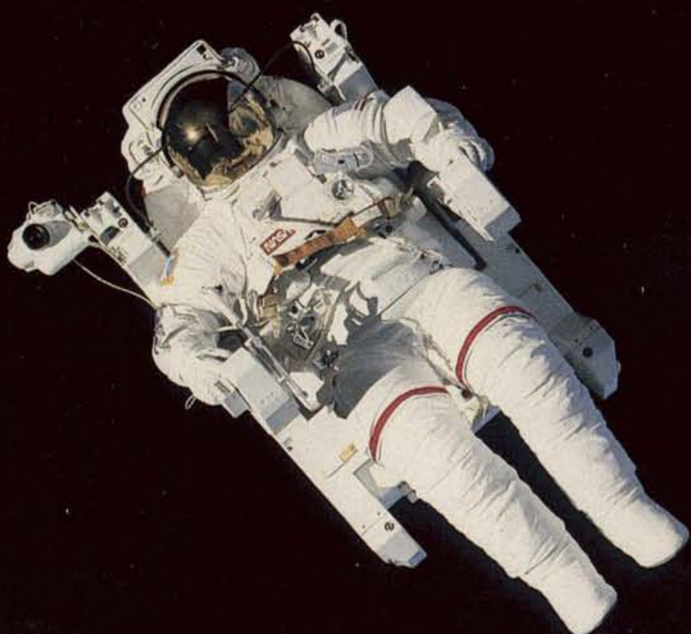
SPINOFF *1986*



NASA

National Aeronautics and
Space Administration

On the cover:

Orbital space and sub-ocean "inner space" are totally different environments that nonetheless share some similarities. A link between them: a line of pressurized pens originally designed for astronauts, now used by oceanographic researchers—and many others (see page 88).

SPINOFF 1986

National Aeronautics and
Space Administration

Office of Commercial Programs

Technology Utilization Division

by James J. Haggerty

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FOREWORD

The year 1986 inevitably will be remembered as the year of the Challenger tragedy and the temporary disruption of America's launch capability.

I hope it also will be remembered as the year of a new beginning for NASA, and the nation's space program—a program that will be better and more reliable because we learned from our mistakes. NASA's belief in the future of space exploration and its attendant goals to that end have not changed, nor has the promise of public benefit through aerospace research.

The Space Station, which NASA is developing in cooperation with friendly nations, will permit continuous long-term space operations. It will afford a significantly improved capability for pursuing scientific and technological research, and provide potentially enormous benefits to improve life on Earth.

NASA's space science effort will continue to provide a wealth of new scientific knowledge. That knowledge is immensely valuable in its own right; but it also is vital to provide an expanded base for tomorrow's practical applications.

In the area of aeronautical research, NASA's major thrusts involve technology for a 1990s generation of superefficient subsonic aircraft and an experimental aerospace plane able to operate within or beyond the atmosphere after ascent from a conventional runway. Successful implementation of the advanced aircraft program could lead to a space transport system capable of delivering payloads that would orbit at a fraction of today's cost, and to the development of a 21st century airliner flying passengers at hypersonic speed.

NASA's new beginning comes at a time when rapid technological progress has created opportunities for revolutionary aerospace advances. It is also a time of increasingly intense competition among nations for the economic and social benefits that will accrue from such advances. It is vitally important that the United States meet the international challenge and maintain its leadership in aerospace technology. NASA is committed to meeting this great challenge.

James C. Fletcher
Administrator

National Aeronautics and Space Administration

INTRODUCTION

Technology, says a dictionary, is the sum of the ways in which a society provides the material objects of civilization. In other words, it is technical know-how, or simply knowledge. And, like other forms of knowledge, it is transferable; technology developed for one purpose can be applied to uses different—and often remote—from the original application.

This secondary use of once-developed technology—spinoff—is important to the Nation because it represents an extra dividend on the original investment, hence is an aid to increased national productivity.

NASA programs, by their challenging nature, are particularly demanding of technological advances and the technologies they generate are exceptionally diverse. Thus, the large storehouse of technology built over more than a quarter century of space exploration and six decades of aeronautical research constitutes a national resource, a bank of knowledge available for new uses.

By Congressional mandate, NASA is charged with stimulating the widest possible use of this valuable resource. Through its Technology Utilization Program, NASA seeks to encourage greater use of the knowledge bank by providing a link between the technology and those who might be able to put it to advantageous secondary use. The aim is to accelerate and broaden the technology transfer process, thereby to gain national benefit in terms of new products, new processes, new jobs and a bonus return on the funds invested in aerospace research.

This publication is intended to foster that aim by heightening awareness of the NASA technology available for transfer and its potential for benefit. *Spinoff 1986* is organized in three sections:

Section 1 outlines NASA's mainline effort, the major programs that generate new technology and therefore expand the bank of knowledge available for future transfer.

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

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

Isaac T. Gillam IV

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Assistant Administrator for Commercial Programs

National Aeronautics and Space Administration

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Aerospace Aims

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

A national policy 'roadmap' charts an exciting course for NASA aeronautical research

The United States has long been the world's leader in aeronautical technology and it is vitally important that the U.S. retain that leadership—important to defense, to American jobs, to the U.S. international trade balance and to the national economy as a whole.

Today, however, U.S. aeronautical preeminence is being challenged by a wave of intense competition that has narrowed the American technological advantage. Countries of Western Europe, the Soviet Union, Japan and even some emerging nations have advanced their technical capabilities to the point where, in a number of aeronautics-related areas, they have achieved competence at least comparable and in some cases superior to that of the U.S.

