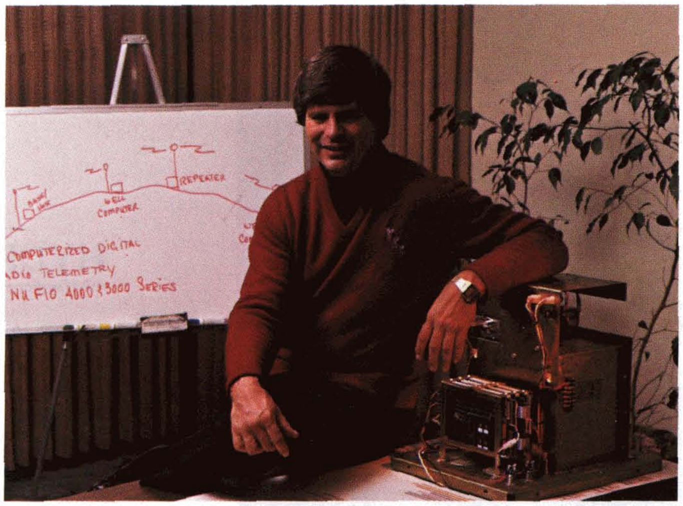
Space telemetry is the process whereby information acquired in orbit is relayed to Earth. Electronic equipment in the spacecraft converts instrument data to coded signals that are transmitted by radio, picked up by an antenna on the ground, fed to a receiver and there decoded to become useful information. Telemetry is a means of moving a lot of information rapidly. The data can be sent in "real time"— meaning right now, as it is acquired, rather than stored on tape and transmitted later. Additionally, a spaceborne system can be interrogated by signals from Earth, or it can be commanded to perform some function.

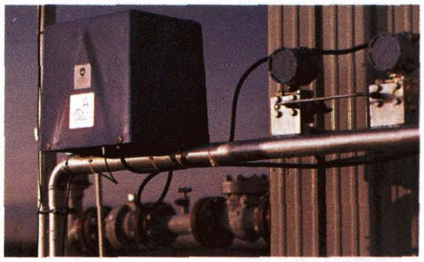
These features make telemetry a natural for Earth applications in an era of explosive communications expansion and growing need for computer-connected systems capable of handling large volumes of information on a two-way, real time basis. It is already being used for air pollution sampling (see page 120), for collecting weather or water quality data from remote stations, by physicians for interrogating human-implanted devices, by hospitals for monitoring the conditions of a number of patients from a single location. A new use of telemetry, introduced last year, is automatic measurement of the flow at unattended oil and gas wells, offering unprecedented accuracy, cost benefits and a variety of ancillary advantages.

This application is the brainchild of Bill Sheen, president of Nu-Tech Industries Corporation, Oklahoma City, Oklahoma, formed in 1981. Sheen saw a need for a better way of monitoring flow, due to high costs of oil and gas, increasing oil field theft and a mounting requirement for more timely information to speed up accounting procedures. For decades, the energy industry relied on mechanical chart recorders for flow data; these recorders provide basic flow data that must be integrated with other data to get a total flow measurement picture, a time-consuming process often subject to error. Sheen felt that a computerized system would offer far greater accuracy, instantaneous calculation and a cost-effective, automatic means of transferring all data of interest from wellhead to producer and purchaser.

Nu-Tech turned to NASA for assistance, which was provided by Kerr Industrial Applications Center (KIAC), located at Southeastern Oklahoma State University, Durant, Oklahoma. KIAC conducted a search of technical literature in a number of areas specified by Sheen and delivered voluminous information that enabled Nu-Tech to evaluate ways of packaging a flow measurement system from existing equipment and techniques. KIAC's service, says Sheen, saved his company time and money, allowed sharper focus of company research and development, and identified proven equipment and methods as a basis for the design effort. Along with telemetry, Nu-Tech incorporated space-derived gas measurement, microcomputer and microswitch technologies.

The system that emerged from two years of research, now in production at Nu-Tech's Fort Worth, Texas facility, is known as the Remote Measurement and Control Network. It operates at several levels, beginning at the wellhead. Nu-Tech's microprocessor-based measurement station—called Nu-Flo—accurately computes the flow twice every second. The wellhead station also includes a power source and a backup to assure uninterrupted operation; the radio telemetry system for relaying the data and for accepting queries and commands from control stations; and a series of sensors for monitoring and reporting the status of all of the equipment at the wellhead. The system generates an alarm when it detects power or communications anomalies, or when an unusual flow rate suggests problems with production equipment, or—an optional feature—when it senses a sudden drop in storage tank level that might indicate theft.





Above, Bill Sheen, president of Nu-Tech Industries, displays a key element of the energy monitoring system he developed: the Nu-Flo measurement station. Shown in a well installation at left, the compact Nu-Flo "blue box" contains computerized equipment to measure flow and other data, make calculations, generate warnings and relay its findings via radio telemetry.

A centrally-located base operations center continually "polls", or interrogates, each of the wellhead stations within its area of cognizance; with a 185-foot-tall antenna, it can communicate with wells within a 50-mile radius. Base operations builds a computerized activity file on each station, then forwards it to a master station, which Nu-Tech calls the Host Computer Complex. Hub of the network, the host computer collects flow information from each base operations center on a periodic basis, then consolidates and stores the data. Customers have access to either up-to-the-minute flow data or historical representations through Remote Data Access Stations—computer terminals—located in their own offices. A large energy company, of course, may want to operate the host complex itself, to protect proprietary information; for smaller companies, Nu-Tech provides the host computer service and employs secure access codes to insure customer protection.

The big advantage of the electronic measurement network is its demonstrated accuracy. The Nu-Tech system was evaluated, along with a mechanical chart recorder, by the Colorado Engineering Experiment Station, Nunn, Colorado, an independent, non-profit testing organization. The results showed Nu-Tech's equipment to be far superior to the chart recorder in flow measurement accuracy; in 13 test runs, Nu-Tech's biggest error was less than one percent, its best showing was off by only one-fiftieth of one percent.

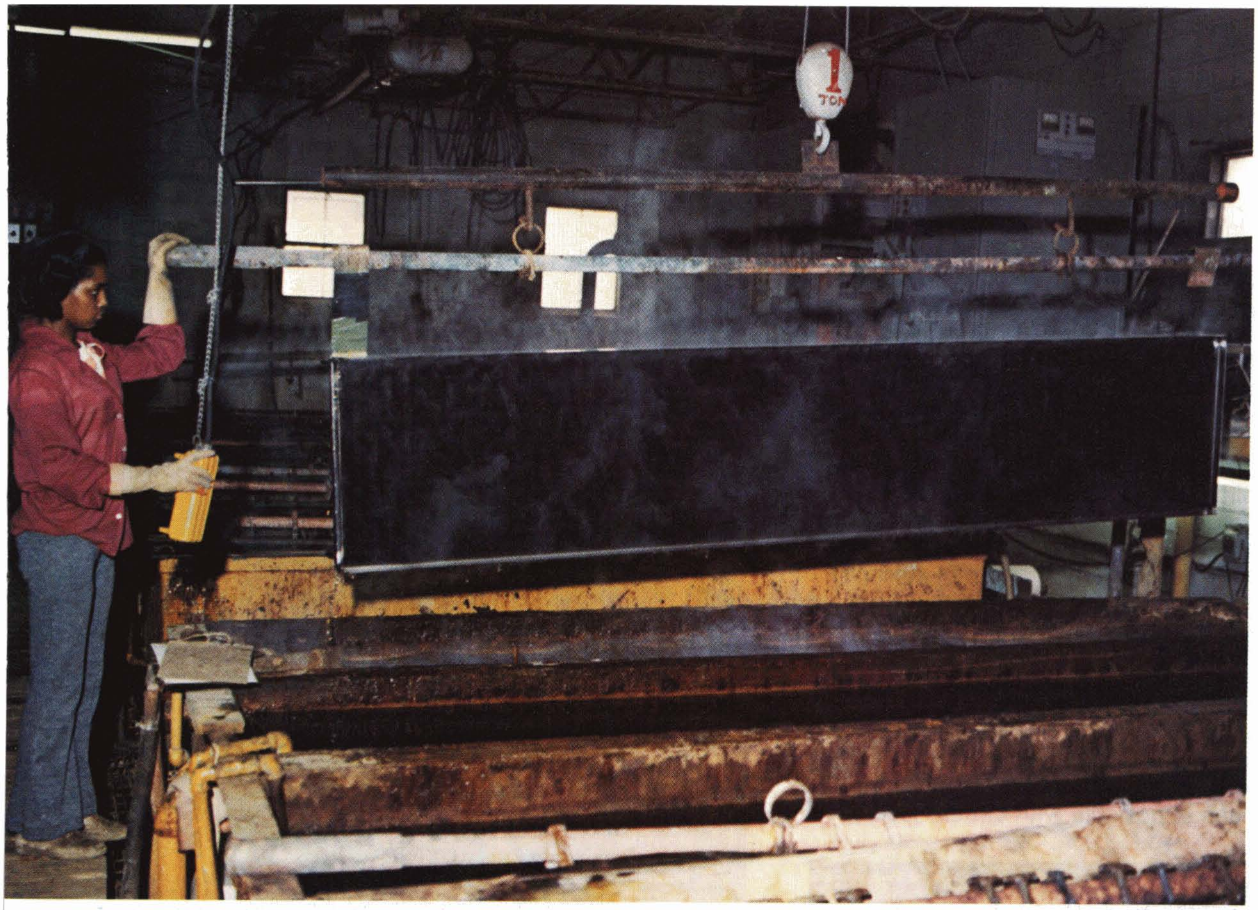
That kind of accuracy has big economic value—for example, it minimizes errors of overpayment by purchasers or underpayment to producers that occur frequently due to faulty flow data. The real time availability of flow information allows billing accounts on a current basis, rather than the customary 60-90 day delay. Other major advantages include the producer's ability to control his wells remotely and to feed the pipeline exactly the amount of product desired; better utilization of maintenance personnel, who can be dispatched to problem wells as indicated by the wellhead monitors; electronic storage and retrieval of data, eliminating the need for manually maintaining files; theft deterrence through the alarm feature; and early detection of leakage. Collectively, these advantages add up to great potential for cost reductions and increased production efficiency.

HYDROGEN GENERATOR

At left is a spinoff system for producing hydrogen on site that went into operation late in 1982 at the Sewaren (New Jersey) Generating Station of Public Service Electric and Gas Company (PSE&G). Called the ES-1000 Hydrogen Generator, the system was developed by General Electric Company's Aircraft Equipment Division, Wilmington, Massachusetts. The hydrogen is used as a coolant for the station's large generators; on-site production eliminates the need for continuous resupply of hydrogen. At lower left, a technician is filling tanks with hydrogen produced by the ES-1000; formerly, the tanks had to be filled once a week from supplies delivered by tube-trailer.

The unit generates high-purity hydrogen by electrolysis, the process of breaking down a chemical compound by passing an electric current through it. In this instance, the compound is distilled water, which is separated into hydrogen and oxygen. Water electrolysis has been tried in the past for this type of application, but the ES-1000 is unique in that its electrolyte—the electricity-conducting medium—is a solid plastic membrane; in other electrolysis systems, electrolytes are usually liquid caustic or acid solutions. The GE-developed Solid Polymer Electrolyte, a membrane about one hundredth of an inch thick, serves as both electrolyte and separator of the hydrogen and oxygen produced. Since the distilled water being broken down is the only liquid in the system, there are no hazardous acids or caustic substances to be handled, monitored or cleaned up. The ES-1000 has an electronic control system that allows unattended operation and automatically shuts the unit down if it is not operating properly; among other advantages are high efficiency for lower operating cost and compact design that reduces installation space.

GE's solid polymer electrolyte technology was originally developed for use in the fuel cell power system of NASA's Gemini manned spacecraft, flown in 1965-66. Under contract to Johnson Space Center, GE has worked for several years to refine the technology and develop a unit for generating oxygen as part of the life support system of a manned space station; the oxygen generator is still being tested. Since 1979, GE has been working with the Electric Power Research Institute and PSE&G in developing the electrolysis system for the utility generator cooling application. The PSE&G unit was the first to go into service; two additional systems have been delivered to Iraq for installation at a generating station in Baghdad.



COATING PROCESS

In the 1970s, Lewis Research Center made an important contribution to the U.S. energy program, and to public acceptance of solar energy, by developing a highly efficient flat plate solar collector. Key to the collector's efficiency is a coating of black chrome on the plate; originally developed for use on spacecraft solar cells, the coating helps the collector absorb more Sun heat and prevents the heat from "reradiating," or escaping. Lewis found a commercially available coating—called Chromonyx® and produced by Harshaw Chemical Company—of particular interest because of its potential for high absorption. A search for a facility capable of electroplating large collectors for Lewis' evaluations led to Olympic Plating Industries, Inc., Canton, Ohio. Olympic and Harshaw Chemical teamed to set up the first Chromonyx black chrome plating facility; Lewis worked with Olympic to "fine tune" the process for maximum coating efficiency.

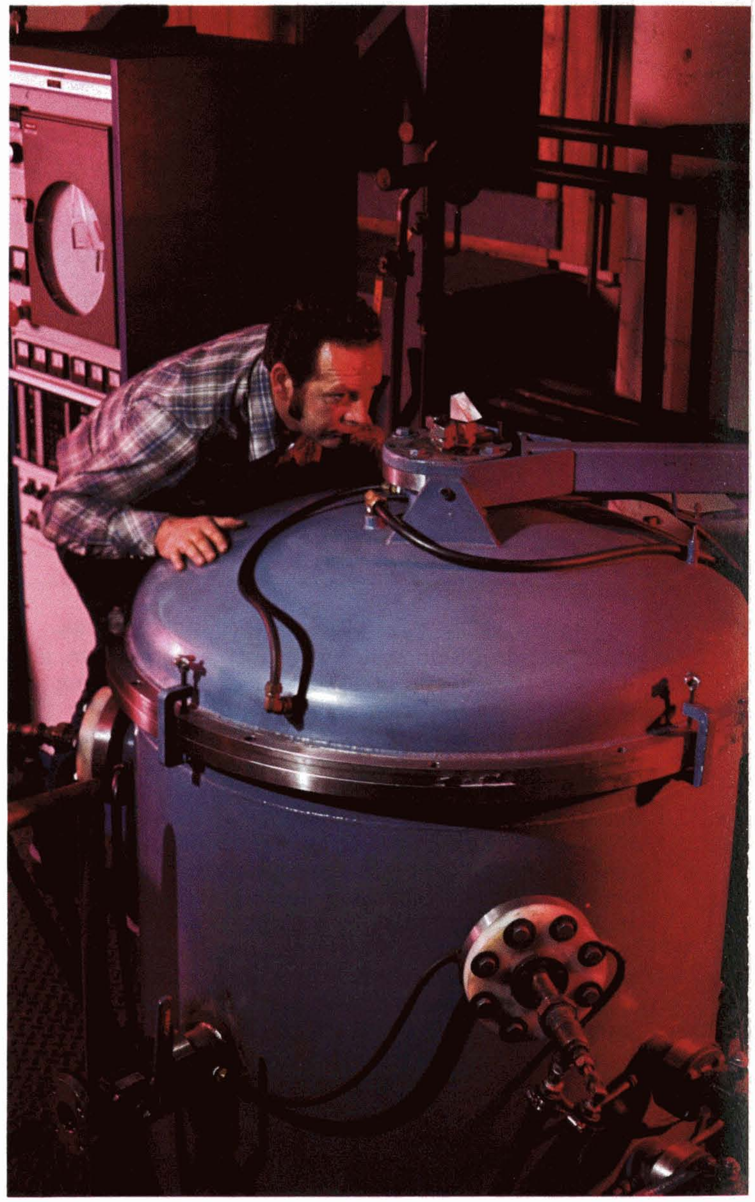
The result of a three year Lewis/Olympic collaboration was the company's development of a 13-step process—called BCO-91—for coating copper absorber plates with black chrome (above). It also resulted in formation of a spinoff company—Olympic Solar Corporation, Canton—to provide the electroplating service. Olympic Solar states that flat plate collectors enhanced by the BCO-91 coating technique convert 95 percent of the Sun's energy to heat and lose only five percent by reradiation. The company's process technology has been used on more than 20 million square feet of collector surfaces; at right is an example, Honeywell Inc.'s office building in Minneapolis, Minnesota. Olympic Solar is establishing a network of licensed facilities for the BCO-91 process; there are now three U.S. licensees and one each in Italy and Australia.

®Chromonyx is a registered trademark of Harshaw Chemical Company.

SOLAR CELLS

Photovoltaic conversion, in which sunlight is converted directly into electricity, is a promising alternative energy source but further cost reductions are essential to its widespread use. To promote broader adoption of photovoltaic, or solar cell systems, the Department of Energy (DoE) is sponsoring research toward reducing the cost to a point where this form of energy would become practicable for many commercial, industrial and residential applications. NASA support of the DoE program is provided by Jet Propulsion Laboratory (JPL), the organization with primary responsibility for developing advanced photovoltaic technology and finding ways to cut costs.

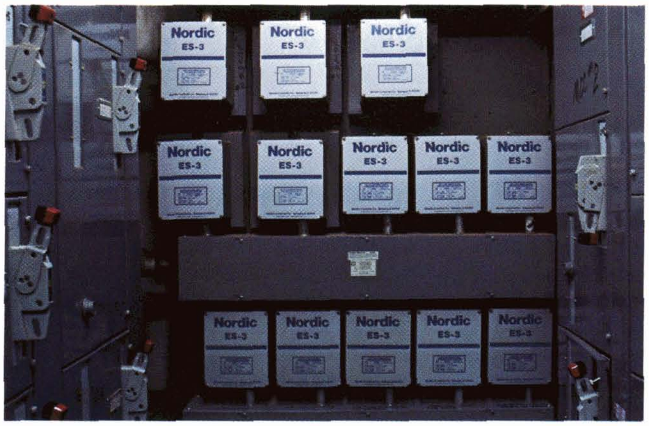
Solar cells are made by "growing" silicon crystals in a furnace. In standard production, the crystal emerges as a long, salami-shaped cylinder; the crystal is then sliced into thin wafers, to which metal contacts are added to create the solar cell. Because the crystal is cylindrical, the solar cell is round. But one of JPL's contractors—Crystal Systems, Inc., Salem, Massachusetts—has come up with an innovative technique that combines low-cost processing with square-shaped wafers that produce higher power from less surface area than is possible with circular cells;



therefore, fewer modules are needed for the desired power output and the cost of the complete solar array is substantially reduced.

Called HEM—for Heat Exchanger Method—the Crystal Systems process produces high-efficiency crystal ingots in an automated, well-insulated furnace that offers low equipment, labor and energy costs. At right is the company's high-temperature ingot-growing furnace; the technician is using a mirror to peer inside the furnace and monitor the melting process. The photo above illustrates the various steps in creating a photovoltaic system: silicon-bearing rock or "meltstock"; a large crystal ingot; a bar cut from the ingot; wafers (foreground) made by slicing the bar; and, in the background, a module composed of square solar cells.

The HEM process is in production status at Crystal Systems; the square wafers it produces are sold to other companies manufacturing solar panels. In another facet of its work, Crystal Systems is developing a method of reducing the cost of converting ingots to wafers by a multi-slicing technique that should be commercially available in two years.