Noting that the U.S. can ill afford or allow any further erosion of its competitive position, the White House Office of Science and Technology Policy (OSTP) responded last year with a policy "roadmap" for a research and development program whose success would assure continued U.S. aeronautical leadership well into the next century. The answer to revitalizing America's competitive posture, said OSTP, is an intensified R&D effort concentrated on certain "high payoff" technologies, those that offer really dramatic improvements in the cost and performance of future aeronautical systems. Such an effort, OSTP continued, "would result in 21st century civil and military aircraft of clear-cut superiority. Their technical excellence and cost advantages would more than overcome foreign competition."

To focus the direction of aeronautical R&D, OSTP made three specific recommendations, including an accelerated effort to advance key technologies for a new generation of superefficient subsonic aircraft; work on pacing technologies for sustained supersonic cruise flight; and a program of "transatmospheric" research aimed toward development of an aerospace plane that could operate routinely in the atmosphere or into orbit from conventional runways.

Administration acceptance of two of those recommendations is reflected in the President's Fiscal Year 1987 budget proposal being deliberated by Congress. The proposed budget supports continued NASA development of key technologies for advanced subsonic aircraft and also calls for initiation of a National Aerospace Plane program. Planned as a joint NASA/Department of Defense effort, the latter program was defined by OSTP as one "to develop and demonstrate the technologies for a revolutionary class of aerospace vehicles, powered by airbreathing engines, that would have the capability to take off and land horizontally on a standard runway, cruise in the atmosphere at hypersonic speeds, or fly into Earth orbit."

The plan calls for accelerated development of the enabling technologies, including propulsion, materials, structures and airframe design. A decision to proceed with construction of an experimental technology demonstrator, or X-plane, would be made in the latter part of 1988. The Air Force has been assigned program management responsibility; NASA is responsible for overall technology direction. Successful demonstration of the advanced technologies in flight would pave the way for a new family of important applications, among them:

- A space transportation vehicle providing rapid access to space and delivery of payloads to orbit at lower costs.
- An entirely new class of military aircraft of extraordinary performance and survivability.
- A 21st century hypersonic passenger transport, typically one flying at altitudes above 100,000 feet at speeds of 4,000 miles per hour or more, possibly much more.

The subsonics goal set forth by the Office of Science and Technology Policy (OSTP) envisions an entirely new generation of extraordinarily efficient aircraft, including commercial transports, military airlifters and high speed rotorcraft. They will burn substantially less fuel than their current counterparts, have dramatically lower overall operating costs, be producible—hence salable—at lower cost, and enable superior transportation at fares lower than today's.

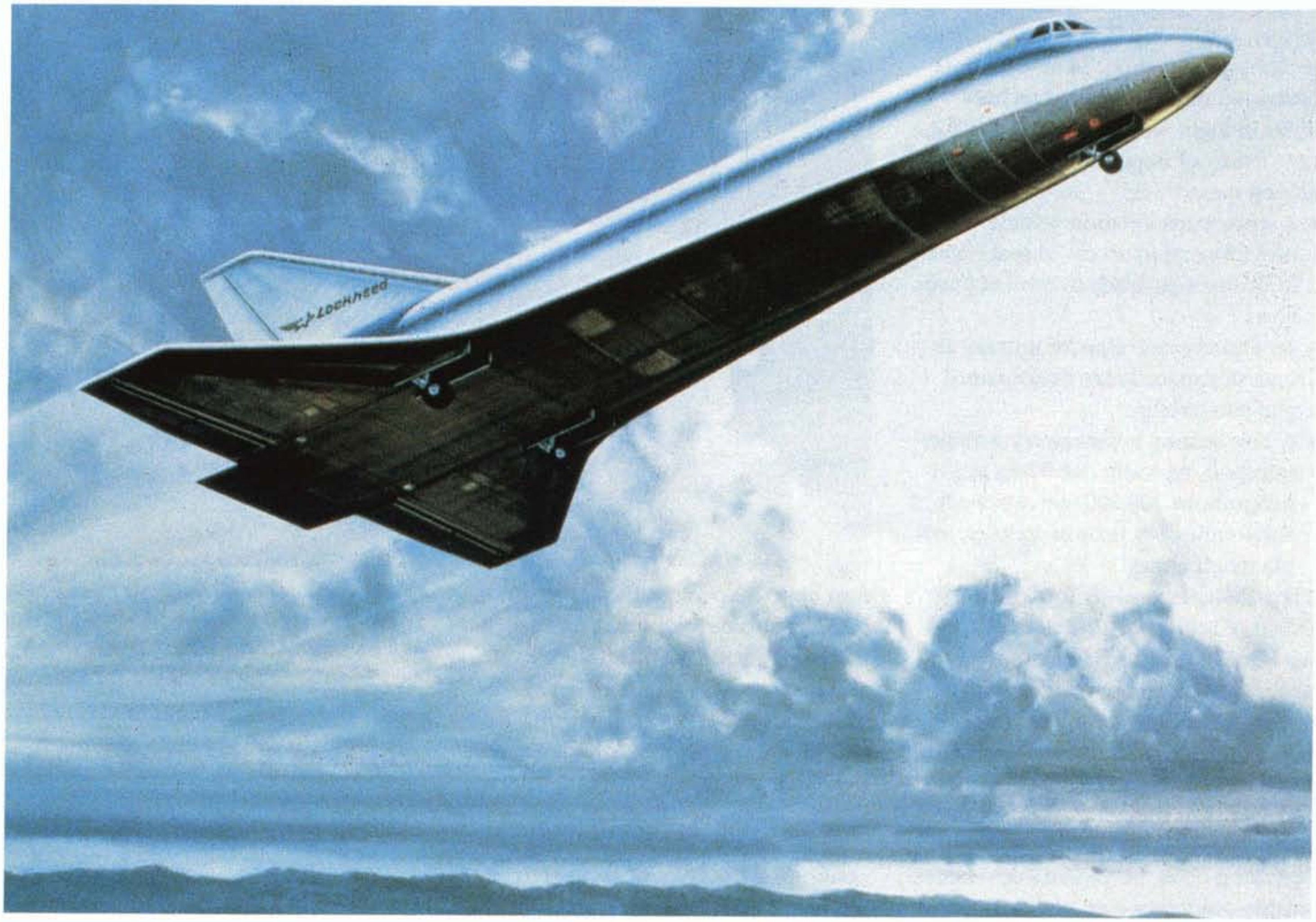
That's a big order, but feasible. NASA is already working on, and has made considerable progress in, the four areas of technology listed by OSTP as "integral" to the development of such subsonic aircraft:

Propulsion systems. A major NASA effort in propulsion research involves investigation of advanced turboprop systems that could power 1990s transports at jetliner speeds with fuel savings up to 30 percent (see page 14). NASA is also developing technology—including materials, instrumentation and controls—for a generation of highly advanced turbofan engines that will be able to operate at higher temperatures and pressures for increased performance and efficiency.

Laminar flow control, a means of controlling the layer of air next to an airplane's skin, keeping it smooth (laminar) to reduce aerodynamic drag and dramatically lower fuel consumption. NASA has identified several promising technologies and some have advanced to flight test status.

Structural materials. NASA has accomplished a great deal of research in secondary structures made of composite materials, generally lighter yet stronger than metals. Composites constitute

One type of airplane envisioned for "trans-century" service is the advanced turboprop airliner, capable of operating at jetliner speeds but with dramatically better fuel efficiency.



The "transatmospheric" goal, an aerospace plane capable of operating within or outside the atmosphere for more flexible, less costly Earth-to-orbit operations.

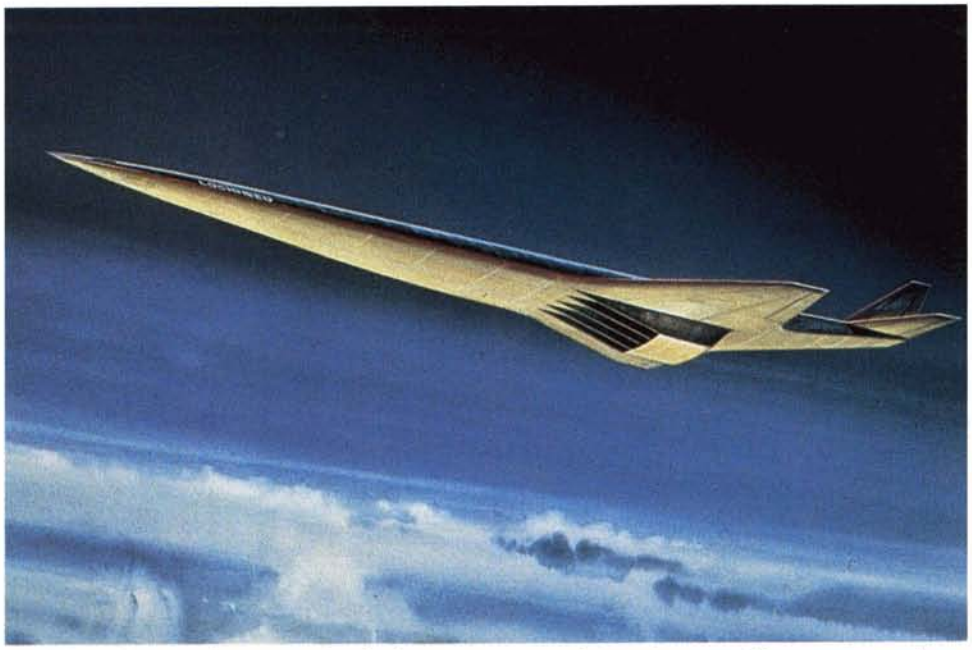
about three percent of the structural weight of the latest U.S. jetliners and their use is growing. NASA is now investigating a new generation of materials and advanced design concepts that exploit the unique properties of composites for reduced weight and increased damage tolerance.

Flight controls. Research over the past several years has built a strong technology base for advanced digital electronic—rather than mechanical—flight controls and for systems of integrated flight and propulsion controls that offer greater airplane efficiency, improved handling qualities and reduced crew workload.

Another of OSTP's stated goals, the transatmospheric goal, envisioned "a capability to routinely cruise into and out of the atmosphere with takeoff and landing from conventional runways." The National Aerospace Plane represents an experimental first step toward that goal, a technology advancement effort that could lead to operational derivatives in the early 21st century.

Defined in a 1984-85 exploratory researched program conducted jointly by the Defense Advanced Research Projects Agency and NASA, the aerospace plane concept centers on a hydrogen-powered, horizontal takeoff and landing aircraft capable of flying from Earth to orbital altitudes at speeds up to 17,000 miles per hour.

The primary hypersonic propulsion system for the aerospace plane is the supersonic combustion ramjet, or "scramjet," burning a mixture of hydrogen and air; this obviates the need to carry on-board liquid oxygen for combustion, as is necessary in today's rocket-powered launch vehicles. The aerospace plane's horizontal takeoff and landing capability would eliminate the costly launch complex currently required for the Space Shuttle and unmanned boosters. Thus, a later derivative of the aerospace plane, needing no on-board oxygen or vertical launch facilities, could potentially operate with airplane-like flexibility and deliver payloads to orbit at a fraction of today's cost, with profound implications for future space operations.