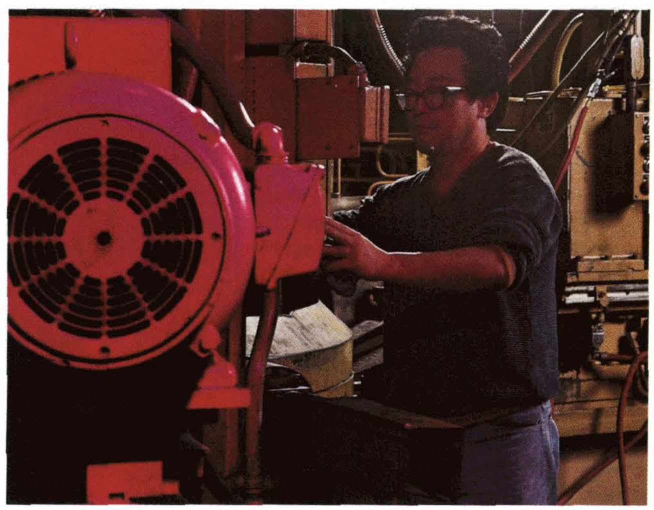
POWER CONTROLLER

A lot of the power consumed by alternating current motors is wasted because power companies feed electricity at a fixed voltage and much of the time motors do not need the voltage they are getting. The fixed voltage is what motors need to handle their heaviest loads, but more often than not they are operating at less than full load conditions. Even when a motor is idling, the fixed voltage creates high current flow and resulting heat loss—just as if the motor were working hard. With multimillions of motors in the United States, the cumulative energy wastage is of enormous order.

As part of its energy conservation research in support of the Department of Energy, Marshall Space Flight Center (MSFC) sought a means of curbing this massive wastage. The result was successful development of a device, invented by MSFC engineer Frank Nola, called the Power Factor Controller (PFC). The PFC senses shifts in the relationship between voltage and current and matches them with the motor's need—for example, when it senses a light load, it cuts voltage to the minimum needed. The power saving thus effected runs about six to eight percent under typical motor loads and as much as 65 percent when the motor is idling. NASA has granted almost 200 licenses for commercial use of the technology and about 30 companies are actively producing or developing systems based on the PFC design.

A major manufacturer is Nordic Controls Company, Batavia, Illinois, a subsidiary of Furnas Electric Company formed exclusively for production and marketing of an improved version of the PFC called the Nordic Energy Saver. The unit has, in addition to voltage control, a "soft start" feature that brings the motor gradually up to speed, protecting equipment from starting shock and thereby lengthening machinery life. Nordic Energy Savers, built in more than 100 models for motors up to 300 horsepower, are now working in more than 400 industrial applications.

An example is West Veneers, Inc., Randle, Washington, which has installed 25 Nordic units (top left) to control machinery at the company's chipper mill (top right), where logs not suitable for veneer or board lumber are chipped and sold as paper pulp. Below is an Energy Saver-equipped drilling machine, one of many machines operated by Smith Tool Division of Smith International, Inc., Irvine, California, which manufactures drill bits for oil wells. Smith Tool has 45 Nordic units on motors ranging from 7½ to 40 horsepower; the company conducted carefully documented studies on 16 Nordic-controlled motors and found that energy savings averaged about 32 percent, or $10,000 a year.



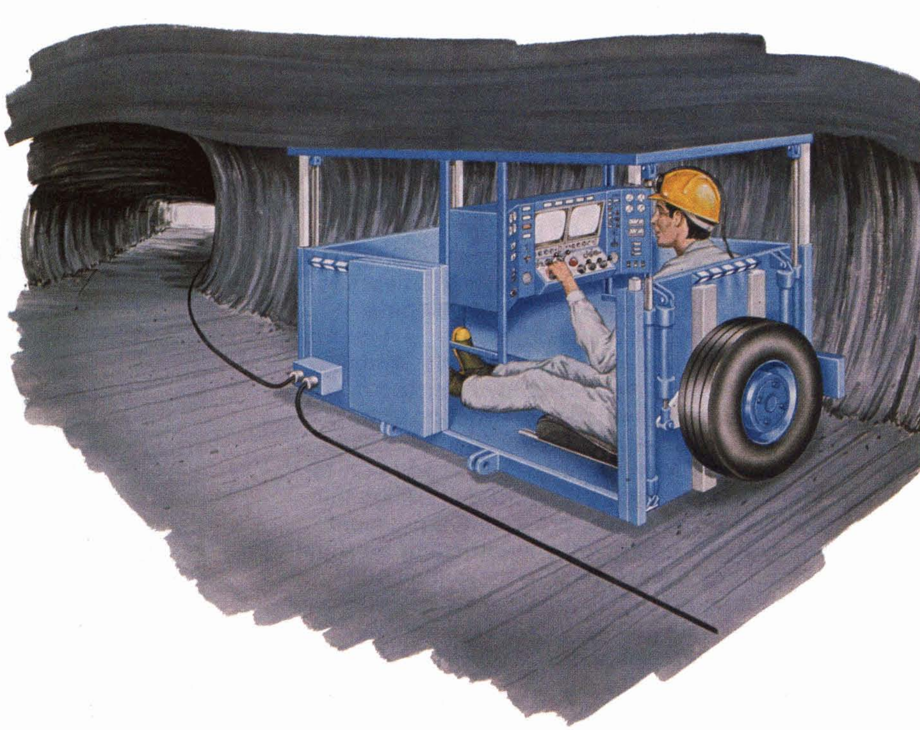
NEW EQUIPMENT FOR MINE SAFETY

Advanced machinery for underground coal mining highlights technology transfers in the field of public safety

Anthropometry is the study of the size, shape and motion characteristics of the human body. It is fundamental to successful design of clothing, equipment and workplaces in flight vehicles, and both NASA and the military services have long been engaged in research to improve the interface between man and the airplane cockpit. The advent of manned spacecraft complicated the design job by introducing such new influences as weightlessness and the need for more complex protective equipment.

In planning for the Space Shuttle, NASA encountered a number of additional considerations: the spacecraft would be the largest ever built and would carry more people than prior spacecraft; missions would involve more motion within and without the spacecraft, including transfers from pressurized to non-pressurized areas; the types of work to be performed would differ from earlier manned space operations; and crew members would include persons of both sexes, many of them non-pilots and most of a different age bracket than earlier astronauts. These and other factors affected design criteria for astronaut clothing, equipment, workspace layouts, habitability areas and life support hardware in both the Shuttle Orbiter and the Spacelab module.

Johnson Space Center (JSC) felt that these multiple design considerations demanded a larger anthropometric data base. Accordingly, JSC undertook to assemble the information available worldwide and to produce a centralized collection of anthropometric knowledge. It was intended for use not only by NASA, the military and aerospace contractors, but for such non-aerospace designers of clothing, equipment and workplaces as engineers, architects and the garment industry. JSC contracted with Webb Associates, Yellow



Above, engineers of The Bendix Corporation are working on the design of a system that would permit an operator to remain outside a danger zone while controlling his coal mining machine remotely. The artist's concept at right shows the operator's cab, connected by cable to the cutting machine, which is working out of sight under an unsupported roof. The two TV screens in the cab show the machine in operation and allow the operator to guide its movement.

In low seam coal mining operations, machines called continuous miners and their operators' cabs must negotiate passageways frequently less than four feet high. This multiple exposure shows how the seat, canopy and control column of the Bendix cab can be adjusted to changing tunnel heights.

Springs, Ohio to compile and edit the information.

The result was a three-volume *Anthropometric Source Book,* which is more than its title suggests; it is not only a complete survey of data—much of it previously unpublished—but also an effective guide to the application of anthropometric information. It includes such subjects as the variability of human body sizes, mass distribution properties of the body, arm and leg reach, joint motion, strength, the design of clothing and workplaces, physical changes to the human body in zero gravity, guidelines for statistical analysis of anthropometric data, and tabulated anthropometric information from surveys of 61 different population groups in the United States, Europe and Asia. Widely distributed to potential users, the work drew acclaim as an important addition to knowledge of human factors engineering, a document that may influence workplace and equipment design in many non-aerospace fields. One dramatic example is a U.S. Bureau of Mines (USBM) project in which the source book contributed to design of advanced mining systems developed by USBM's contractor, The Bendix Corporation's Energy, Environment and Technology Office, Englewood, Colorado.

The USBM project, supervised by the Pittsburgh Mining Research Center, seeks safer working conditions for operators of equipment employed in what is known as low seam coal mining, where a low-profile machine called a continuous miner (CM) cuts into coal seams less than four feet high. The CM has a rotating drum on which are mounted carbide-tipped "spikes" that dig into a wall of coal and reduce it to rubble; the coal is automatically conveyed to a wheeled shuttle vehicle or another conveyor for removal. As the CM bites further and further into the wall, cutting out only the coal and leaving the overhead material, it creates a low tunnel with an unsupported roof.

After advancing about 20 feet into the seam, the CM withdraws to make room for a roof bolting machine, with which an operator drills holes in the overhead strata, inserts large bolts and tightens them to secure the tunnel roof to the solid rock above. Like the roof bolter, the CM and the shuttle vehicle are controlled by human operators. Although some have remote control provisions, these machines generally have small cabs in which the operator is tightly confined, working at times under a ceiling that might be considerably less than 40 inches high. A high risk situation exists for these operators, who frequently incur injuries from striking their heads against very low ceilings while their machines are in motion, or are battered by rock falls.

Bendix has designed a remote cab for the CM and a new roof bolter that would remove the operators from these dangerous situations. The CM would be operated by remote control from a cab located well away from the cutting area under a secured roof. Two television cameras, mounted on the CM and connected to a display screen in the operator's cab, provide a visual link enabling the operator to see the cutting area for guidance of the machine. Roof bolter operators normally drill holes and manually install bolts from standing work stations under the unsupported roof. With the Bendix system, the operator would sit in a cab, located under secured roofing and protected from rock fall by a strong metal canopy, while using "hands off" automatic drilling and bolt tightening equipment.

Bendix engineers used the *Anthropometric Source Book* in determining optimal dimensions of the operator cab and in placement of controls. The controls allow the operator to work his machinery more efficiently and to raise or lower his cab seat or cab roof for maximum comfort as the height of the tunnel ceiling changes. Assessment of anthropometric factors was particularly important in determining the operator's proper eye height for best visibility, and in designing an adjustable seat for such a restricted and dynamic workplace. Bendix has built prototypes of both vehicles, which are undergoing evaluation by USBM; if approved by the Bureau, they will be demonstrated to representatives of the mining industry and mining equipment manufacturers.

Companion to the continuous miner cab is this cab for the operator of a roof bolting system. Located outside of unsafe areas and protected from rock fall by a strong canopy, the remote operator remains in his cab while using automatic equipment to secure mine roofs to solid rock.

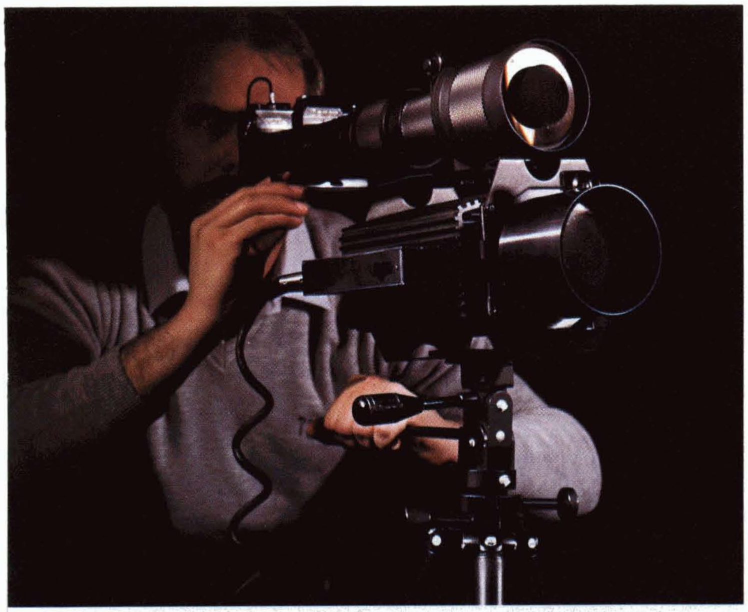
HIGH INTENSITY LIGHTS

During the Apollo program, NASA found a need to develop special high intensity lights to simulate the effect of sunlight on the spacecraft and its occupants. Johnson Space Center developed xenon arc lamps for use as solar simulators in the Center's environmental test chamber; the light spectrum of the xenon beam is as close to sunlight as any substitute yet devised. This technology served as the basis for a family of commercial lights developed by Streamlight, Inc., Norristown, Pennsylvania.

Shown above is the company's Streamlite™ SL-15 flashlight and its wall-mounted plug-in recharger. The SL-15 is one of four types of rechargeable flashlights featuring computer-focused quartz-halogen lamps with light intensities ranging from 15,000 to 35,000 candlepower. Streamlight also produces several other types of flashlights and emergency handlights for home and professional use.

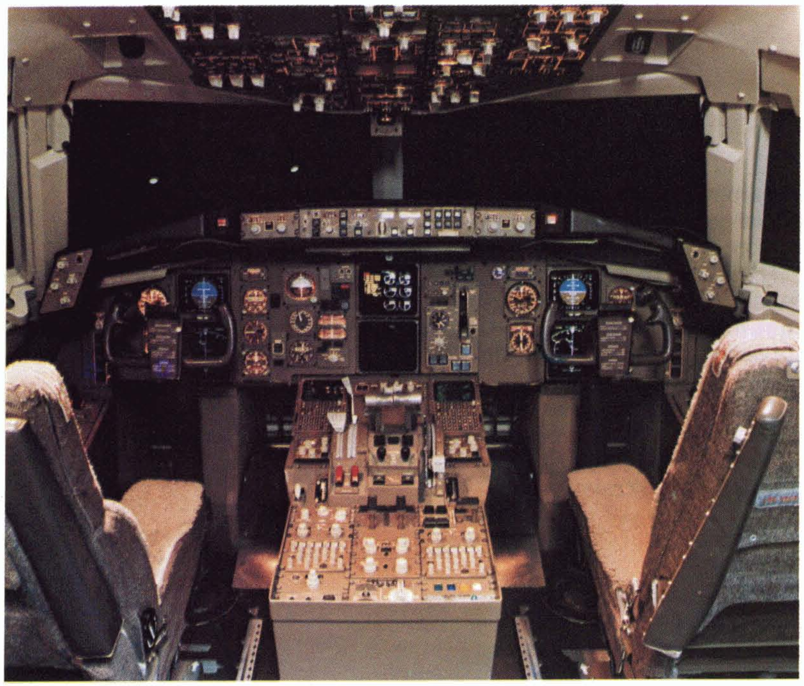
Top of the line (left) is the Streamlite 1 Million, which uses a xenon arc lamp to project one million candlepower, the brightest portable light made. Used primarily by law enforcement agencies and the military services, Streamlite 1 Million throws a light some 50 times brighter than the high beam headlights of an automobile. It can project a narrow beam of pure white light more than a mile; as a signal, its light can be seen for more than 30 miles. Its high intensity beam is especially useful in penetrating fog and smoke, because it returns less back-scatter light. The

™Streamlite is a trademark of Streamlight, Inc.



Streamlite 1 Million operates either on a 12-volt rechargeable portable power pack or on any 12-volt auto or boat battery.

There is also an infrared model of the 1 Million, called Streamlite Plus, which produces totally invisible light for certain military or law enforcement covert surveillance applications; the light output becomes visible to the user by means of infrared decoders. At left the Streamlite Plus—coupled to a camera with a telephoto lens—is projecting long range infrared light for police photography; the result—a simulated drug sale—is shown below.



JETLINER ALERT SYSTEMS

For years, jetliner cockpits have been getting more complicated, due to more complex on-board systems and increasing regulatory requirements; this is particularly true of systems that alert crews to malfunctions or other hazards. American manufacturers are taking steps to halt that trend. The newest transports, including the Boeing 757 and 767 (right) and the McDonnell Douglas DC-9 Super 80, incorporate technology designed to reduce the complexity of crew alerting systems. Several years of research and design verification, by aircraft manufacturers, the Federal Aviation Administration and NASA, preceded the 1981–83 introduction to service of these jetliners.

Shown above is the flight deck of the Boeing 757, in the exact center of which is the primary display panel for the Engine Indication and Crew Alerting System (EICAS). The EICAS system automatically monitors more than 400 inputs from sensors and provides three levels of alert messages: warning, when a condition requires immediate crew action; caution, when immediate crew awareness and future action is required; and advisory, for conditions that require crew awareness and possible future action. Written messages appear on the EICAS displays in different colors, according to alert category: red for warning, amber for caution and advisory. Aural alerts on the 757 are signaled by bells, sirens, caution beepers and, in some cases, synthetic voice messages; the 757 employs voice alerts only for ground proximity messages and relies on the centralized visual displays for most alerts. The DC-9 Super 80 features expanded use of voice alerts. Generally, advanced systems like EICAS are designed to reduce alert ambiguity, to order alerts by priority and to put visual displays where they are best viewed by both pilots to assure earliest awareness.

Almost a decade ago, Ames Research Center pioneered research in cockpit applications for computer-controlled voice synthesizers capable of constructing messages from basic speech sounds. To help pilots monitor several flight parameters during difficult landing approaches, Ames developed experimental systems for synthesized voice readout of altitude, airspeed, descent rate and deviation from flight path. Concurrently, Ames was researching the human factors associated with crew alert systems, such as defining the pilots' field of view to aid placement of visual displays, study of flight deck background noise that might interfere with aural alerts, and other considerations of the most effective ways to advise crews of problems. Ames expertise was made available to aircraft manufacturers, providing contributions in synthetic voice alert criteria and human factors guidelines for alert systems in general.

FLOW CALIBRATION

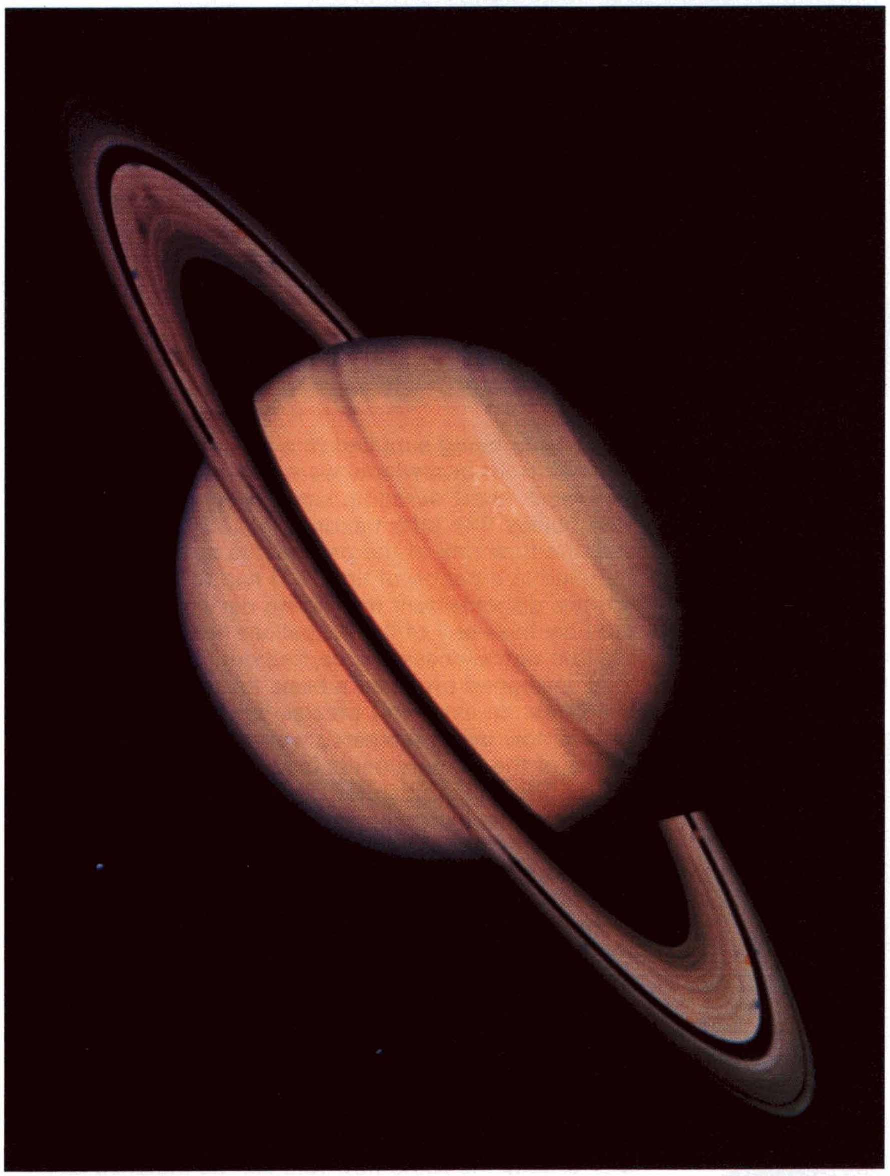
In the photo above, a technician of Moog Inc., East Aurora, New York is using a Microtrak calibrator, a fluid flow measuring device shown in closeup below. Manufactured by Flow Technology, Inc. (FTI), Phoenix, Arizona, the Microtrak system is a commercial offshoot of work performed by FTI for Lewis Research Center. Lewis wanted a system for monitoring the two different propellants being supplied to a spacecraft rocket thruster. Both propellants were fed to the thruster in very rapid, short duration, simultaneously occuring fluid pulses. The information Lewis sought was not only the flow rate of the propellants but the total fluid supplied in a period of time, FTI had to develop a positive displacement measuring device that could not possibly miss any of the propellant flow, a challenging job that was successfully carried out. The technology thus developed provided a basis for later design of the Microtrak, an extremely precise low-flow calibration system now being marketed worldwide.