Successful development of the experimental National Aerospace Plane would make possible a derivative hypersonic transport carrying passengers at speeds upward of 4,000 miles per hour.

Although it might seem that little technology exists for such an advanced concept as the aerospace plane, NASA in fact has a long history of interest and involvement in hypersonic and transatmospheric vehicle technologies. It began in the 1950s with the X-15 research airplane, which first explored manned hypersonic flight; it continued in the 1960s with research on hypersonic airbreathing propulsion systems, in the early 1970s with lifting body aircraft research and more recently with the Space Shuttle. Thus, although the National Aerospace Plane will demand extensive development of new technology, there already exists a solid technology base to serve as a departure point. ▲

For more than 20 years, the military services have been operating aircraft whose wing sweep angles can be changed in flight to get the best aerodynamic efficiency for a given speed. A long-desired complement to the variable sweep wing is the variable camber wing, one whose camber—the fore to aft curve of the airfoil—can also be changed to get the optimum wing shape for a given flight condition, for example, approach, landing, cruise, maneuvering or maximum speed operation.

Such a wing, known as the Mission Adaptive Wing (MAW), is part of the Air Force/NASA Advanced Fighter Technology Integration (AFTI) program, which involves flight testing of aerodynamic and electronic advancements that might be incorporated in future military aircraft. The MAW wing was built under Air Force contract by Boeing Military Airplane Company and installed on a NASA NF-111 aircraft earlier used on several research programs. Known as the AFTI F-111 (top photo) the testbed aircraft has variable sweep capability (as does the standard F-111 fighter) in addition to variable camber.

Covered by a flexible composite material, the MAW wing has a computerized system of sensors, controls and internal hydraulic acuators to change the fore to aft contour. The MAW program is intended to demonstrate the use of variable camber technology as a means of effecting dramatic improvements in aircraft payload, range, maneuverability, fuel efficiency and handling qualities. First flown in October 1985, the AFTI F-111 completed its flight test program this year at NASA's Ames-Dryden Flight Research Facility.

Also in flight test status at Ames-Dryden is the X-29A advanced technology demonstrator (left center), sponsored by the Defense Advanced Research Projects Agency with support from NASA and the Air Force. The X-29A features a unique forward-swept wing, made of composite materials, which offers weight reduction of as much as 20 percent in comparison with conventional aft-swept wings. It also has a variable-camber system, similar in part to that of the AFTI F-111, that alters the shape of the wing's trailing edge to provide the best wing shape for a given set of flight conditions. Among other advanced technologies incorporated in the X-29A are a digital flight control system; flaperons that combine the functions of flaps and ailerons in a single airfoil; and forward "canard" wings whose angles relative to the airflow are computer-adjusted 40 times a second as a means of improving flight efficiency and aircraft agility. The X-29A program is intended to demonstrate that this combination of technologies makes it possible to build smaller, lighter and more efficient aircraft without sacrificing performance.

Another AFTI project at Ames-Dryden is the AFTI F-16 (left bottom), a test version of the General Dynamics F-16 in operational service with the USAF. Ames-Dryden earlier conducted a Phase 1 program that focused on evaluation of the F-16's computerized flight control system and, in 1985, initiated Phase 2 to investigate the aircraft's Automated Maneuvering Attack System, which integrates flight controls and fire controls to achieve automatic delivery of weapons. Phase 2 will be completed this year.

In cooperation with the Navy, NASA is starting a new program that involves flight testing of an advanced oblique wing concept. An oblique wing is one that can be pivoted in flight to form oblique angles with the airplane's fuselage. During takeoff and low speed operation, such a wing would be at right angles to the fuselage or "straight." At faster speeds, it would swing around a pivot so that the leading edge on one side is swept forward, the other swept aft. In that configuration, the airplane would encounter less air drag, so the oblique wing concept offers greater aerodynamic efficiency at high speed while maintaining efficiency at low speed.

In 1980-81, with a small research craft known as the AD-1, NASA successfully demonstrated the feasibility of pivoting a wing in flight—but only at low speeds. The new program, which will employ the fuselage of a NASA F-8 research plane with a new oblique wing (upper right), will extend the technology to transonic and supersonic speeds—up to Mach 1.4 or close to 1,000 miles per hour. First flights are planned for 1988.

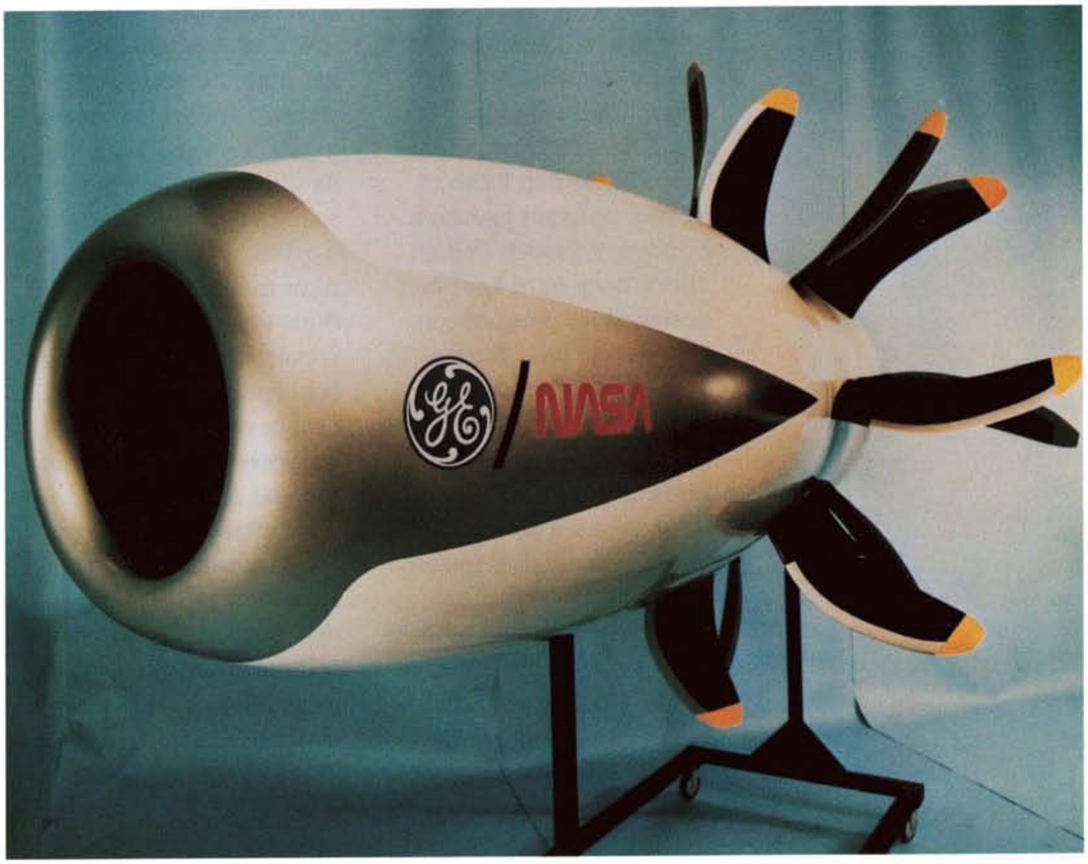
Among other NASA projects are flight tests of a Navy F-18 fighter to investigate further stability and control problems and other phenomena experienced by high performance aircraft operating at high angles of attack (the angle of the wing to the airflow moving over it); the F-15 HIDEC (Highly Integrated Digital Electronic Controls) program, involving flight research of advanced technology for integration of flight controls and propulsion controls; tests of advanced flight and engine controls and cockpit displays in a Marine Corps AV-8B vertical lift shipboard fighter; and wind tunnel tests of various configurations for a supersonic STOVL (Short Take-Off and Vertical Landing) aircraft (above). ▲

Despite moderation of jet fuel prices in recent years, fuel cost remains a pressing problem for the airline industry and operators of business jets. Today, fuel accounts for about 30 percent of an airline's total operating costs and no one can be sure that there will not be another sharp price escalation, such as those experienced in the oil crises of the 1970s. Thus, there is increasing interest in the potential of the advanced turbine/propeller engine, or turboprop, which has inherently better fuel consumption than the jet engine.

When the jetliner made its U.S. debut in the late 1950s, the turboprop rapidly lost favor among commercial operators, because the propellers of that day were limited in tip speed and that in turn restricted airplane speed. Now, however, researchers have found that advanced propellers, or propfans, can provide jetliner speeds when coupled with similarly advanced drive systems and other new propulsion technologies—and they can do so at fuel consumption rates 15 to 30 percent lower than a turbofan engine of the same time period. If this potential is confirmed by flight research, and if other turboprop drawbacks—such as noise and vibration—can be overcome, the propeller may stage a comeback in commercial air service and allow airline fuel savings of billions of dollars annually.

For several years, Lewis Research Center has been developing technology for propfan systems that could be available to aircraft manufacturers in the early 1990s. The type of propeller that is emerging from Lewis research bears little resemblance to the turbine-driven propeller of the 1950s. Instead of the straight blades of their ancestor, propfan designs feature extremely thin blades that sweep away from the direction of rotation (top left) to provide greater efficiency at high tip speeds. The blades are shorter than those of earlier turboprops, so the tips do not have to move as fast for a given airplane speed requirement. And where the old turboprops generally had four blades, the propfan has more, typically eight, in order to compensate for the thrust reduction caused by shortening the blades.

One advanced turboprop system has been extensively ground tested and is now being readied for flight testing under NASA's Propfan Test Assessment program. The system includes a nine-foot-diameter propfan assembly developed for Lewis by Hamilton Standard Division of United Technologies; a drive system consisting of a modified existing engine and gearbox, built by General Motors' Allison Gas Turbine Division; and a new-design engine nacelle built by Rohr Industries, Inc. The whole assembly will be mounted as an "extra engine" on the wing of a twinjet Gulfstream II light transport (lower left) being modified by Lockheed-Georgia Company. The latter company will conduct a series of flight tests, beginning late this year and focusing on propfan structural integrity and acoustic characteristics, the two remaining technical issues that cannot be adequately investigated at model scale. Lockheed-California Company will conduct separate ground tests, analyze acoustic data from the flight tests and develop new concepts for cabin noise reduction, an important part of the program if the reborn propeller is to gain passenger acceptance and realize its potential in commercial service.