One of the primary users is Moog Inc., an international manufacturer of precision controls based on electronic, hydraulic and pneumatic technology. The company's core product is an electrohydraulic servovalve. In this valve, the distance between the flapper and the nozzles is extremely critical and must be precisely established. The only way this can be accomplished is by use of two sapphire orifices, small disc-shaped sapphires with pin-sized holes through their centers; one orifice is used for each nozzle. Moog uses the Microtrak to measure the flow rate, or the speed at which hydraulic oil flows through these tiny holes. Oil is forced through the orifice at different pressure rates and the Microtrak measures the flow rate at various pressure drops. Using this data, two orifices with exactly the same flow rate can be matched as a pair; these matched pairs are then used repeatedly as "masters" in the production of servovalves.

Moog's Microtrak is calibrated with flow rate standards that have been calibrated by the National Bureau of Standards, so it can also be used for calibrating other flowmeter equipment, such as turbines. The turbines, in turn, can be used to measure the flow performance of other Moog products or to calibrate other measurement instruments.

SPACE-SPURRED COMPUTER GRAPHICS

A line of sophisticated image generating equipment highlights examples of technology transfers in the field of computer processing



This picture of the planet Saturn was created by a DICOMED Corporation film recorder, which constructed the image by processing digital signals from a Voyager spacecraft.

Computer-generated graphics, the art of converting digital information into pictorial presentations, is one of the most rapidly growing businesses in the United States. This technology is finding increasing acceptance in resources management, industrial design, business slide shows, company publications, motion pictures, video games and a mushrooming variety of other activities. Yet little more than a decade ago this bustling industry was virtually non-existent. It came to life only after certain major graphics users, mostly scientific organizations, sparked development of technology improvements necessary to realization of the art's commercial potential. A principal influence in advancing computer graphics technology was NASA's introduction of imaging spacecraft, such as the Landsat family of Earth resources satellites and the far-roaming Voyagers that returned thousands of magnificent pictures of Jupiter and Saturn.

Imaging spacecraft do not take photographs in the conventional sense. Their instruments make electronic impressions of a scene and beam them back to Earth as digital signals. On Earth, the signals are translated into imagery by computer processing, displayed on a screen and photographed. The processing equipment is an integral and very important part of the data gathering function, hence must be as advanced as technology permits. NASA's ever-increasing need for greater processing capability and better image resolution, or clarity of detail, spurred technology gains and contributed substantially to the widening commercial acceptance of computer graphics. That point is exemplified by the experience of DICOMED Corporation, Minneapolis, Minnesota.

In the early 1970s, when

DICOMED was an infant producer of graphics equipment, available display screens had very limited resolution and just two intensity levels: on and off. DICOMED developed a display unit that offered excellent resolution and allowed 64 intensity levels—meaning that a gray area in the picture could actually be shown in various shades of gray, rather than as varying ratios of black and white dots. That represented a big jump in the art—but it wasn't good enough for what NASA had in mind. To record images sent from Mars by Viking spacecraft, NASA needed processing capabilities that were well beyond the state of the art at that time. DICOMED was asked to develop them.

Under contract with Jet Propulsion Laboratory (JPL), DICOMED produced a D47 Film Recorder that provided a major advance in resolution, an increase to 256 intensity levels, and a capability for color recording across virtually the entire spectrum. That development gave DICOMED a strong technology base that the company has built upon to create an increasingly sophisticated line of computer graphics equipment for an ever-widening range of markets.

In addition to film recorders, DICOMED now manufactures computerized design stations that allow an artist to create images on a terminal screen and—by giving simple commands—to change colors, shapes, sizes and relationships of the figures involved or to add text in a variety of type styles. When the design is completed, the image can be converted to high resolution 35 or 16 millimeter films, 8 by 10 inch transparencies, or video tape. It can also be recorded and stored as digital data by a film recorder such as DICOMED's D148S, a refined and considerably improved version of the first DICOMED system developed for NASA/JPL. The D148S Film Recorder, a computer and the essential software are all combined in the company's Dicomedia Color Slide System, which takes input from a design station and records it on film as color graphics, including slides, simulation, animation and direct color microfiche.

DICOMED still provides equipment to NASA and other scientific organizations, but its customer list has expanded considerably. In addition to a variety of business graphics applications, DICOMED systems are being used by industrial engineers to record Computer-Aided Design and Computer-Aided Manufacturing information; film makers are using DICOMED equipment to produce computer-generated animation; and the Hennepin County (Minnesota) Surveyor's Office is using a DICOMED unit to update maps at substantial savings to the taxpayer. These and many other applications, DICOMED says, owe their origins to the demanding requirements of the aerospace and scientific communities, which dictated the technology developments that made commercial systems possible.

DICOMED's D148S Film Recorder is an improved version of an image processing system developed for NASA.

Using a DICOMED design station, an artist produced this graphic—the metamorphosis of a caterpillar into a butterfly—by manipulating computerized figures to create the caterpillar at far left and the butterfly at far right, then commanding the computer to interpolate the intermediate stages.

DRONE CONTROL SYSTEM

The photo shows a pair of Teledyne Ryan Firebee unmanned drone aircraft being readied for test at White Sands Missile Range, New Mexico. They are part of an Army program in which several types of drones—subscale vehicles like the Firebees and full-scale retired military aircraft—are flown in tests of air defense missile systems. Simulating attacking aircraft in close formation, the drones test the missile systems' capability for discriminating among multiple targets. The drones are precisely controlled by means of a Drone Formation Control System (DFCS) developed by IBM Federal Systems Division, Oswego, New York. The DFCS computer can track 10 drones at once and

control as many as six drones flying in multiple formations or singly on independent flight paths.

When the Army decided to introduce an advanced drone—the QF-100, an unmanned version of the Air Force's Korean War vintage supersonic fighter—IBM was awarded a contract to modify the existing software to accommodate the new drone. As part of the project, Federal Systems Division (FSD) engineers employed a program called ORACLS, which was used in generating new and improved software to track and control QF-100s in formation. Originally developed by Langley Research Center and supplied to FSD by NASA's Computer Software Management and Information Center (COSMIC)®, ORACLS provided the numerical calculations required for dealing with multi-input and multi-output control systems. FSD estimated savings of approximately one man-year in avoiding development of new software had ORACLS not been available.

Located at the University of Georgia, COSMIC routinely supplies to industry and government customers software packages that can be adapted to uses other than those for which they were originally developed by NASA and other technology-generating agencies of the government. Seeking broadest secondary use of these computer programs in the interests of national productivity, COSMIC maintains a library of more than 1,300 programs applicable to a broad spectrum of business and industrial operations. COSMIC customers can purchase a program for a fraction of its original cost; in most instances, users get a return many times their investment.

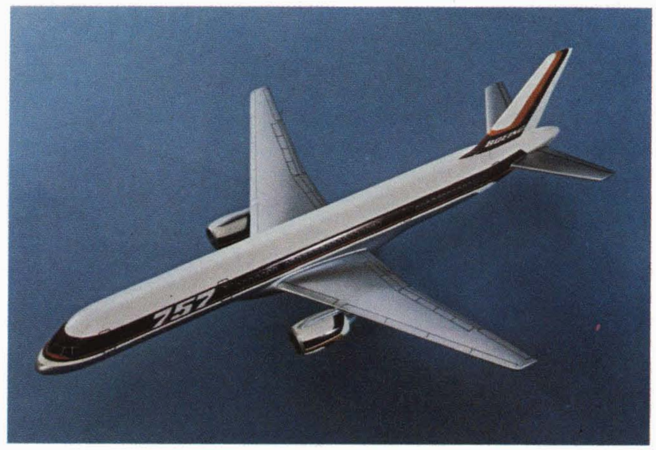
® COSMIC is a registered trademark of the National Aeronautics and Space Administration.

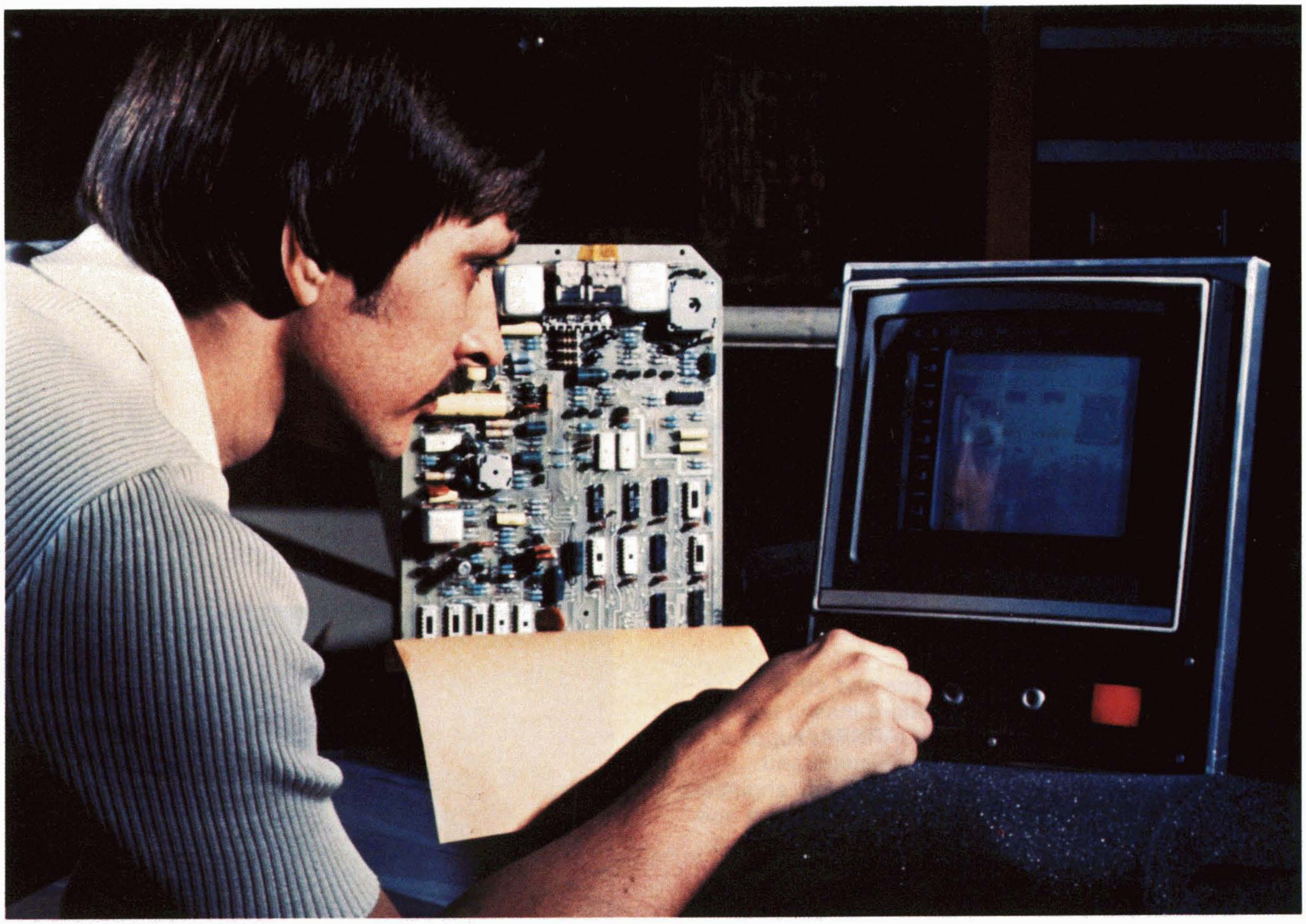
AIRCRAFT CONTROLS

United Technologies' Hamilton Standard division, Windsor Locks, Connecticut, manufactures a broad line of aerospace, automotive and industrial equipment. Among the company's key products are electronic jet engine controls and digital flight controls. The engine controls are computerized systems that meter fuel in precise amounts and regulate a number of other functions to enhance engine performance, reduce fuel consumption, curb emissions and lower maintenance costs. An advanced type of engine control designed to provide utmost fuel efficiency makes its debut this year with the introduction to airline service of the Boeing 757 jetliner (right).

Hamilton Standard's digital flight controls are used on a number of military helicopters and some advanced fixed-wing aircraft, such as the Northrop F-20 fighter shown below. These controls employ motion sensors, electrical connections and on-board computers to actuate control surfaces instead of the conventional complex of rods and linkages; they provide fully automatic flight control and exceptional stability to enhance aircraft performance and maneuverability.

In predicting the reliability of these and other electronic systems, Hamilton Standard makes use of a computer program known as CARSRA, supplied by NASA's Computer Software Management and Information Center (COSMIC). With CARSRA, engineers can study a proposed design for a control system and predict whether each of its redundant (backup) units will operate acceptably; if not, improvements can be made in the design. CARSRA was selected to provide increased flexibility over previous techniques. After determining that CARSRA was an accurate, flexible tool, Hamilton Standard used the best features of the COSMIC software to develop an advanced reliability modeling technique.





HEAT TRANSFER RESEARCH

In support of its telecommunications equipment manufacturing activities, Western Electric Company operates the Western Electric Research Center at Princeton, New Jersey, which conducts research in such areas as chemical processes, organic material processes, lasers, optics and thermal energy. The researcher pictured is engaged in the latter work; he is a member of the Center's thermal engineering section, which studies heat transfer processes to develop new manufacturing applications or improve existing applications. In the course of this work, the Center employs a COSMIC computer program called RAVFAC, for Radiation View Factor Program; it is used in analyses of high temperature processing.

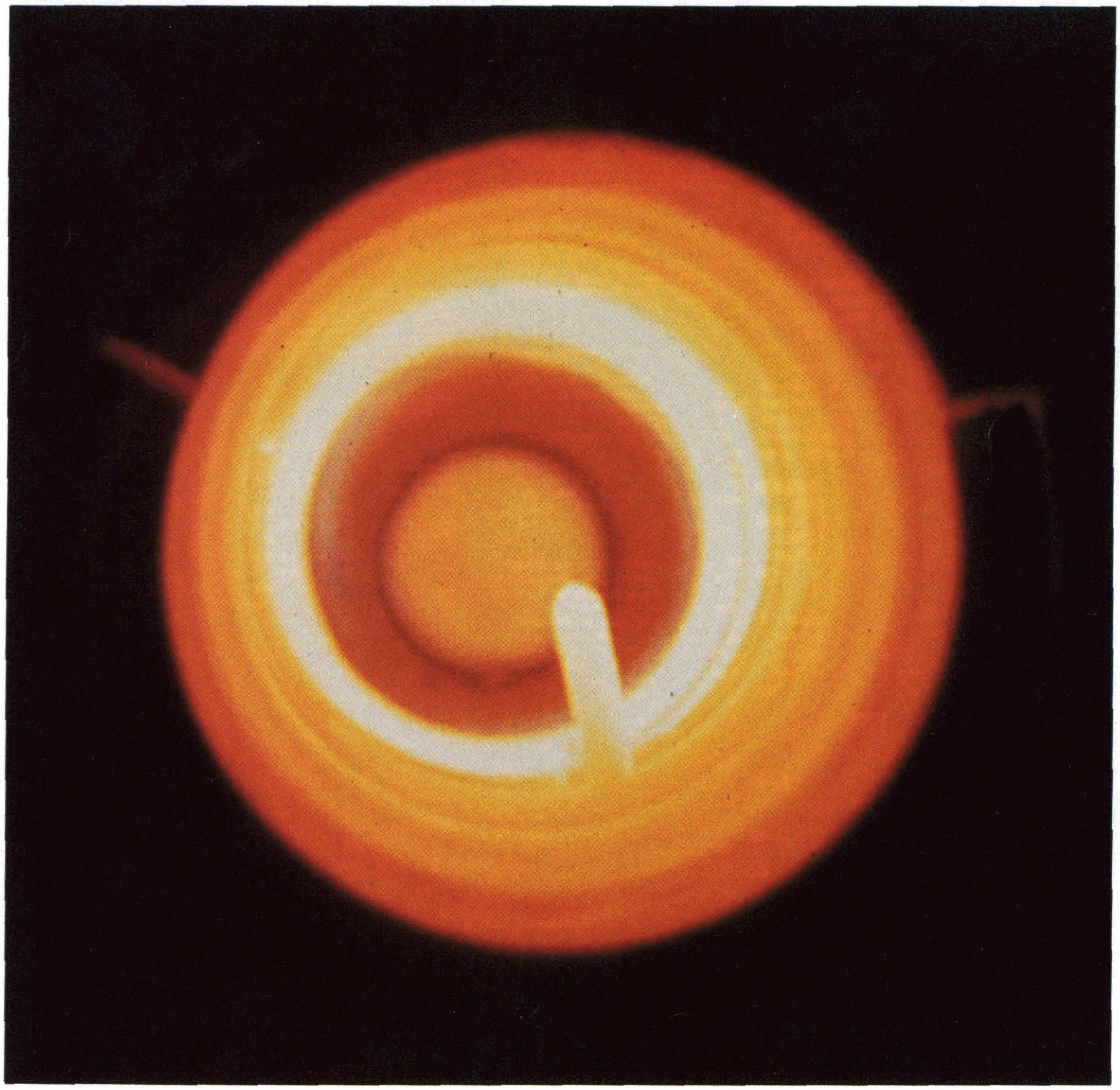
There are more than 100 steps involved in manufacturing semiconductor wafers. A number of them involve temperatures of more than 1,000 degrees Centigrade. In one step being studied, the silicon wafers are placed in an apparatus that must produce uniform temperature gradients throughout the thickness of the wafer; if the gradients are not sufficiently uniform, circuits produced near the edges of the wafers are not usable. The RAVFAC program helps assess proposed new designs by calculating heat transfer to determine whether temperature gradients vary from wafer edge to center. Research Center engineers report that RAVFAC is a powerful analysis tool that offers ease of computing heat transfer data; they estimate that it saved several man-months that would have been required to develop a new program.

OIL RECOVERY SYSTEM

Foster-Miller Associates, Inc., mechanical engineering and design consultants located in Waltham, Massachusetts, has developed a Downhole Steam Generation System for use in heavy oil recovery projects; it delivers high pressure steam to bring up oil from reservoirs as much as 3,000 feet below the surface. Developed under contract to Sandia Laboratories and the Department of Energy, the system consists of a steam generator, a "packer" that keeps the steam from leaking up the wellbore, and a tube string that supplies air, fuel, water and hydraulics to the generator and packer; all are encased in a standard seven-inch well casing.

The term "downhole" means that the steam generator is located far down the well casing rather than on the surface, as in conventional steam pressure recovery systems. Foster-Miller believes that, for recovery from deep reservoirs of heavy oil, the downhole design offers time and cost savings over surface generated steam.

The photo provides an inside look at the downhole combustion zone. In the combustor, fuel is injected through a nozzle and burned in the presence of pressurized air. The combustor is designed to provide a high degree of flame stability as well as long residence time for the combustion products, key factors in the efficiency of the system. In designing the system, Foster-Miller used a computer program from the inventory of NASA's Computer Software Management and Information Center (COSMIC) in an extensive analysis of the combustor section. The company reports that the COSMIC program was the only one available that could provide the requisite calculations relative to combustor efficiency over a wide range of thermodynamic conditions.



NUCLEAR PLANT INSPECTION

The photos of the nighttime New York City skyline, with millions of lights consuming electric power, symbolize the massive job of the Power Authority of the State of New York, the largest non-federal public power organization in the United States. The Power Authority represents an unusual blending of public and private enterprise. It exists to carry out the orders of the legislature and the governor relating to energy matters, but its projects are financed by the private sector through investment in the Power Authority's bonds. To meet the state's energy needs, the Power Authority operates a complex of hydroelectric, oil-fired and nuclear facilities, plus a transmission line network that connects with municipal and private utilities throughout New York, in Vermont and in the Canadian provinces of Ontario and Quebec.

At right below is one of the Power Authority's two nuclear facilities, the James A. Fitzpatrick Nuclear Power Plant on Lake Ontario near Oswego, New York; the Power Authority also operates Indian Point 3 Nuclear Power Plant in northern Westchester County. Since they started operating in 1975 and 1976 respectively the two facilities have produced more than 50 billion kilowatt hours of electricity.

At each of the nuclear plants, a yearly inspection is performed to insure safety. For one stage of the inspection, engineers use a computer program—Crack Growth Analysis Program—supplied by NASA's Computer Software Management and Information Center (COSMIC). A check is first made to determine whether any cracks have developed in the welds of

the nuclear steam supply system. Radiographs, dye penetration inspections and visual inspections are performed to obtain information as to the size and location of any cracks in the metal structure and welds. This information is used in the crack growth analysis, which determines whether a particular crack will get larger and, if so, its expected rate of growth. Necessary repairs can then be planned and carried out before serious problems develop.

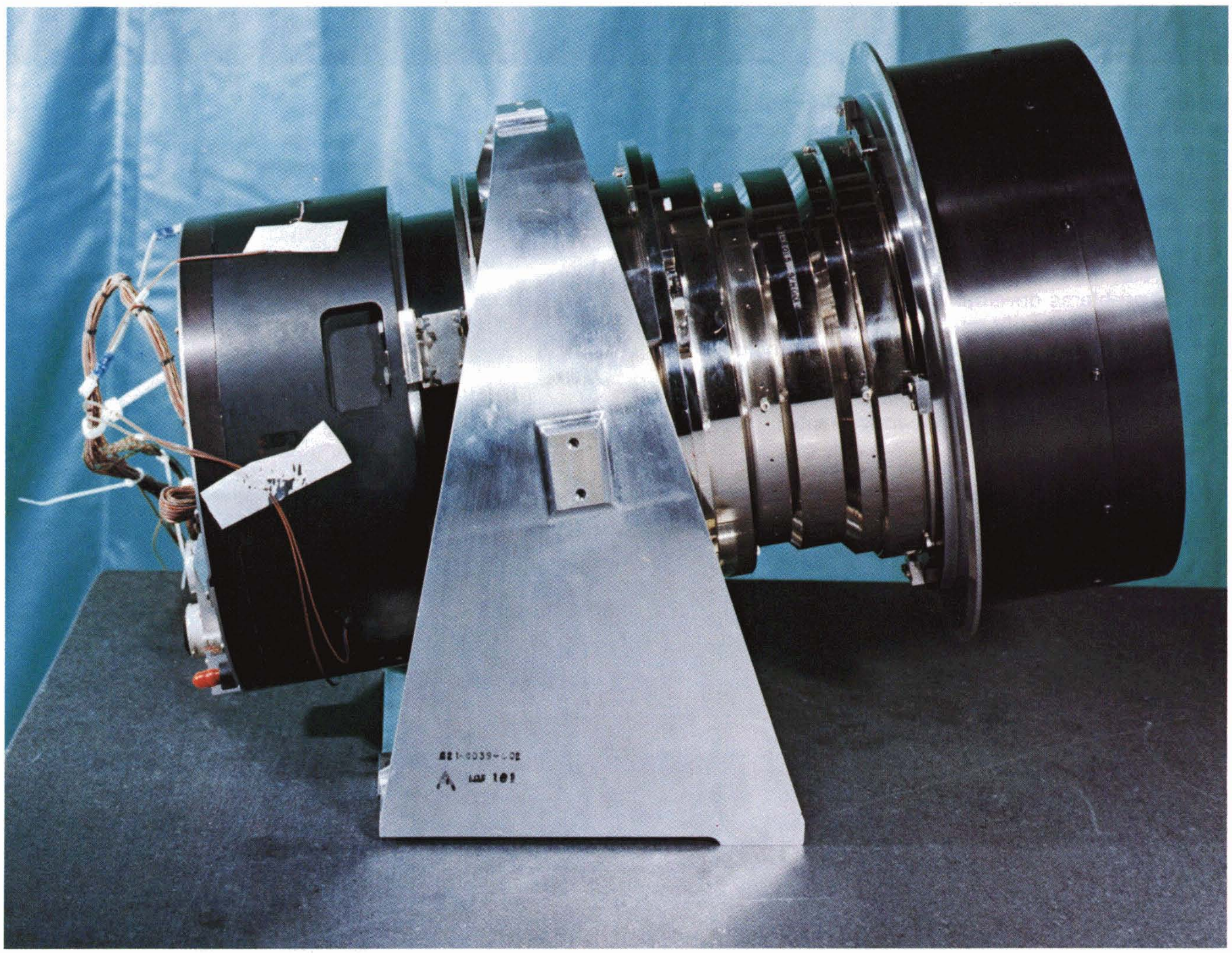
The Power Authority reports that the COSMIC software package was selected because it includes three separate crack growth analysis models. Each model can provide an acceptable analysis; in combination they offer significantly greater assurance of accuracy.

STAR MAPPER

Perkin-Elmer Corporation, Norwalk, Connecticut, prime contractor for the Optical Telescope Assembly of NASA's Space Telescope (see page 35), is conducting research on advanced space astronomy systems that will be operating in the 1990s and beyond. A major requirement of such systems is an exquisitely accurate method of pointing—aiming the spacecraft's telescope, camera and other instruments. The instruments may have to point for a long time at a single star, while in other instances they may have to change pointing angles in a smooth, continuous sweep to scan a large region of the heavens. For precision pointing and estimation of the spacecraft's attitude, Perkin-Elmer's Optical Technology Division, Danbury, Connecticut is developing new types of sensors, such as the star mapper pictured.

Because earlier star mappers using photoelectron tube detectors cannot easily meet the stringent pointing requirements for the advanced astronomical spacecraft NASA is contemplating, Perkin-Elmer is concentrating its development efforts on "charged coupled device" detectors, or CCDs. CCDs are microelectronic silicon "chips" that sense starlight and convert it to electrical signals, which are processed to determine the attitude of the spacecraft. Attitude determination provides accurate measurement of pointing angles.

In computerized simulations of star sensor performance, Optical Technology Division engineers use a computer program supplied by NASA's Computer Software Management and Information Center (COSMIC). Known as Skymap Star Catalog and Data Base, the program provides an accurate star map of any part of the sky. Skymap data is used to determine the number of stars that can be detected by the CCD sensors, information necessary to the design of an optical system of proper size and field of view. Perkin-Elmer reports that the Skymap software has allowed them to confirm the design integrity of their star sensors, which provide extraordinary accuracies and represent a major advance in optical technology.



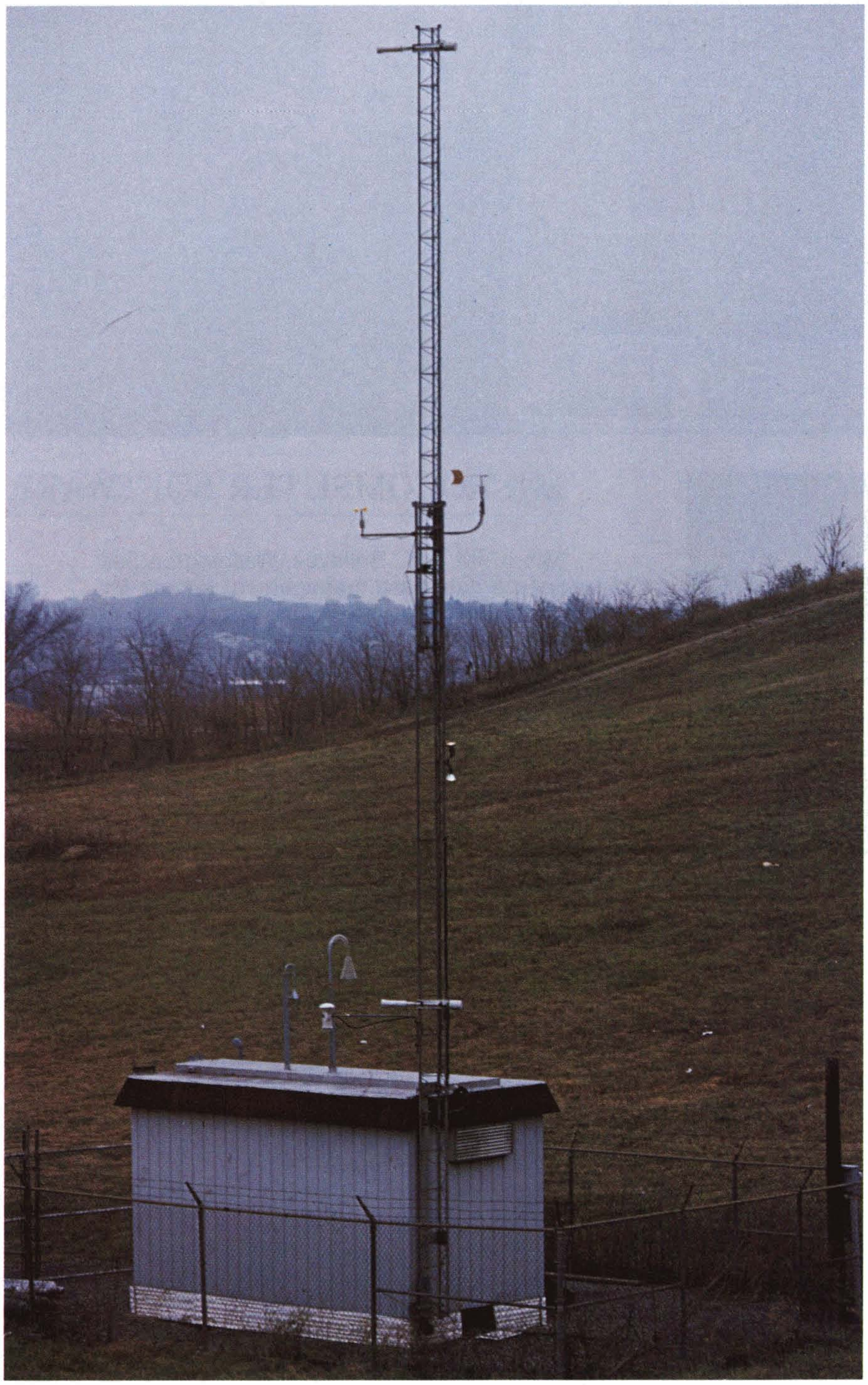
MICROCOMPUTER SOFTWARE

MicroRIM, Inc., Bellevue, Washington has developed a data base management system for microcomputers that offers, the company says, the sophistication and versatility normally available only in a "mainframe" software package. MicroRIM provides a means to store, sort and retrieve data for a wide variety of business, scientific, educational and government applications. The software allows non-technical personnel to define the data base structure and allows changes in the structure to accommodate new requirements or changing applications. The program is readily convertible to different computers.

MicroRIM is a derivation of a mainframe data base management system called RIM (Relational Information Management) that was developed under NASA funding and used by NASA to store the voluminous data required for analyzing the heat shield tiles on the Space Shuttle Orbiter. RIM is used by several hundred major industrial companies and universities. Typical applications include structural analysis, design data management, personal file management, problem tracking, airport data management, and subcontractor business reporting/tracking.

SPACE-DERIVED AIR MONITOR

An air pollution surveillance system based on space sensors and telemetry leads a sampling of environment-improving spinoffs



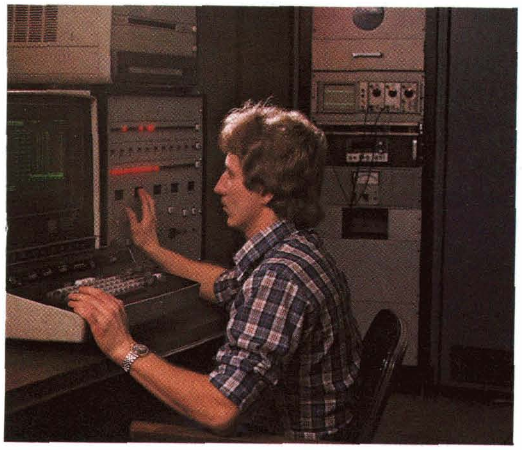
This is one of 17 remote units in the Commonwealth of Pennsylvania Air Monitoring System (COPAMS). Air intakes on the roof of the station send sample air to sensors that measure pollutants in the atmosphere, and instruments on the antenna tower simultaneously report weather data.

Air monitoring systems play an important part in the national quest for improving the quality of the air we breathe. Operated for the most part by federal, state and local governments, in some cases by industrial firms, these systems help assure compliance with air quality standards, aid in formulation of regulations and control measures, and provide warning when air pollution exceeds acceptable levels.

One particularly effective system is COPAMS, an acronym for Commonwealth of Pennsylvania Air Monitoring System. Developed for Pennsylvania's Department of Environmental Resources by General Electric Company's Space Systems Division, Valley Forge, Pennsylvania, COPAMS is a spinoff from space research.

Much of the technology in COPAMS derives from GE's experience in building unmanned spacecraft, in particular NASA's Nimbus satellites. NASA launched seven Nimbus spacecraft, five of them prior to the COPAMS project, in a program aimed at development of advanced technology for weather forecasting and environmental studies. In addition to cameras for cloud cover photography, they carried experimental sensors to

Every minute the COPAMS stations report their data to this central station in the state capital, where a computer processes, displays and stores the information. Console warning lights indicate pollution levels beyond prescribed limits.

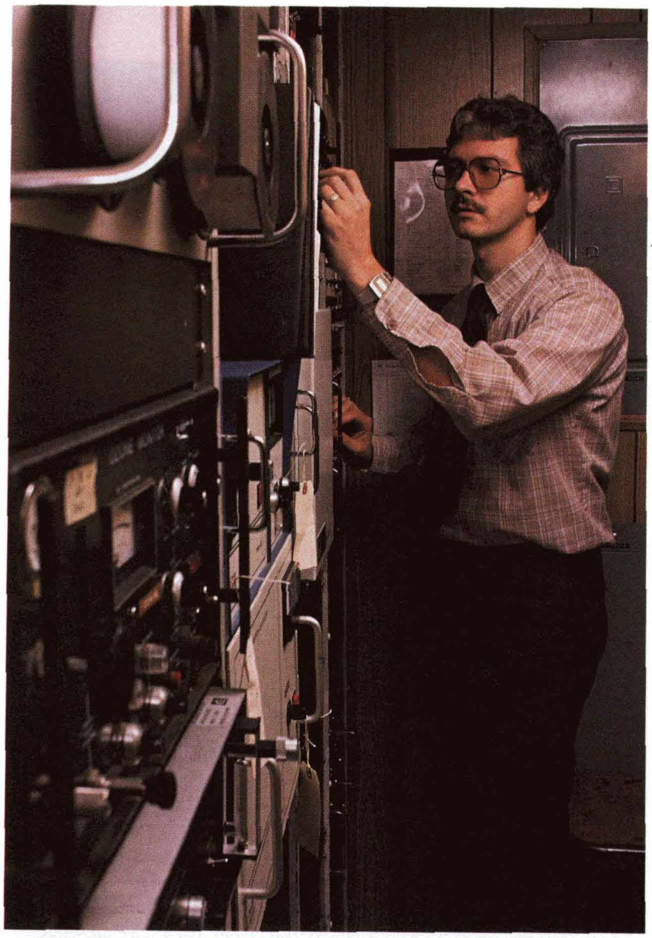


measure such atmospheric variables as temperature, pressure, ozone and water vapor, along with instruments for studying solar radiation in the atmosphere. Their findings were relayed to Earth by telemetry, a process whereby instrument data is converted to electrical signals that are sent to a receiver on the ground and there reconverted to usable information. These technologies, telemetry and atmospheric sensing, formed the basis for COPAMS.

COPAMS is a network of 17 data acquisition units, located in as many Pennsylvania cities, continuously feeding information to a central station in the capital city of Harrisburg. Each remote station automatically measures and records the levels of pollutants in the atmosphere and additionally senses wind speed, wind direction, temperature, dew point and other meteorological variables. Sensor readings from the remote units are transmitted every minute to the central station, along with a status report on how the outlying unit's equipment is performing. The data reporting process is essentially telemetry, but it differs from space telemetry in one respect: in space, data is necessarily sent to Earth by radio, but in COPAMS the information is transmitted over dedicated telephone party lines to reduce operating costs.

At the central station in Harrisburg, a computer digests the flow of data from the outlying units, processes it and displays the results on video terminals, magnetic tape and printed readouts. Pollution levels are computer-compared with prescribed limits. When the concentration of pollutants is below the regulatory limit, the system illuminates—on an operations panel at the central station—a coded status lamp showing the letter N, for normal. When conditions are abnormal, an A (alert), W (warning) or E (emergency) lights up and a horn signals the need to initiate control procedures. The whole COPAMS system works automatically, including self checking equipment that reports malfunctions when they occur. However, operators periodically review printed readouts and there are provisions whereby an operator at the central station can send special commands to the outlying units, allowing human control during pollution emergencies.

COPAMS is supplemented by a second network—called PAQSS, for Pennsylvania Air Quality Surveillance System—consisting of several microprocessor-controlled air sampling modules. These modules continuously monitor two or three air pollution factors and record the data on magnetic tape for forwarding to Harrisburg and integration into the data base.