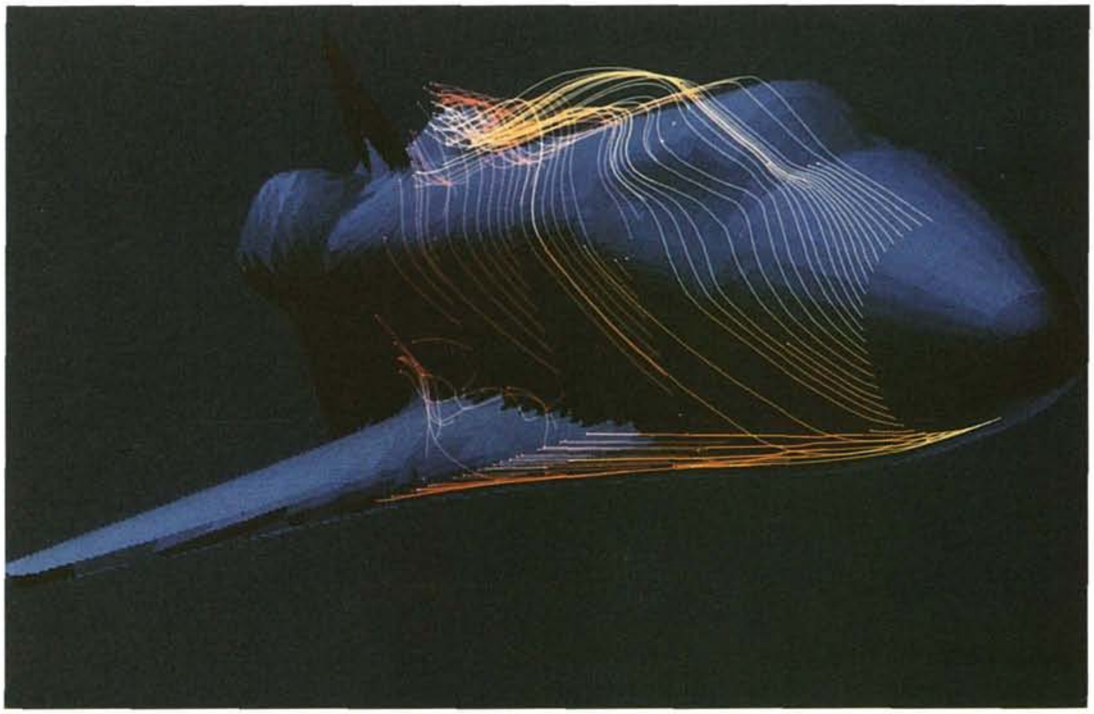
The Hamilton Standard/ Allison propfan is a single rotation system. Lewis is also conducting research, both analytical and experimental, on counter-rotating propellers and their drive systems to determine the aerodynamic and acoustic characteristics of both geared and ungeared designs and to evaluate the relative merits of the single rotation and counter-rotation systems. Now undergoing ground test at General Electric Company is a unique type of propfan known as the "unducted fan" or UDF (right), a counter-rotation system with two rows of eight blades. The UDF's fan blades are highly swept airfoils made of composite material to provide stiffness and strength at light weight; the fans are driven directly from the turbine without an intervening gearbox. ▲

At left is a model of a new "X-wing" rotor concept that will be extensively flight tested, beginning this year, in a NASA/Defense Advanced Research Projects Agency program managed by Ames Research Center. The X-wing rotor has been designed for proof-of-concept testing on a Rotor Systems Research Aircraft (RSRA), two of which were built by Sikorsky Aircraft for investigations of promising rotorcraft concepts with future commercial or military potential.

The X-wing rotor has four extremely stiff blades that can be stopped in flight to become, in effect, an X-shaped fixed wing. For takeoff, hovering and low speed flight, the rotor operates in the spinning mode as a helicopter rotary wing; at a speed of about 200 miles per hour, the rotor is stopped and locked in place to provide fixed-wing lift for attaining much higher speeds, perhaps approaching 500 miles per hour. The rotor can be restarted in flight for landing in the helicopter-mode. The X-wing concept offers utility as a civil or military short-haul transport beginning about the end of the century.

In another area of rotary wing research, NASA signed an agreement with the Federal Aviation Administration and the Department of Defense to study the possible national benefits of further development of tilt-rotor aircraft, which combine the vertical lift advantages of the helicopter with the greater forward speed of the fixed-wing airplane. The feasibility of this concept has been demonstrated in seven years of flight tests—conducted by Ames Research Center and Bell Helicopter Textron—of the XV-15 Tilt-Rotor Research Aircraft pictured at left, a joint NASA/Army project. Bell built the two experimental XV-15s, which have helicopter-like rotors that provide vertical lift for takeoff, then tilt forward to become propellers for cruise flight at speeds up to 350 miles per hour.

The success of the XV-15 led to a Department of Defense design and development program for a larger, more advanced tilt-rotor known as the V-22 Osprey, being built by Bell Helicopter Textron and Boeing Vertol Company. The three-agency study will center on the V-22, including the potential for other versions and sizes, both civil and military; the considerations of certifying tilt-rotors for civil operations; the impact of civil production on the defense industrial base; and identification of possible technology spinoffs. Targeted for first flight in 1988, the V-22 is expected to bring tilt-rotor technology closer to maturity and thereby reduce the investment risk involved in developing commercial versions. ▲



Earlier this year, Ames Research Center introduced to service the High Speed Processor-1, a Cray 2 system that is the fastest supercomputer yet designed. It represents the first major building block in the NASA-Ames Numerical Aerodynamic Simulation (NAS) program, an effort to develop the world's most powerful computational facility for aeronautical research and development.

Researchers have long employed computer design techniques in developing new aircraft, creating mathematical airplane models and "flying" them by computer simulation; this enables study of the performance and structural behavior of many different designs before settling on one configuration. In recent years, computational simulation has expanded enormously to embrace calculation and visual imagery (right) of many types of forces acting on airplane and engine components, including phenomena that cannot be realistically simulated in wind tunnels.

The NAS will be an evolutionary development; in 1989, when its extended operating capability has been attained, the facility will permit realization of a major goal in aeronautical science: the ability to simulate routinely the immeasurably complex three-dimensional airflow about a complete airplane. Such a capability will allow solution of many previously intractable problems and it will make possible performance of most of the calculations required to develop an advanced airplane with increased accuracy and reliability. Thus, NAS will not only improve the design process, providing cost savings and aircraft performance gains, it will also reduce the long and expensive wind tunnel and flight testing necessary to validate a design.