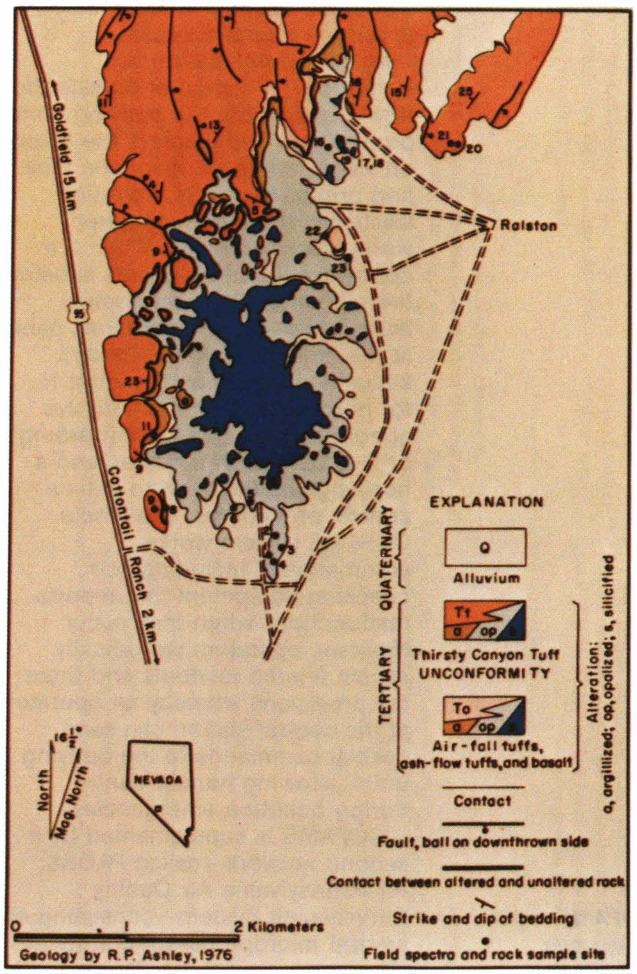


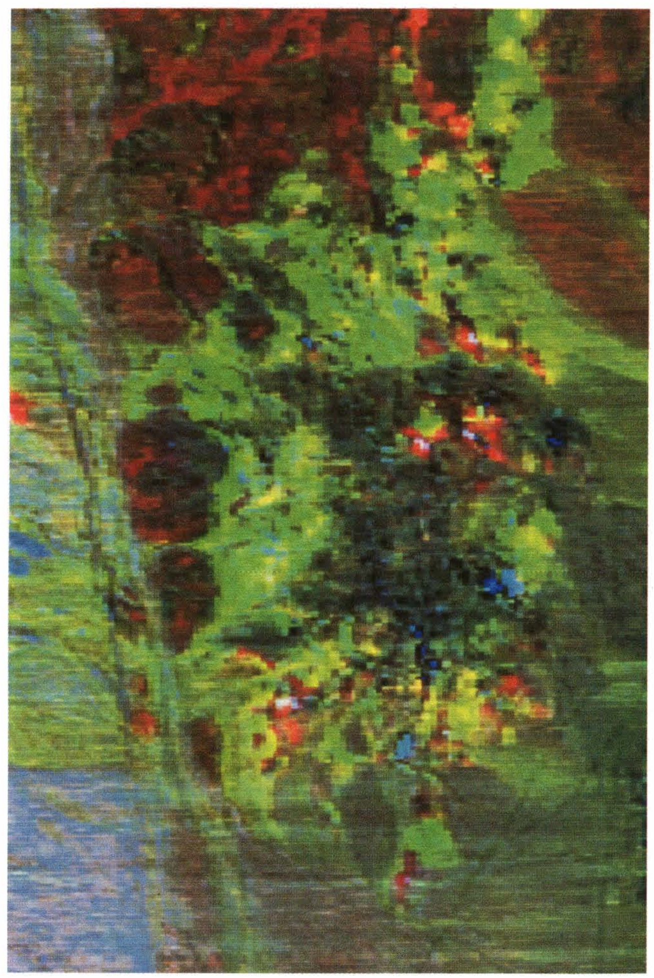
An interior view of a COPAMS remote station, which normally operates unattended but requires periodic equipment checks. In addition to gathering pollution and weather information, the system also monitors its own operation and alerts the central station when a malfunction occurs.

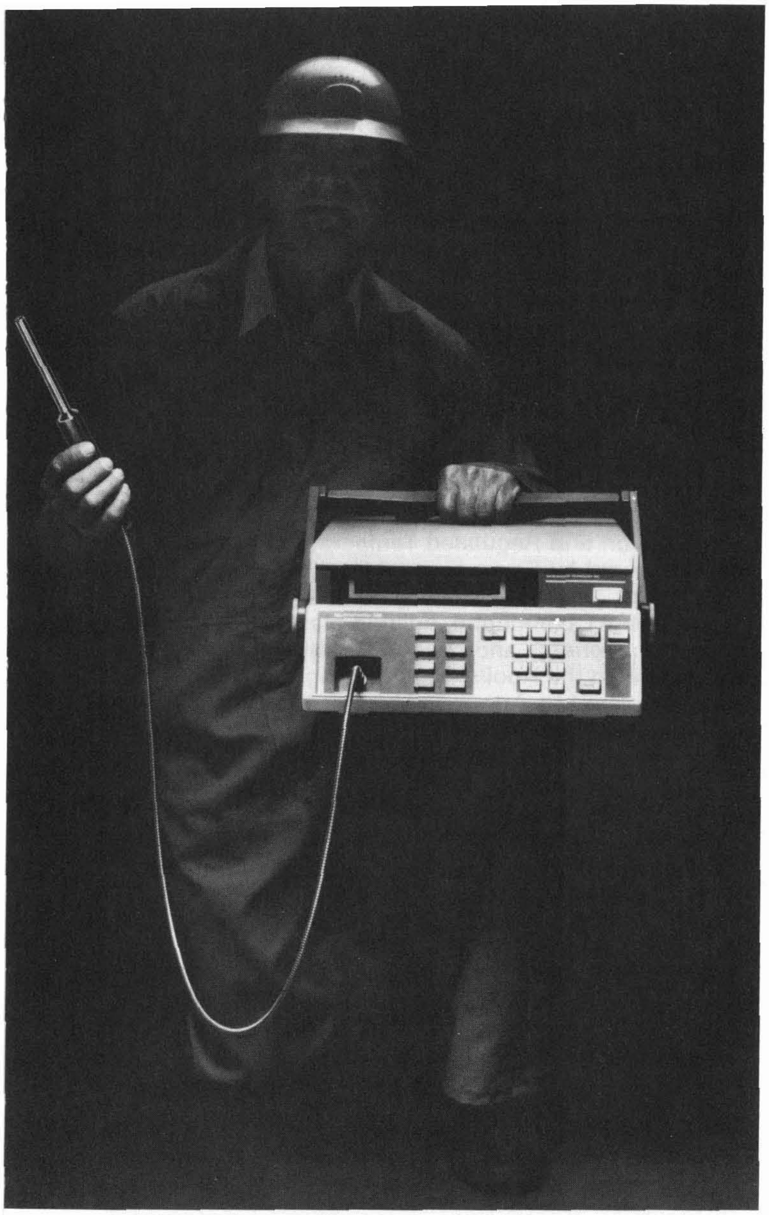
AIRBORNE IMAGERY

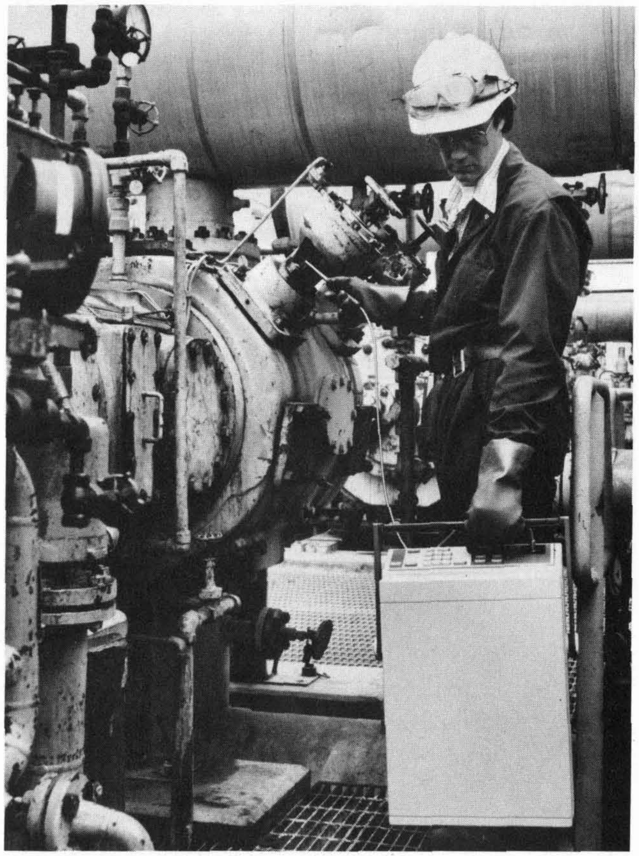
At left below is a geologic map of an area known as the Cuprite mining district near Tonopah, Nevada. Prepared as an aid to locating mineral deposits, this map was produced from data acquired in a number of field explorations, a tedious and time-consuming process. At right is an image of the same area taken by an Airborne Thematic Mapper (ATM) developed for NASA by Daedalus Enterprises Inc., Ann Arbor, Michigan; the ATM data was computer processed—by Geospectra Corporation, also of Ann Arbor—to reveal the maximum color differences among the various rock types in the area. To the skilled interpreter, the colored image represents a geologic map bearing close similarity to the map produced by ground investigation—but the data was acquired on a single flight of a Gates Learjet. Airborne photographic and imaging systems have been used for some time in geological work, but the Daedalus AADS1268 ATM and a related system, the AADS 1285 Thermal Infrared Multispectral Scanner (TIMS), offer expanded capabilities for timely, accurate and cost-effective identification of areas with prospecting potential.

Daedalus' ATM was developed for Ames Research Center, which is using it in agricultural studies and in validations of data from the Landsat 4 Thematic Mapper (TM) that went into service last year; from 40,000 feet, the airborne system provides resolutions approximately the same as those of the TM at altitudes above 400 miles. Daedalus developed the TIMS for NASA's National Space Technology Laboratories; Jet Propulsion Laboratory is using TIMS data in studies of discrimination of quartz-bearing rock types by airborne scanning. Both systems developed for NASA are now being offered commercially by Daedalus Enterprises for sale, lease or for data collection services. One data collection program involved use of the ATM to cover more than 35,000 square miles of the western United States. Sponsored by 13 energy and mining companies, it provided data used to map exposures of clay minerals and to segregate iron oxides; such exposures are associated with deposits of gold, silver, uranium, copper, lead and zinc.







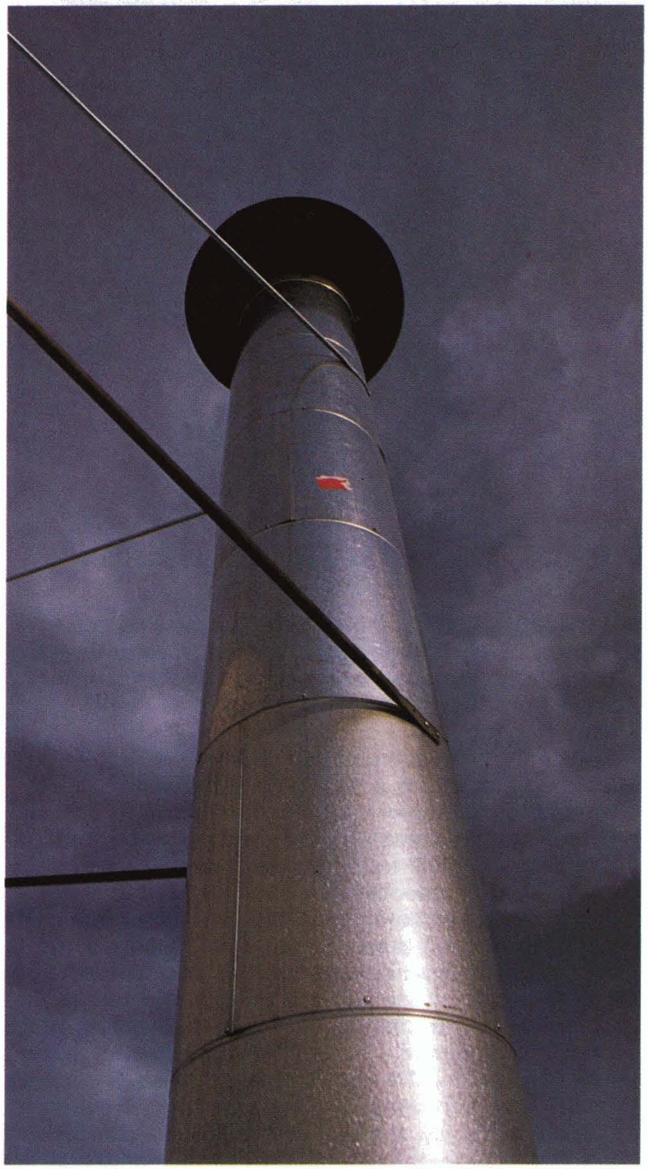


GAS ANALYZER

One of the instruments planned for NASA's Viking Landers, two spacecraft that investigated the possibility of life on Mars, was a miniature gas chromatograph (GC), a system that separates a gaseous mixture into its components, then measures the concentration of each gas in the mixture. Widely used by industry and research organizations, the GC is usually a bulky device. For the Viking Landers, the GC had to be highly sophisticated, capable of detecting respiratory gases given off by microbes if they existed, but it also had to be extremely small and lightweight to fit in a spacecraft packed with instrumentation for life detection, soil analysis and atmosphere sampling.

More than a decade ago, Ames Research Center conducted the initial research and designed such a system. Additionally, NASA contracted with Stanford University for development of flight hardware for the Viking Landers. The device was not developed in time for the Viking missions, but the technology interested the National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio. Looking for a portable device for detecting toxic gas leaks in industrial environments, NIOSH provided funds for further development of the Ames/Stanford GC. Subsequently, three researchers who had worked on the GC project left Stanford to form a new company—Microsensor Technology Inc., Fremont, California—to produce a portable gas analyzer for the commercial market. Introduced in 1982, it is known as the Michromonitor 500.

Shown in the accompanying photos, the Michromonitor 500 is a battery-powered system designed for field use—in plants, on towers or drilling rigs, down mine shafts—by unskilled operators with little or no technical training. The system consists of a sensing wand connected to a computerized analyzer that measures gas concentrations as small as one part per million in most cases, 10 parts per million for some gases. A pushbutton keyboard allows selection of up to 10 gases for analysis at a time; the system is programmed for a total of 100 gases. It takes just 30 seconds to complete a measurement cycle and, at the touch of a button, the results of each analysis—identity of gas, its concentration and the time of analysis—appear in a display window. The Michromonitor 500 has a wide range of applications, such as industrial safety, monitoring work areas for gas leaks or volatile chemical spills; analyzing industrial process gases; monitoring stack gases for compliance with pollution laws; identifying gases produced during energy explorations; in police work, breath alcohol analysis and arson investigations; and, in medicine, respiratory and anesthetic analysis.



NOISE ABATEMENT

A growing field of business in the United States is provision of materials and services to control noise, particularly in industrial environments. Many firms are finding it necessary to institute noise abatement procedures in order to comply with federal, state and local laws; labor unions are also insistent about curbing factory noise because studies indicate that long exposure to high noise levels can have adverse effect on human health. Among the various noise abatement techniques and systems being employed is a line of highly effective acoustic materials known as SMART® Products, which are based on a compound that emerged from space research. The SMART (Sound Modification and Regulated Temperature) line is manufactured by Environmental Health Systems (EHS), Inc., Framingham, Massachusetts.

The SMART compound, a liquid plastic mixture with exceptional energy and sound absorbing qualities, had its genesis in the Apollo lunar landing program. It was discovered by Arthur C. Metzger, then a NASA employee working on the Apollo guidance system, an early version of which experienced severe vibration problems. The trouble was traced to the plastic compound encapsulating the system's electronics; the compound did not absorb sufficient energy to dampen vibrations. Looking for a solution, Metzger found a better compound, a very elastic type of plastic that literally soaked up energy and, in addition to its

vibration-damping ability, offered extraordinary potential as a noise abatement material. After his retirement from NASA, Metzger founded EHS to develop and market the compound and a number of associated products, such as noise-curbing adhesives, partitions and enclosures.

At top left on the opposite page is Mrs. Mary Hilton, president of Dy Dee Services, Inc., standing by an EHS acoustic enclosure that solved a big problem for her company. Dy Dee Services, a diaper laundry, has four plants in Michigan and Indiana. The Grand Rapids, Michigan facility, which borders on a residential area, was having trouble with the community because of plant noise; there were angry complaints, threatening phone calls, a company vehicle was vandalized and there was even a bomb threat. The City of Grand Rapids ordered compliance with the sound code and that meant a very large reduction of 20 decibels.

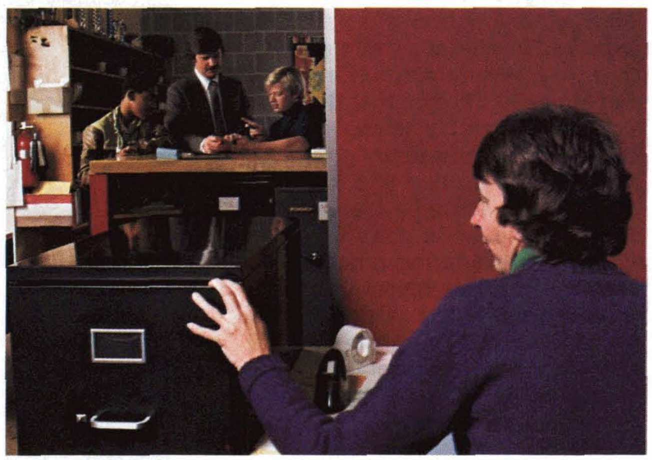
Mrs. Hilton learned of SMART Products and sought assistance from Arthur Metzger. His survey indicated that the crux of the noise problem was in the laundry's big dryers, specifically in the gas burners and highpowered blower motors of the dryers; the exhaust—and noise—was vented to the plant's roof. EHS designed and built the rooftop enclosure pictured, made of noise-blocking honeycomb panels treated with layers of SMART compound. As an ancillary measure, EHS painted the inside of the plant's boiler stack (far left) with SMART compound; in the adjacent photo, a technician is preparing the compound. These measures worked and Dy Dee Services has complied with the Grand Rapids sound code.

Refined Sugars & Syrups, Yonkers, New York faced a similar problem. The company's plant is just across the railroad tracks from a residential zone and the neighborhood initiated legal action to curb the plant's noise. EHS pinpointed the noise source: a pair of blowers atop the facility where the company makes confectioners sugar. EHS built two acoustic enclosures (the green "boxes" in the bottom photo, opposite page) and the neighborhood is again peaceful.

EHS also supplied the sugar refinery an audiometric test booth (below left). EHS manufactures these booths for industrial firms that must comply with a federal regulation requiring periodic hearing tests in soundproof rooms for employees who are consistently subjected to high noise levels.

Another SMART product is the Acoustical Office Partition shown below. This one is located at Weston (Massachusetts) Middle School; it enables the administrative staffer to work in quiet despite loud student activity on the other side of the panel. EHS is producing a large number of these partitions, under contract with the Government Services Administration, for use as sound-blocking, efficiency-improving walls in government offices.

®SMART is a registered trademark of Environmental Health Systems, Inc.

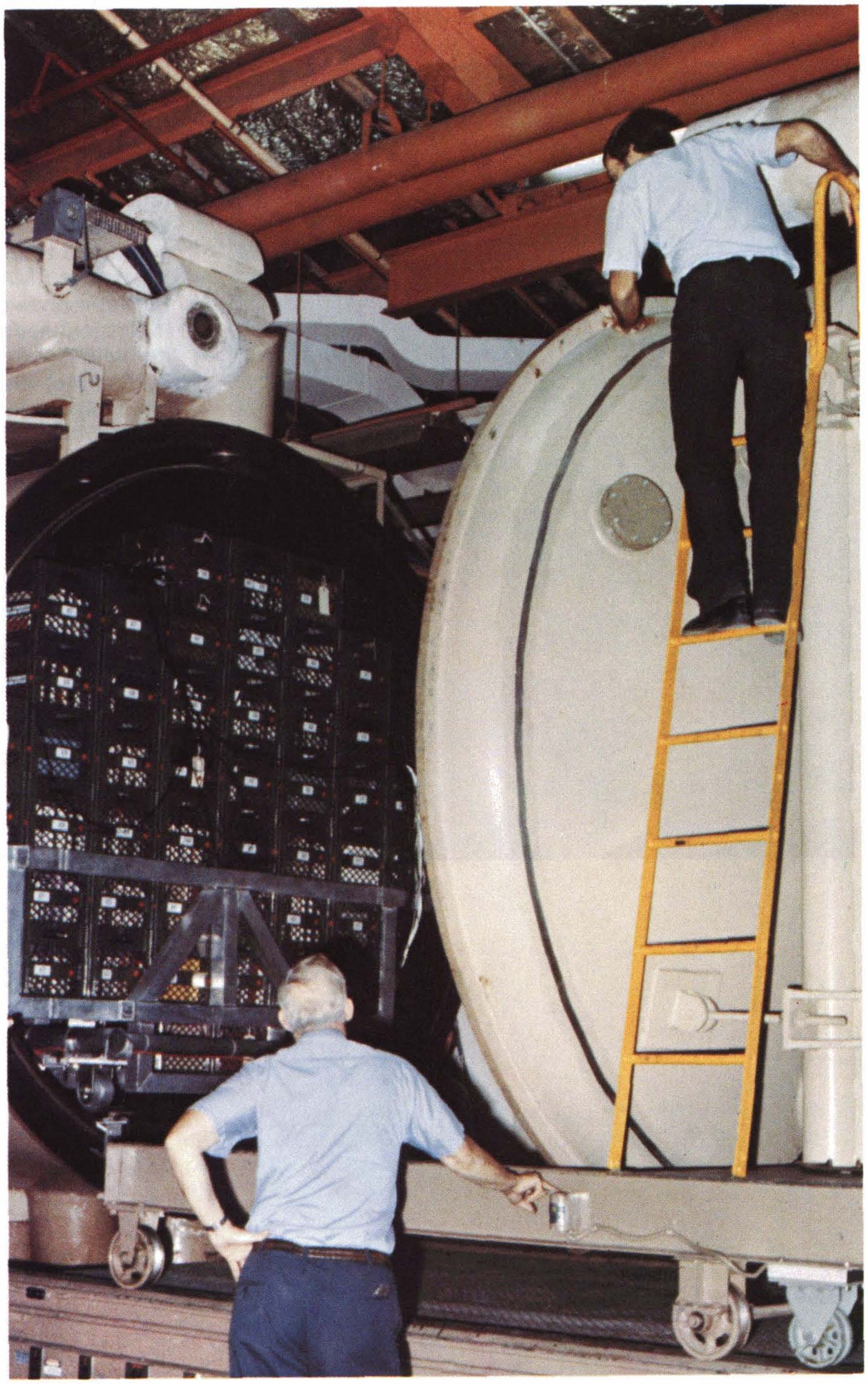


SPACE TECHNOLOGY FOR BOOK PRESERVATION

A cooperative program with the Library of Congress aimed at extending the useful lives of books exemplifies NASA technology demonstrations of better ways to meet public needs

Among the many facilities at NASA's Goddard Space Flight Center, located in the Maryland suburbs not far from Washington, D.C., is a large vacuum chamber normally used to simulate airless space for tests of satellites and their instruments. In a two-week long run last fall, however, the chamber had quite a different payload: books, more than 500 cartons of them, some 5,000 books in all. They were undergoing vacuum treatment with a gaseous chemical in a feasibility test of a process developed by the Library of Congress for extending the lives of books and valuable documents.

The Library of Congress has some 20 million books and almost a third of them have deteriorated considerably. Yet some of the Library's oldest books are still in excellent condition. The reason is that they were printed on handmade paper, made of rags, that does not degrade as rapidly as modern paper. Handmade paper gave way more than a century ago to machine-processed paper made from ground wood pulp. Today's paper manufacturing process employs chlorine bleaching and alum as part of the "sizing," which helps keep print ink from blurring on the paper. This chemistry introduces acid that in time makes



Technicians prepare to remove some 5,000 books from the vacuum chamber at Goddard Space Flight Center after a chamber run in which the books were chemically treated to neutralize the acid in the book paper. The deacidification process, developed by the Library of Congress, is designed to extend book lifetimes five to six times.

Book processing must be accomplished in an airless environment—a vacuum chamber—because the chemical vapor used is a highly volatile substance. Called DEZ, it is shown being transported carefully to the Goddard vacuum facility.

pages so brittle they crumble when handled. As a result, the lifetimes of most books printed in the 20th century are on the order of 25 to 100 years, where many older books have survived for centuries.

Obviously, a means of "deacidifying" books on a large, economically-viable scale is of great interest to research libraries and documentation centers. The Library of Congress, after several years of experimentation, has patented a process it considers almost ready for commercial use. Called vapor phased deacidification, it involves use of a chemical vapor known as DEZ (for diethyl zinc) that neutralizes the acid and deposits on book pages an alkaline reserve to combat their later return to acid condition; in this manner, the Library hopes to extend book lives at least five to six times their anticipated span. DEZ, however, is a highly volatile substance that flames instantaneously on contact with oxygen; thus, book processing with DEZ must be accomplished in an airless environment.

The Library originally tested the process in an ordinary pressure cooker, treating only a few books. Later, 400 books at a time were successfully treated in a series of experiments at Valley Forge, Pennsylvania; these tests were conducted in a vacuum chamber operated by General Electric Company's Space Systems Division. The Goddard vacuum chamber used in the 1982 tests served multiple purposes: it created an environment where DEZ could do its job without the presence of oxygen; it removed moisture—600 pounds of it—from the books, a necessary preliminary step in the process; and it provided a means of determining the efficacy of the process in treating much larger numbers of books in a single chamber run.

In addition to supplying the vacuum chamber, Goddard Space Flight Center and its support contractor, Northrop Services, Inc. contributed expertise in vacuum technology and handling of volatile substances; they also originated procedures and process-monitoring techniques for the test run that will provide a technology base for development of safe deacidification on a large-scale basis.

Last year's test at Goddard demonstrated that 5,000 books can be treated at once and it appears feasible that, given a large enough chamber, it would be possible to handle 15–20,000 books on a single run; treatment on that scale would bring the cost down to a few dollars per book. The Library of Congress development plan envisions eventual operation of a facility near Washington, D.C. for processing half a million books a year; the Library would also license the technology to private companies offering commercial deacidification services to many other libraries. Evidence of the interest in the process is the fact that the libraries of Columbia, Yale and Stanford universities, the New England Document Conservation Center, the New York Public Library and the National Archives all contributed books for the Goddard test.

The assistance provided the Library of Congress typifies a special facet of NASA's Technology Utilization Program: demonstrations to show how advanced technology may help solve major problems or create better ways of meeting public needs. Spinoff products sometimes emerge from such demonstrations, but product commercialization is not the primary aim. NASA's intent is to expand public awareness of advantageous technology and inspire its broader application by government agencies, communities, medical institutions and other organizations. Additional examples of technology demonstrations are contained on the following pages.

Dr. Peter Sparks (center), Director for Preservation, Library of Congress, is performing a post-treatment test on a sample book; the paper's reaction to the chemical he is applying shows whether the acid was properly neutralized. Sparks is flanked by Henry Maurer, NASA project manager, and William Welsh, Deputy Librarian of Congress.

ARTWORK SEPARATION

It is not unusual for art conservators to find evidence of a second painting beneath another artwork. It seems that painters of old, impoverished and unable to afford fresh canvas or wood surfaces, simply painted over a prior work, their own or another's. Thus, when a conservator acquires a new work, he usually has it x-rayed and often this confirms the existence of an underpainting.

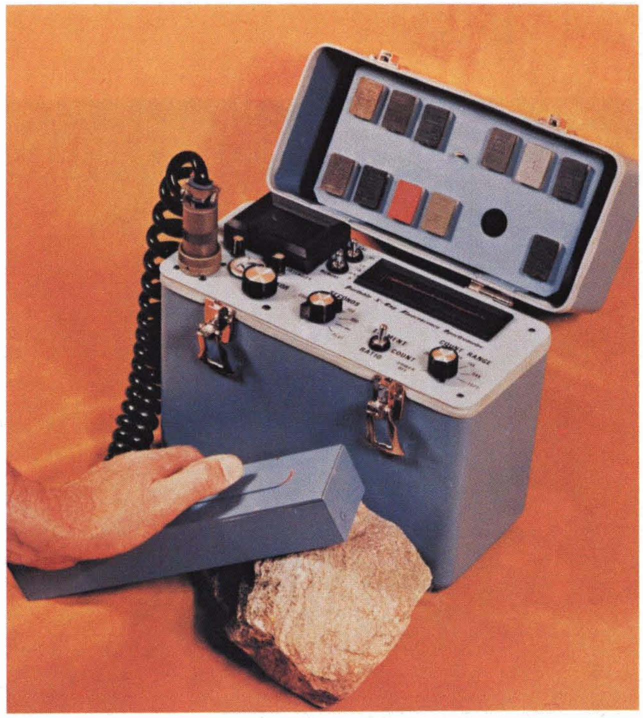
However, x-ray photography shows the two works as a blurred double image that usually affords insufficient detail for identifying the subject or the creator of the underpainting. When x-rays show a different but undelineated composition underneath, it's a maddening experience for the museum curator, in whose mind there will always be a question as to whether an unknown masterpiece lies beneath the outer paint.

When William R. Leisher, head of conservation at Los Angeles County Museum of Art (LACMA) examined the painting above—"The Crucifixion," a 17th century oil on wood by an unknown Flemish painter—he learned from x-rays that there was another painting underneath. He asked Jet Propulsion Laboratory (JPL) for help in delineating the underpainting. Under a grant from California Institute of Technology, JPL and LACMA teamed in an effort that resulted in the first successful use of image enhancement techniques to separate x-ray images of paintings where two or more exist on the same surface. Derived from computer processing of spacecraft-acquired imagery, the technique will allow conservators to better evaluate earlier compositions found beneath paintings.

JPL image-processing specialists developed computer programs for "subtracting" the top painting from the bottom, so that the hidden painting may be seen in more detail. Instructions to the computer minimized the grain pattern of the wood on which the original was painted. Next, a photo of the top painting was matched with the x-ray image; any brushstrokes in the x-ray that coincided with the top painting were

subtracted. Additional subtractions removed much of the top painting. The underpainting, a scene of a man and a woman in 17th century clothing, was then computer-enhanced to bring out detail. An intermediate step in the process is shown above; still visible parts of "The Crucifixion" are shown in dotted lines.

JPL scientists believe that the subtraction technique provides a basis for development of a more advanced system designed especially for discerning and separating multiple x-ray images of paintings. That would be an invaluable tool for conservators and curators. JPL officials also think that computer processing can be adapted to dating paintings on wood by determining the age of the wood. That's done now by a technique that requires shaving away some of the original wood; computer enhancement of the wood grain would eliminate the need for removing material.



MINERAL/WATER ANALYZER

In 1975, NASA launched what was to become one of the most successful space science missions ever conducted, the exploration of Mars by a team of four Viking spacecraft—two Viking Landers built by Martin Marietta Aerospace, Denver, Colorado and two Orbiters built by Jet Propulsion Laboratory. Among the complement of instruments aboard each of the Landers for photographing and investigating the planet's surface was an X-ray Fluorescence Spectrometer—developed for Langley Research Center by Martin Marietta Aerospace—that automatically analyzed the Martian soil and determined its composition. Modified versions of the instrument are finding Earth-use applications in geological exploration, water quality monitoring and aircraft engine maintenance.

X-ray fluorescence is a commonly used laboratory technique for determining the composition of samples. An x-ray source irradiates the sample, causing the sample to emit x-rays at various energies characteristic of the chemical elements in the sample. A spectrometer then measures the energy levels of the x-rays emitted for analysis of the sample's composition. The system designed by Martin Marietta Denver Aerospace for the Viking mission had to be highly miniaturized for compactness and extremely economical of power consumption. These qualities made it attractive for conversion to a portable Earth-use instrument.

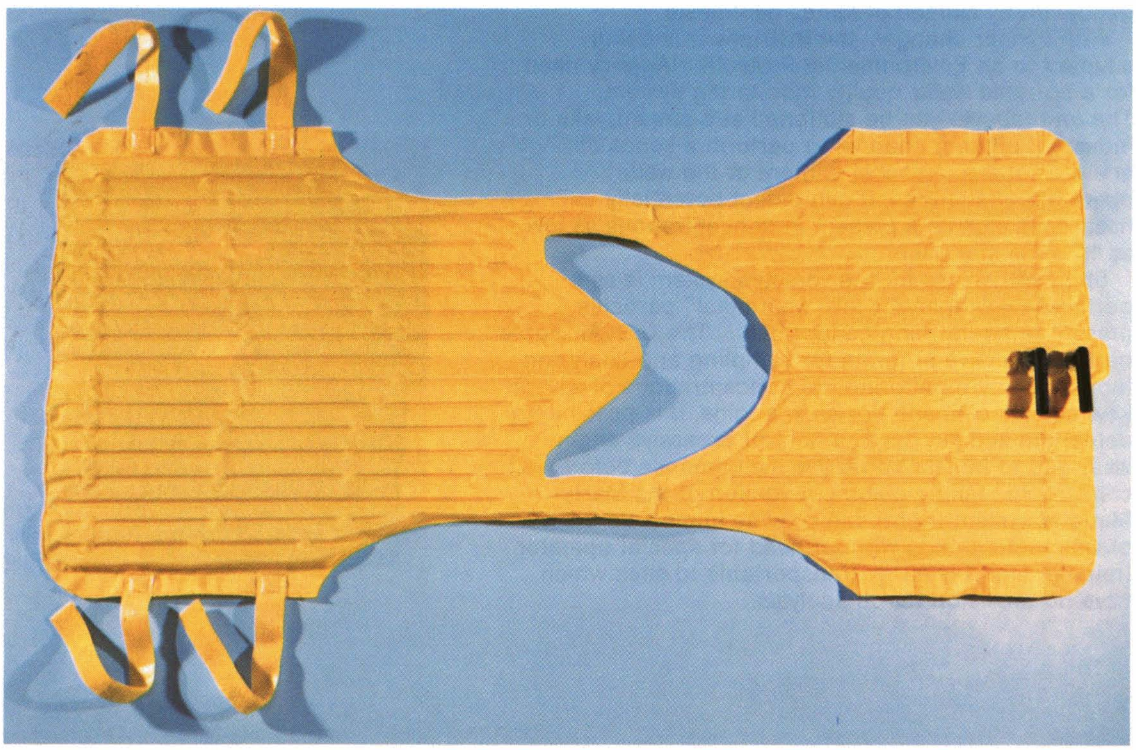
A prototype unit was used successfully in analysis of subocean samples during a 1979 National Geographic expedition to the volcanic "vents" of the East Pacific Rise. The x-ray fluorescence system contributed important scientific data on the composition of copper, iron and zinc sulfide brought up from the sea floor in the first comprehensive study of the unique subocean phenomena in a region of high-temperature vents.

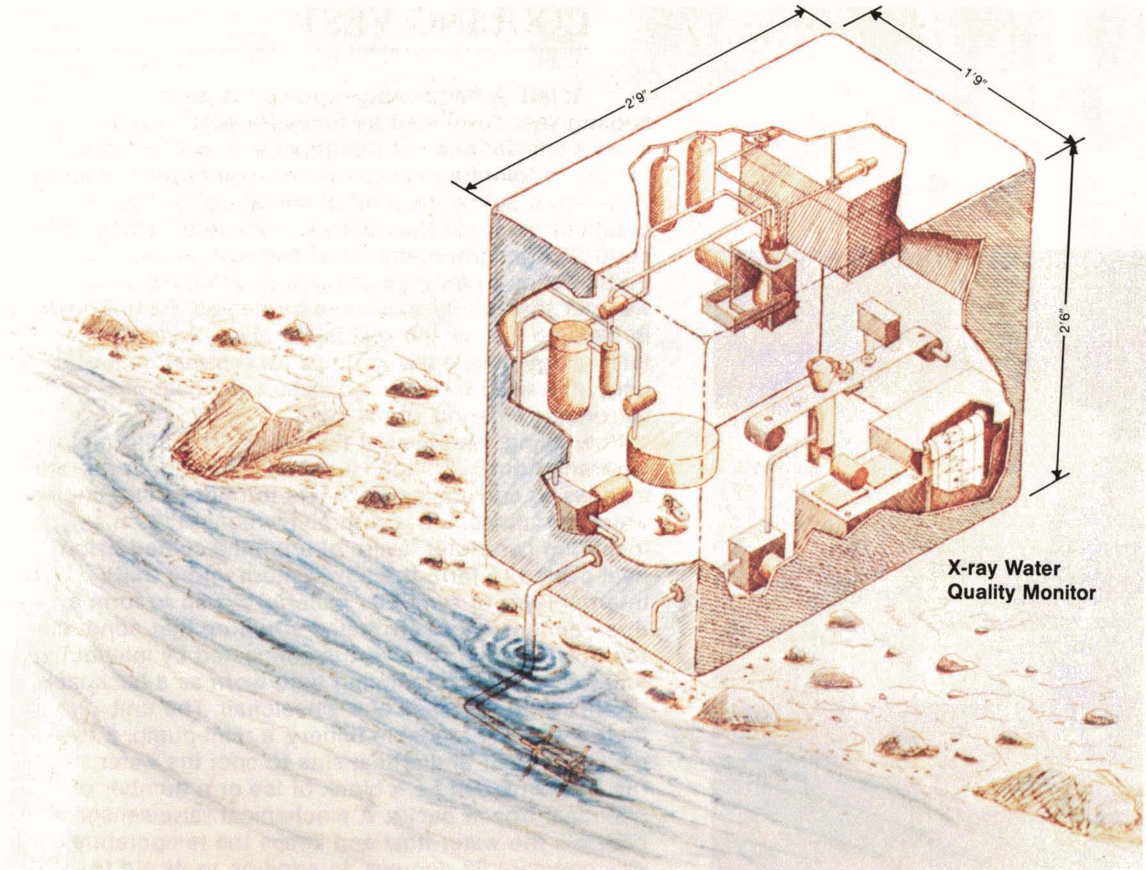
Subsequently, Langley Research Center and Martin Marietta modified the system to meet a Bureau of Mines need for a portable geological exploration unit. Shown undergoing field test at left and in closeup above, the system successfully demonstrated an ability to identify rapidly at least 60 elements—copper, uranium and tungsten, for example—and their relative concentrations in ore samples. Thus, potentially

COOLING VEST

At left, a handicapped person is wearing a cooling vest developed by Ames Research Center to meet a special need of quadriplegics, who are often unable to tolerate heat stress because of their inability to perspire below the level of spinal injury. This condition restricts their activity outside of temperature controlled environments; thus the vest allows their participation in a range of outdoor activities in hot weather that would otherwise be denied them. Shown in closeup below, the vest is an adaptation of technology developed at Ames for thermal control garments used to remove excess body heat of astronauts wearing space suits.

Now being evaluated at the Palo Alto (California) Veterans Administration Hospital, the vest incorporates a series of corrugated channels through which cooled water circulates. It has a three-ply construction including two outer layers of urethane-coated nylon heat-sealed to form the flow pattern and a third, internal layer of synthetic material woven to form a three-dimensional corrugated structure that conducts the flow of water. The vest is connected by inlet/outlet tubes to a compact cooling unit, worn as a backpack or affixed to the back of a wheelchair. The unit includes a rechargeable battery, a mini-pump, a two-quart reservoir and a heat sink to cool the water; the heat sink can be a block of ice or a number of chemical frozen packs. A mechanical valve/sensor controls the water flow and keeps the temperature at a constant 68 degrees. In addition to its aid to quadriplegics, the system can be used by ambulatory patients who have heat control problems and it is suitable for industrial applications where personnel cooling is necessary.





valuable seams of ore deposits can be detected on site and samples taken for more detailed laboratory assay. The X-ray Fluorescence Spectrometer, also known as the Portable Element Analyzer, is undergoing trial and evaluation by Bureau of Mines geologists.

With further changes, the instrument is being adapted to an Environmental Protection Agency need for a portable water quality monitoring system. The unit (above) can be stationed at a stream, lake or industrial effluent channel to perform a series of analyses of the chemical content of the water; operating unattended, it can detect potentially hazardous elements present in concentrations as low as 10 parts in a billion.

Still another use for the versatile system is as a portable x-ray analyzer for "wearmetal" particles present in aircraft engine lubricants. The U.S. Air Force has an extensive program for sampling and analyzing lubricants; by monitoring the concentrations of several key metallic elements for each engine, it is possible to detect the sudden development of excessive engine wear and to initiate corrective maintenance before catastrophic failure occurs. A version of the Martin Marietta system (right) can provide immediate analysis of wearmetal trends without need for special operator training, and it is easily transportable to sites which have no provision for oil analysis.