The key to attainment of the goal is far greater computer capability than has hitherto been available to NASA and industry. The High Speed Processor-1 can perform 250 million operations a second, more than three times faster than the previous generation of supercomputers. But even that extraordinary performance represents only one step toward the goal; NASA hopes to expand NAS in 1987 to a processing rate of *one billion* operations per second. In addition to its important advantages in aircraft design, NAS will further benefit U.S. science and industry as a national facility for research in other areas, such as non-aerospace structures, materials, weather and chemistry. ▲

The airplane pictured above, though more than a quarter century old, is extremely rugged and the ideal craft for an unusual flight research job: trying to get hit by lighting. Operated by Langley Research Center, it is an extensively instrumented and lightning-hardened F-106B that has recorded more than 650 lightning strikes on its surfaces.

The work of the F-106B and its pilots is part of NASA's Langley-conducted Storm Hazards Program, intended to improve the capability for detecting and avoiding severe storm hazards and to provide a knowledge base for protecting aircraft against hazards that cannot be avoided. Equipped with two movie cameras and other sensors, the F-106B serves as a laboratory for studying the electromagnetic characteristics of lightning strikes and improving knowledge of the susceptibility to lightning of various parts of the aircraft surface. This lightning physics research is important to the safety of tomorrow's aircraft. Current airplanes are protected by their aluminum skins, which are natural conductors; but future aircraft may have skins of less conductive composite materials and they will also have electronic controls potentially more sensitive to lightning damage than today's mechanical controls, so protective measures must be devised.

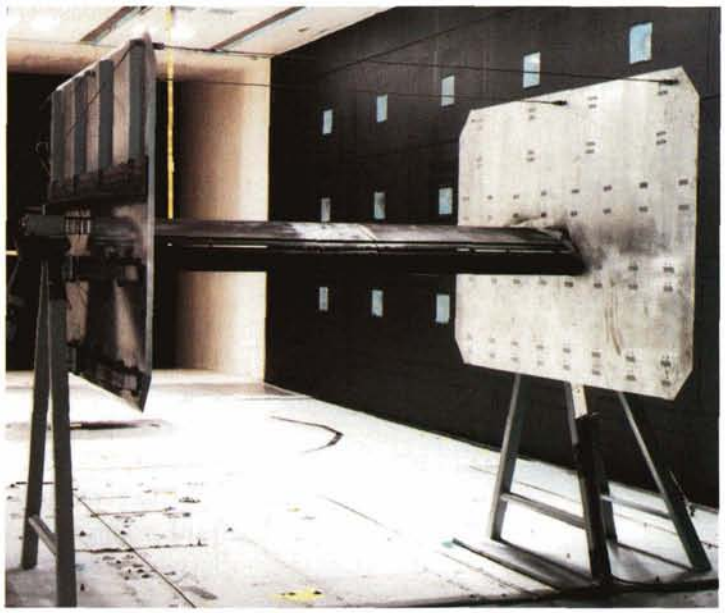
Another part of the Storm Hazards Program is research on heavy rain effect. Heavy rain can momentarily blur airfoil shapes, hence change the airflow and cause loss of airplane performance, possibly severe enough to affect safety. Investigations are conducted in the Langley facility shown below, a wind tunnel equipped with a

spray system that simulates moderate to extremely heavy rainfall on a wing model instrumented to record force, moment and pressure data. The aim is improved understanding of the mechanisms involved and predictability of rain-caused changes in airplane performance (right).

Flying a B-57B research airplane, Langley is acquiring detailed data on turbulence in severe environments, including tornadoes, funnel clouds and thunderstorm "outflows." Measurement of gust velocities in vertical, lateral and longitudinal components are made by "flow booms" (above) on either wingtip and on the nose of the B-57B. This information is important to aircraft structure design and to formulation of pilot training programs.

A related effort is research on wind shear, a sudden shift in wind velocity and direction often associated with severe storms. The "microburst," the most violent form of wind shear, has been identified as the probable cause of many aircraft accidents. NASA research is directed toward development of technology for advanced ground and airborne systems to detect wind shear and cockpit displays for warning and avoidance of the hazard.

In a separate program, Lewis Research Center is engaged in laboratory and flight investigations of icing on fixed-wing and rotary-wing aircraft. Icing can cause increased aircraft drag, reduced lift, stall, engine power loss and other hazards. Lewis' Icing Research Tunnel simulates natural icing conditions for tests of full-scale aircraft



components, ice protection systems and instrumentation for flight tests. The center also operates an instrumented research airplane to fly into icing conditions and study icing problems under natural, rather than simulated conditions. Researchers are seeking ways to prevent ice from forming, remove it after forming, or both. ▲

NASA's space science and applications program seeks greater knowledge of the universe and expanded Earth benefits through practical applications of space technology

Uranus, the seventh planet of the solar system, was discovered in 1781 by Sir William Herschel, a British musician, astronomer and telescope builder. Two hundred and five years later, the Voyager 2 interplanetary probe made the first spacecraft encounter with Uranus and provided scientists their first close view of the distant planet, some two billion miles from Earth.