3

TECHNOLOGY UTILIZATION

A description of the mechanisms employed to encourage and facilitate practical application of new technologies developed in the course of NASA research and development activities and those of the agency's contractors

RECYCLING TECHNOLOGY

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

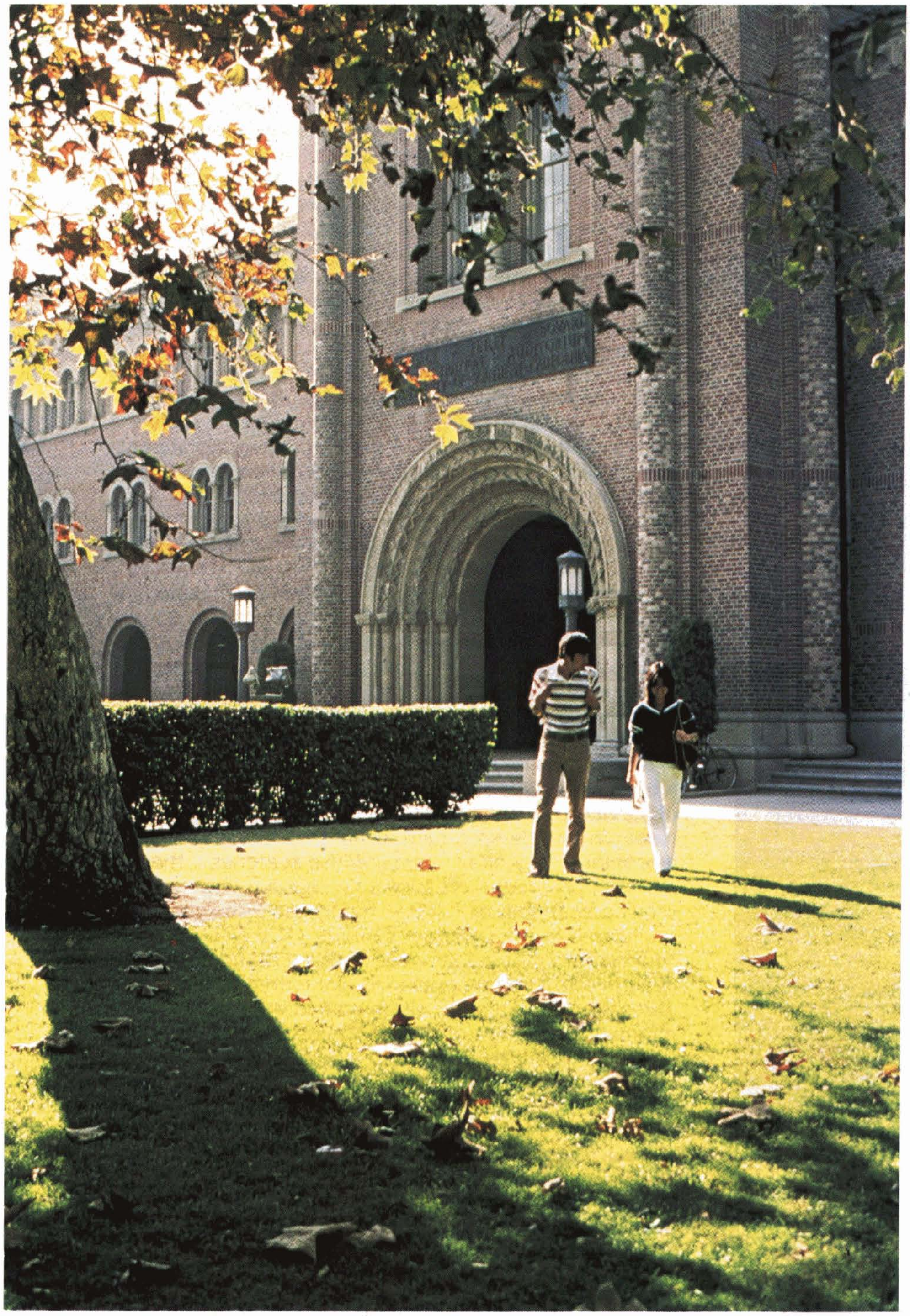
The wealth of aerospace technology generated by NASA over the past quarter-century is an important national resource in that it can be reused by industry for development of new products and processes, to the benefit of the U.S. economy. Such a bank of technology is a particularly valuable asset today, when American manufacturers are facing an unprecedented competitive challenge from abroad. It is industry's job to meet the challenge by developing better—hence more competitive—products and processes; it is NASA's job, in the interest of national productivity, to help American industry by making the technology bank readily accessible to those who want to take advantage of it.

To accomplish that job, NASA conducts the Technology Utilization Program, the aim of which is to get aerospace technology out of the storehouse and into the mainstream of the national economy, thereby producing bonus return on the nation's investment in aerospace research. Established in 1962, the program is designed to broaden and accelerate the transfer of aerospace technology to other sectors of the economy. It has been a remarkably successful program; in the 21 years of its existence, literally thousands of technology transfers have been effected.

Focal point of the program is NASA's Technology Utilization and Industry Affairs Division, headquartered in Washington, D.C. That office coordinates the activities of technology transfer specialists located throughout the U.S. at NASA field centers, dissemination centers and other offices. These specialists provide a link between the developers of technology and those who might effectively reuse it. Their jobs involve keeping abreast of aerospace technical advances, identifying new ways to employ the technology productively, promoting interest among prospective users, and providing assistance to expedite the transfer process.

A key element of the Technology Utilization Program is making private companies aware of what technologies NASA has developed or is developing, and encouraging them to participate more directly in the transfer process. One mechanism is the Corporate Associates Program, a joint effort on the part of NASA and the American Institute of Aeronautics and Astronautics (AIAA). Under an unfunded agreement, AIAA acts as an industrial broker to introduce non-aerospace firms to NASA, its technologists and its research and development activities. This program involves a series of seminars—each focused on one main area of technology—attended by industry personnel and by NASA technologists. An indication of the success of this effort is the fact that the first 13 seminars drew more than 500 industry executives representing 170 of the nation's largest non-aerospace companies. Another indicator is the high volume of post-seminar contacts initiated by industry with NASA technologists, efforts to follow up the seminar briefings and pursue

At seminars like this one at Langley Research Center, representatives of private companies get an introduction to NASA, its technologists and its research and development activities. Jointly sponsored by NASA and the American Institute of Aeronautics and Astronautics, the seminars are part of a program designed to make industry more aware of NASA technology available for transfer and to encourage broader private sector participation in joint government/industry projects.



NASA application centers, located at universities across the country, provide information retrieval services and technical assistance to industry and government clients.

further some type of technology transfer—perhaps simply additional information, perhaps an active development project.

In a number of instances, post-seminar contacts have led to Technical Exchange Agreements between NASA and industrial firms. Under these agreements, NASA makes available facilities and expertise so that a company can become more familiar with NASA technology and identify areas it may explore to improve its product line. In a supporting activity, AIAA—under contract to NASA—conducts a program in which personnel familiar with NASA field centers and technology transfer activities work to couple the interests of a specific company with appropriate NASA expertise. A related mechanism is a program whereby an industrial firm may participate in a major NASA project of special interest to the company by assigning one of its own scientists or engineers, who works on the project as a Guest Investigator on loan to NASA. Still another type of NASA-industry cooperation is the Joint Endeavor Agreement, wherein NASA and private enterprise work together to promote the utilization of space, teaming on projects where a technological advancement appears feasible and where there is potential for commercial application.

Other mechanisms employed in the Technology Utilization Program include Technology Utilization Officers, located at NASA field centers, who serve as regional program managers; application centers, channels through which potential users of innovations and inventions may avail themselves of NASA expertise; a software center that provides computer programs adaptable to secondary use; and a quarterly publication that informs potential users of new technologies available for transfer. NASA also undertakes, in cooperation with other organizations, applications engineering projects wherein existing aerospace technology is adapted to specified needs of government agencies and public sector institutions. These mechanisms are covered in greater detail on the pages that follow.

APPLICATIONS CENTERS

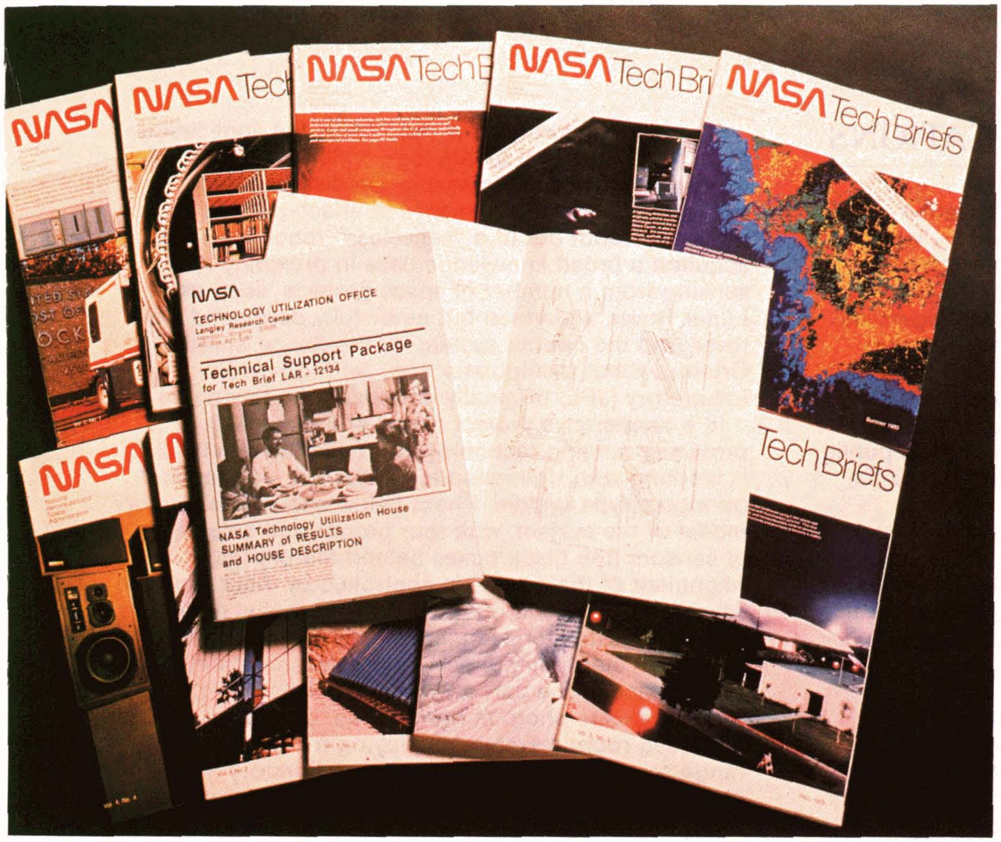
To promote technology utilization, NASA operates a number of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government clients. There are seven Industrial Applications Centers (IAC) and two State Technology Applications Centers (STAC) affiliated with universities across the country. The centers are backed by off-site representatives in many major cities and by technology coordinators at NASA field centers; the latter seek to match NASA expertise and ongoing research and engineering in areas of particular interest to clients.

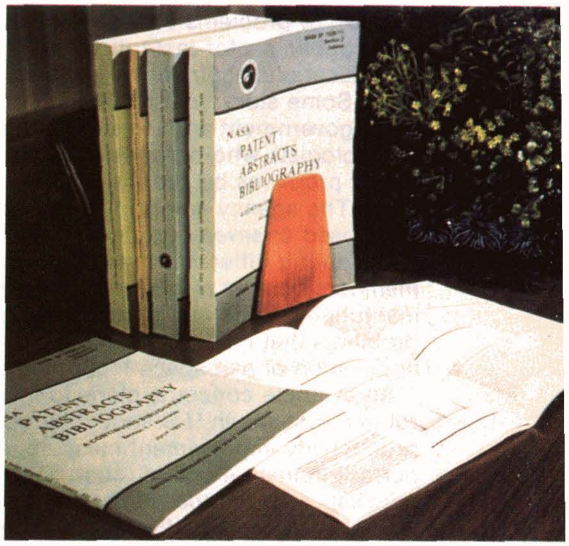
The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval. Through the applications centers, clients have access to more than 10 million documents. Almost two million of these documents are contained in the NASA data bank, which includes reports covering every field of aerospace-related activity plus the continually updated, selected contents of 15,000 scientific and technical journals.

Intended to prevent wasteful duplication of research already accomplished, the IACs endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems. By taking advantage of IAC services, businesses can save time and money and the nation benefits through increased industrial efficiency.

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

The State Technology Applications Centers supplement the IAC system. They facilitate technology transfer to state and local governments, as well as to private industry, by working with existing state mechanisms for providing technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state. For further information on IAC/STAC services, interested organizations should contact the director of the nearest center; addresses are listed in the directory that follows.





PUBLICATIONS

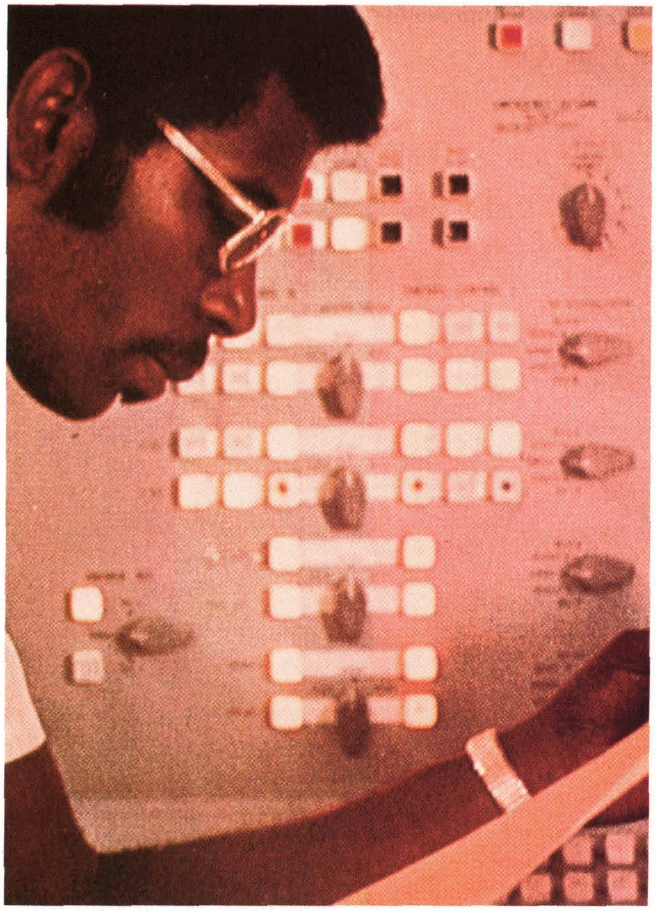
An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This aim is accomplished primarily through the publication Tech Briefs.

The National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. Those reports provide the input for Tech Briefs. Issued quarterly, the publication is a current-awareness medium and a problem-solving tool for its many industrial readers. Each issue contains information on approximately 140 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on a particular product or process described in the publication. Innovations reported in Tech Briefs last year generated more than 120,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader secondary use of NASA technology.

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

A related publication deals with NASA-patented inventions available for licensing, which number almost 4,000. NASA grants exclusive licenses to encourage early commercial development of aerospace technology, particularly in those cases where considerable private investment is required to bring the



invention to the marketplace. Non-exclusive licenses are also granted, to promote competition and bring about wider use of NASA inventions. A summary of all available inventions, updated semi-annually, is contained in the NASA Patent Abstracts Bibliography, which can be purchased from the National Technical Information Service, Springfield, Virginia 22161.

TECHNOLOGY APPLICATIONS

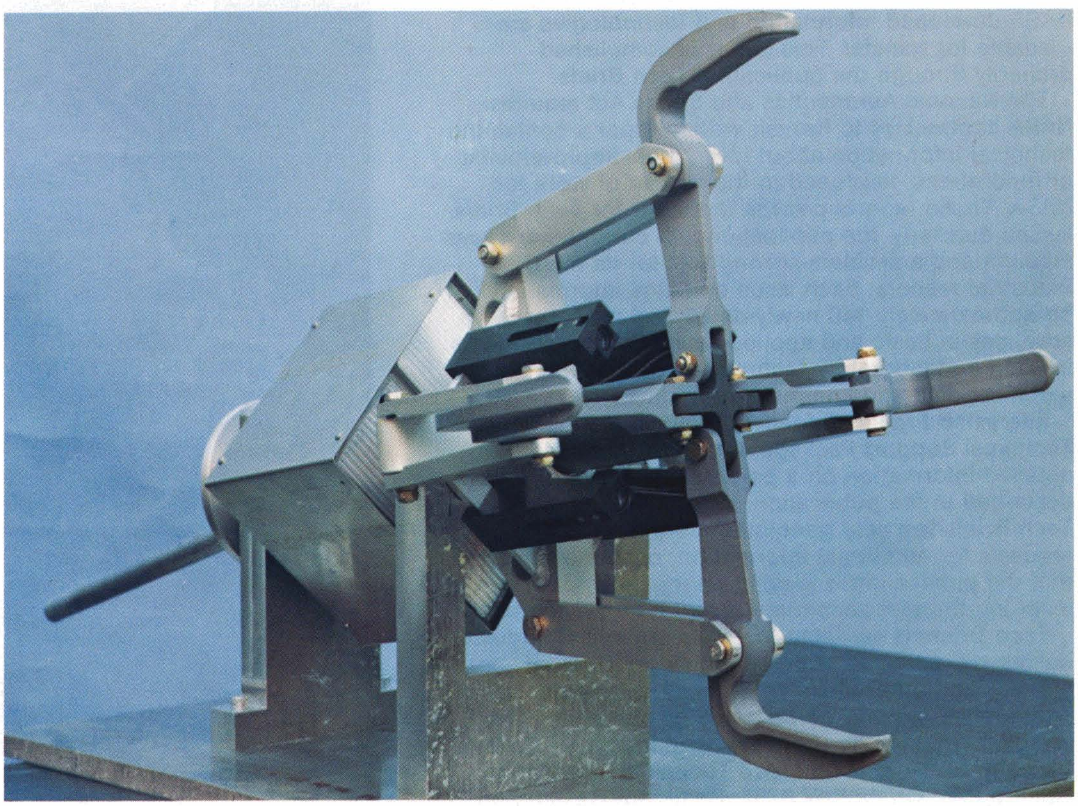
One facet of NASA's Technology Utilization Program is an applications engineering effort, which involves the use of NASA expertise to redesign and reengineer existing aerospace technology for the solution of problems encountered by federal agencies, other public sector institutions or private industries.

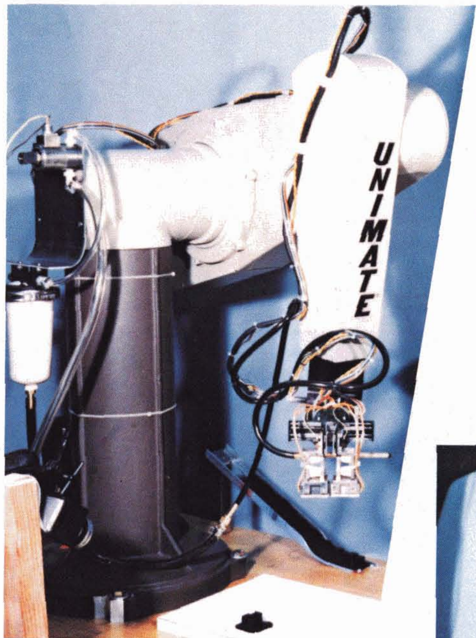
Applications engineering projects originate in various ways. Some stem from requests for assistance from other government agencies; others are generated by technologists who perceive possible solutions to public sector problems by adapting NASA technology to the need. The agency employs an application team composed of several scientists and engineers representing different areas of expertise. The team members contact public sector agencies, medical institutions, trade and professional groups to uncover problems that might be susceptible to solution by application of aerospace technology.

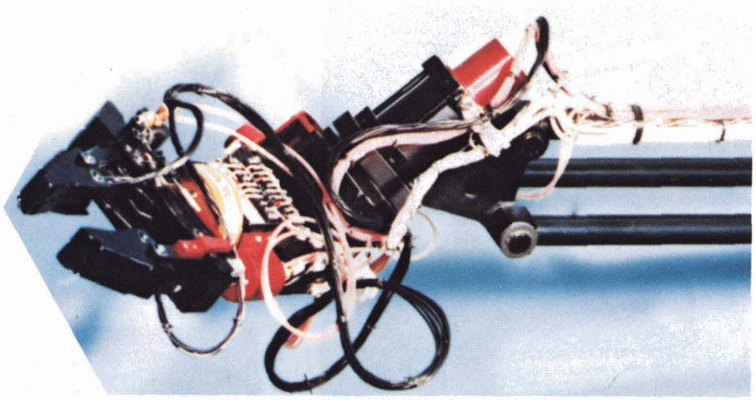
An example concerns plans to increase the use of robotic systems in U.S. industrial operations as a productivity improvement measure. A problem in current industrial use of robots is the difficulty of precisely aligning the robot with the component on which it is working. Misalignment can cause damage to the product, but to get extremely accurate alignment involves extensive, costly tooling—and that reduces the productivity improvement potential of the robot system.

A possible answer to the problem is the application of proximity ranging technology, which employs sensors to detect and measure the distance to a surface for precise alignment—in effect, making a "smart" robot out of a "senseless" robot. NASA has acquired a broad knowledge base in proximity range sensing from a number of space projects, such as the Lunar Rover, a planned but never fully developed Mars rover, and the control system for the Space Shuttle Orbiter's robot manipulator arm. Jet Propulsion Laboratory (JPL) originally developed the technology.

In a cooperative project aimed at transferring proximity ranging technology to industrial robots, JPL is working with Unimation Inc., Danbury, Connecticut on a prototype system. Photo below shows a laboratory model of the system, with four prongs and a series of sensors (the black boxes behind the prongs). Alignment of the prongs is controlled by input from the sensors, which send out infrared light that is reflected back to a computerized measuring system, providing a basis for determining precisely the distance from prong to a surface of the part on which the robot is working. The composite photo at right shows, clockwise, a more advanced robotic system employing the proximity range sensing technology, another laboratory model, a control box and a computer terminal used to program a sequence of operations for the robot to perform; it can also provide a display of distances from robot to work surface. Successful application of proximity ranging to industrial use would increase robot







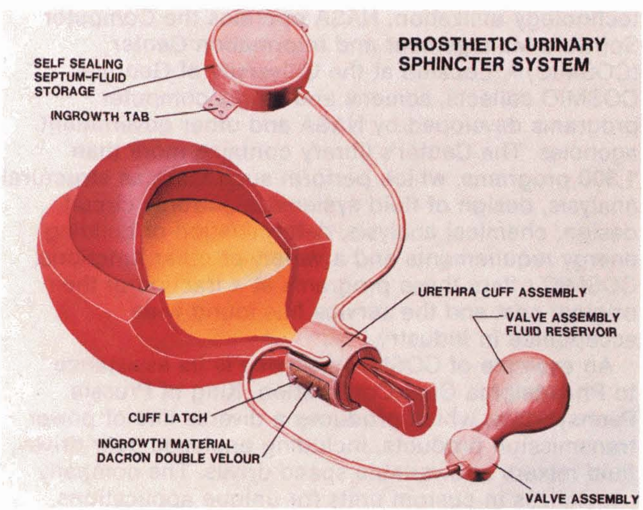
productivity, substantially reduce tooling costs and eliminate the product damage frequently caused by senseless robots.

Another example of an applications engineering project is a prosthetic urinary sphincter being developed by Marshall Space Flight Center in cooperation with Rochester General Hospital (RGH), Rochester, New York and two medical equipment manufacturers: Parker-Hannifin Corporation, Irvine, California and Medical Engineering Corporation, Racine, Wisconsin; the NASA Application Team at Research Triangle Institute, Research Triangle Park, North Carolina is coordinating activities among Marshall, RGH and the two companies. The human-implantable prosthesis is intended to help an estimated four million people in the United States who suffer urinary incontinence caused by a variety of conditions, such as spinal cord injuries, cerebrovascular disease, birth defects, multiple scelerosis, diabetes, and surgical complications following prostate operations.

A malfunctioning sphincter is often responsible for the inability to control emptying of the bladder. Continence can sometimes be restored by an implanted device that occludes (closes) the urethra, the canal that carries off the urine from the bladder; the device allows voluntary voiding by manual release of the occluding pressure. However, two factors have prevented widespread use of existing devices by the medical community: the surgical complexity of the implantation procedure and a high rate of device malfunction, often due to valve failure.

The NASA project is an effort to obviate such objections through development of a simpler, more reliable system for occluding the urethra. Key to the development is adaptation of the low pressure, zero leakage, high reliability valves used on the Viking spacecraft that explored Mars. The manufacturers have jointly fabricated a valve/bulb assembly designed for commercial use after successful completion of clinical trials, which are to begin this year.

The illustration below shows the operation of the prosthetic urinary sphincter system, which is implanted so that the valve/bulb assembly is accessible to manual pressure through the skin. The cuff applies pressure to occlude the urethra and maintain continence. The pressure can be released for voiding, then restored by manual manipulation of the valve.

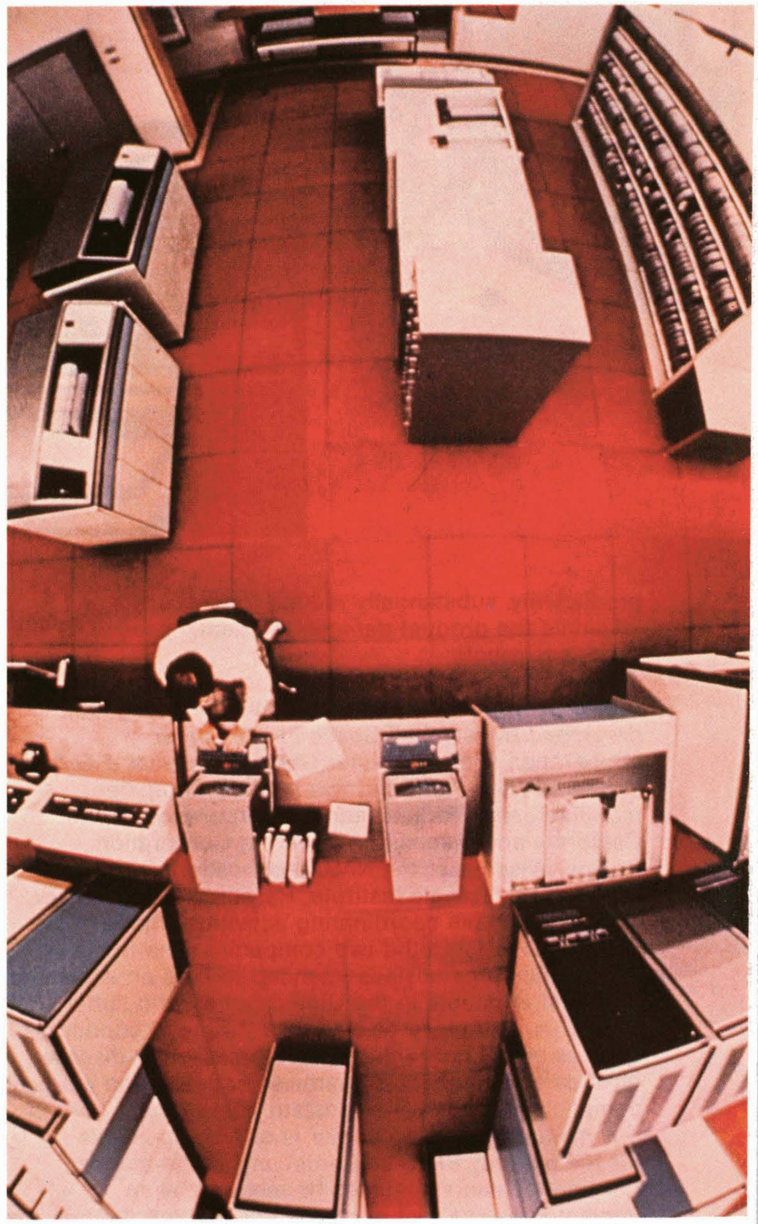


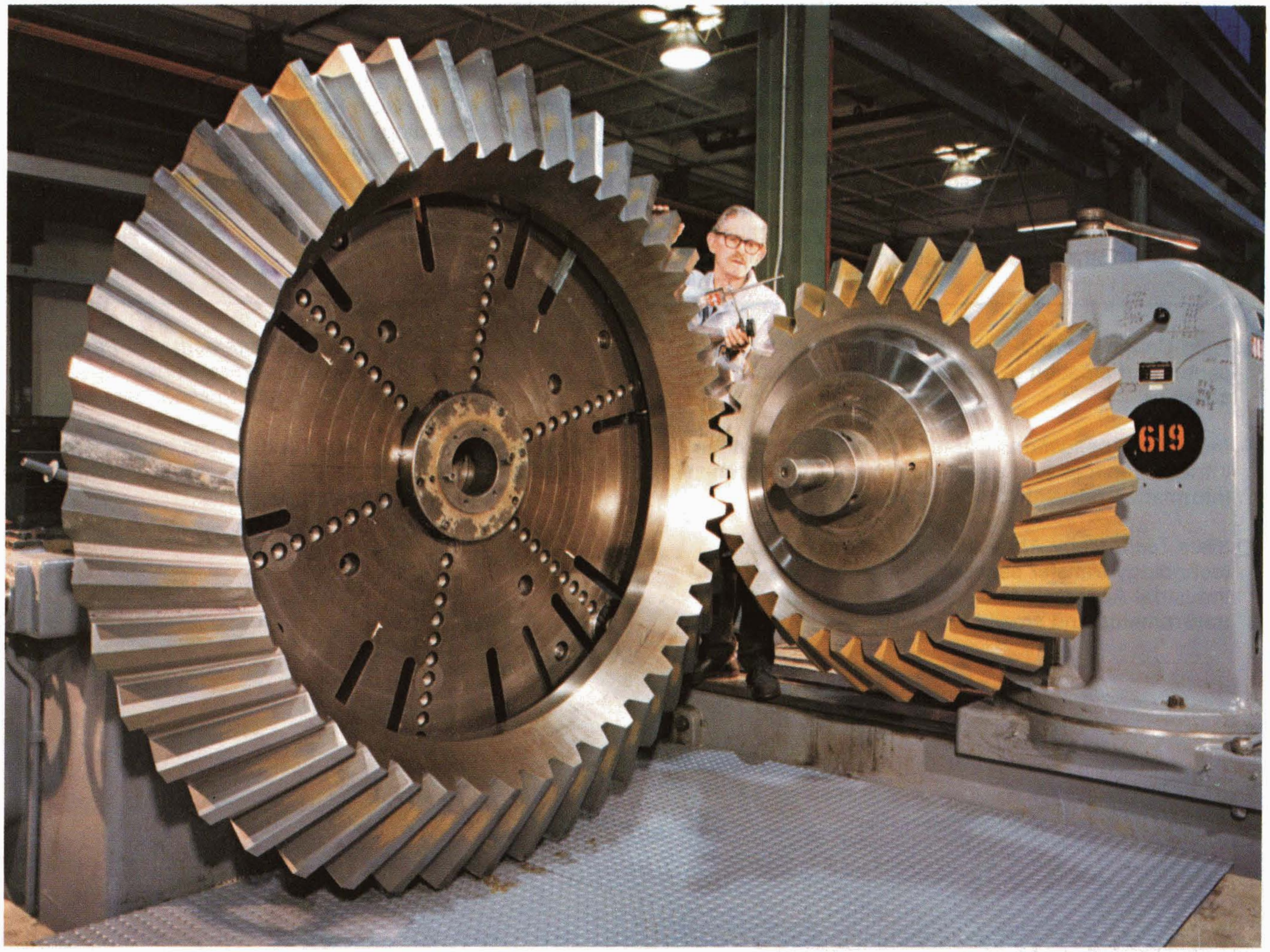
SOFTWARE CENTER

In the course of its varied activities, NASA makes extensive use of computers, not only in Space Shuttle missions but in such other operations as analyzing data received from satellites, conducting aeronautical design analyses, operating numerically controlled machinery and performing routine business or project management functions. Operation of computers requires software, computer programs that are essentially sets of instructions telling the computer how to produce desired information or effect from its stored input. Thus, NASA and other technology-generating agencies of the government have of necessity developed many types of computer programs, a valuable resource available for reuse. Many of these programs are directly applicable to secondary use with little or no modification; some can be adapted for special purposes at far less than the cost of developing a new program from scratch.

To help industrial firms, government agencies and other organizations take advantage of this type of technology utilization, NASA operates the Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC collects, screens and stores computer programs developed by NASA and other government agencies. The Center's library contains more than 1,300 programs, which perform such tasks as structural analysis, design of fluid systems, electronic circuit design, chemical analysis, determination of building energy requirements and a variety of other functions. COSMIC offers these programs at a fraction of their original cost and the service has found wide acceptance in industry.

An example of COSMIC's service is its assistance to Philadelphia Gear Corporation, King of Prussia, Pennsylvania, which produces a diverse line of power transmission products, including enclosed gear drives, fluid mixers and variable speed drives. The company specializes in custom units for unique applications, such as Coast Guard ice-breaking ships, steel mill





drives, coal crushers, sewage treatment equipment and electricity-generating wind turbines. Above, a Philadelphia Gear inspector is checking teeth contact of an 80-inch diameter gear and pinion set for the steel industry. At right, a quality assurance engineer is measuring tooth spacing of a 24-foot diameter cement mill gear.

Philadelphia Gear used two NASA COSMIC computer programs—one dealing with shrink fit analysis and the other with rotor dynamics problems—in computerized design and test work. The COSMIC programs, developed by Lewis Research Center, were used to verify existing in-house programs, in accordance with Philadelphia Gear's practice of insuring design accuracy by checking its company-developed computer methods against reliable procedures developed by other organizations.

To assist prospective customers in locating potentially useful programs, COSMIC publishes an annual indexed catalog of all the programs in the Center's inventory. Available on either microfiche or computer magnetic print tape, the catalog may be purchased directly from COSMIC. The Center also helps customers define their needs and suggests programs that might be applicable. For information on COSMIC's services, contact the director at the address in the directory that follows.

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

NASA'S TECHNOLOGY TRANSFER SYSTEM

The NASA system of technology transfer personnel and facilities extends from coast to coast and provides geographical coverage of the nation's primary industrial concentrations, together with regional coverage of state and local governments engaged in transfer activities. For specific information concerning the activities described below, contact the appropriate technology utilization personnel at the addresses listed on the following pages.

For information of a general nature about the Technology Utilization Program, address inquiries to the Director, Technology Utilization and Industry Affairs Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240, or phone (301) 621-0242.

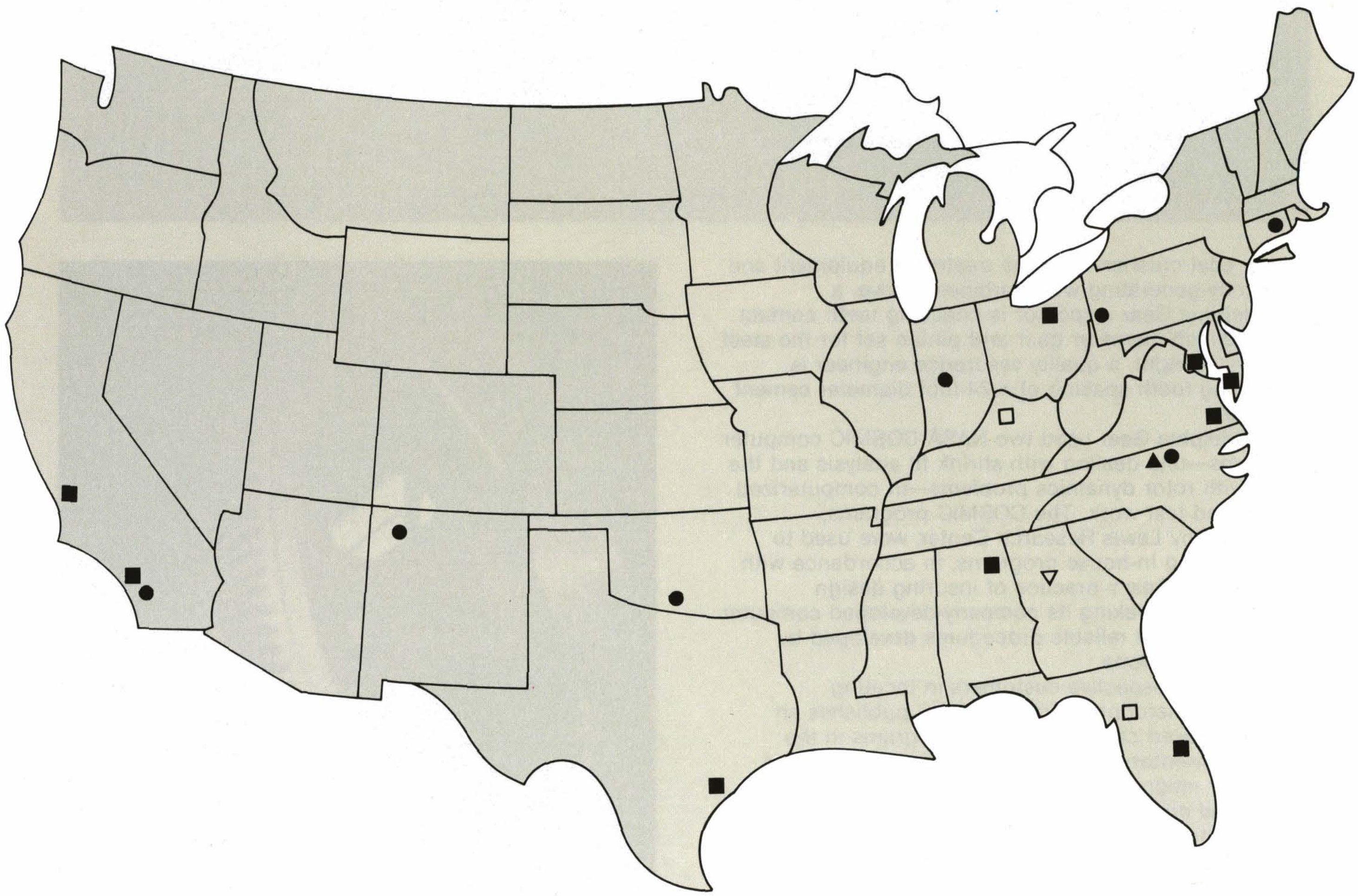
■ *Field Center Technology Utilization Officers:* manage center participation in regional technology utilization activities.

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

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

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

▲ *Application Team:* works with public agencies and private institutions in applying aerospace technology to solution of public sector problems.



FIELD CENTERS

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

Technology Utilization Officer: *Stan Miller*
Phone: (415) 965-6471

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

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

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

Technology Utilization Officer: *Marvin F. Matthews*
Phone: (713) 483-3809

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

Technology Utilization Officer: *U. Reed Barnett*
Phone: (305) 867-3017

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

Technology Utilization and
Applications Programs Officer: *John Samos*
Phone: (804) 865-3281

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

Technology Utilization Officer: *Harrison Allen, Jr.*
Phone: (216) 433-4000, ext. 422

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

Director, Technology Utilization Office: *Ismail Akbay*
Phone: (205) 453-2223

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

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, ext. 663

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

Technology Utilization Officer: *Aubrey D. Smith*
Phone: (213) 354-4849

INDUSTRIAL APPLICATIONS CENTERS

Aerospace Research Applications Center
P.O. Box 647
Indianapolis, Indiana 46223

John Ulrich, director
Phone: (317) 264-4644

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

Tom J. McRorey, Ph.D., director
Phone: (405) 924-6822

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

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

NASA Industrial Applications Center
University of Southern California
Research Annex, 2nd Floor
3716 South Hope Street
Los Angeles, California 90007

Robert Mixer, Ph.D., director
Phone: (213) 743-6132

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

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

North Carolina Science and
Technology Research Center
Post Office Box 12235
Research Triangle Park, North Carolina 27709

James E. Vann, Ph.D., director
Phone: (919) 549-0671

Technology Applications Center
University of New Mexico
2500 Central Avenue, S.E.
Albuquerque, New Mexico 87131

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

STATE TECHNOLOGY APPLICATIONS CENTERS

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

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

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

William R. Strong, manager
Phone: (606) 257-6322

COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER

COSMIC
112 Barrow Hall
University of Georgia
Athens, Georgia 30602

John A. Gibson, director
Phone: (404) 542-3265

APPLICATION TEAM

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

Doris Rouse, Ph.D., director
Phone: (919) 541-6980