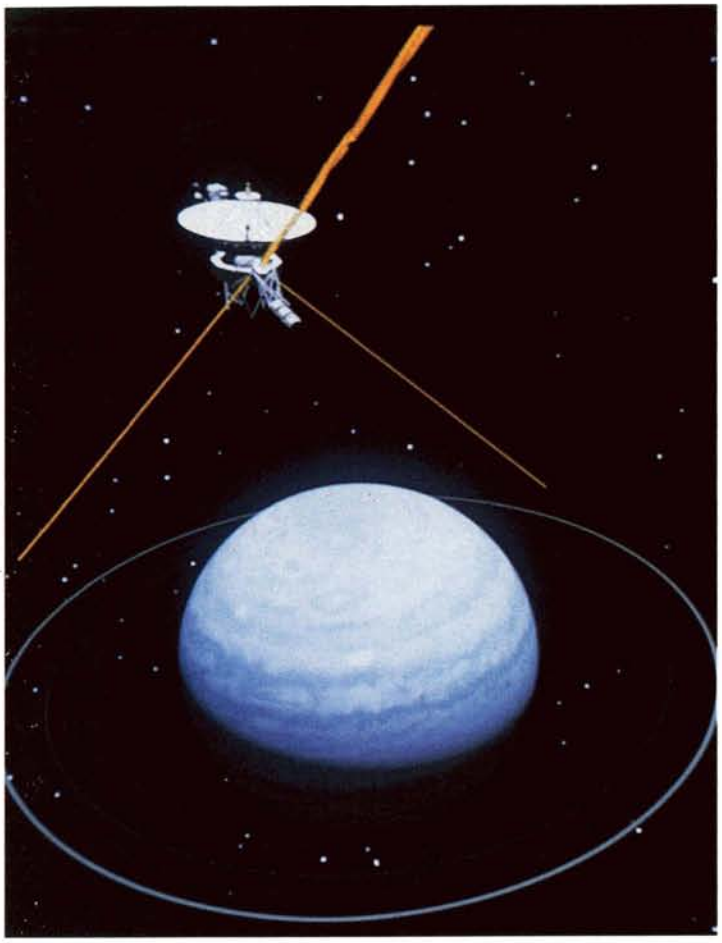
That great distance makes the planet's detail visible only to the most powerful Earth-based telescopes and then only dimly, so not much was known about Uranus, its moons and its rings, until the Voyager reconnaissance. Thus, science has learned far more about the Uranus system from the Voyager 2 encounter than was learned in all the prior years since the planet's discovery.

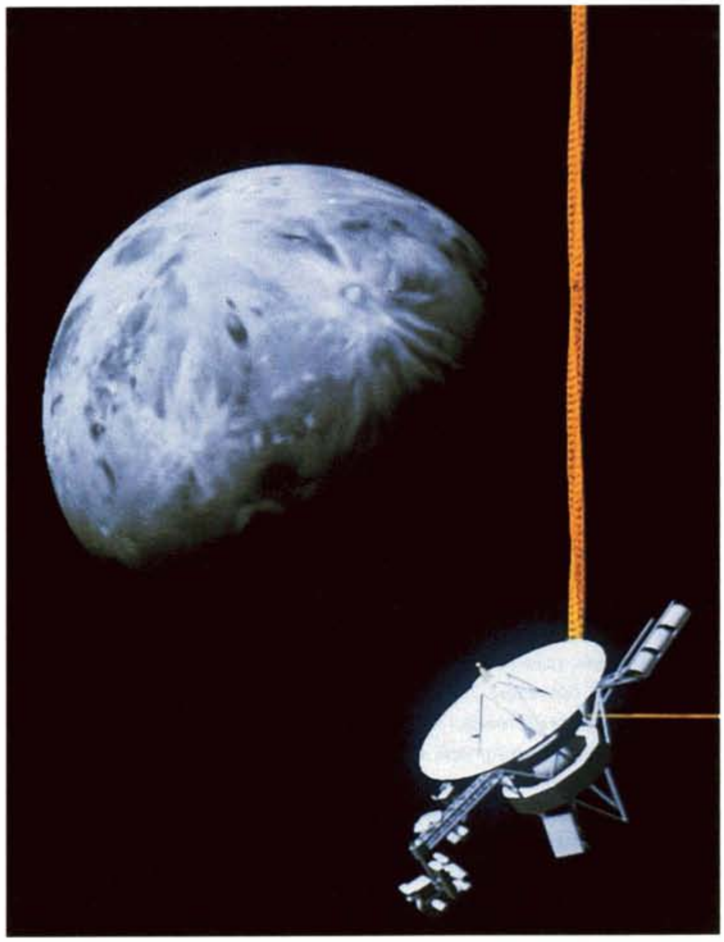
Voyager made its closest approach to Uranus—50,000 miles—on January 24, 1986. However, the Uranus encounter officially began on November 4, 1985 and continued for 113 days, through February 25, 1986. During that time, the spacecraft's 11 instruments sent to Earth volumes of data and thousands of images of incalculable scientific value.

Among Voyager's findings,

- In addition to the five known moons of Uranus, which range in size from 300 miles in diameter to more than 1,000, there are 10 others, small satellites averaging about 30 miles across.
- Never before seen in detail, the two largest Uranian moons—Oberon and Titania—have wide cracks in their surfaces and are crater-pocked like Earth's moon. Voyager 2 also confirmed earlier telescopic observations of ice on the moons.
- Unusual Miranda, innermost of the five large moons, has a crazy quilt surface made up of virtually all the geologic forms found elsewhere in the solar system, for example, high cliffs, cratered areas, rolling hills, grooved terrain, linear valleys and ridges, fault systems and varying surface reflectivity.
- Uranus has 10 rings, not nine as previously believed; the nine rings, incidentally, were not discovered until 1977.
- The planet has a surprisingly strong magnetic field and its magnetic poles are tilted sharply away from the axis of rotation. The degree of tilt—about 55 degrees—is unique in the solar system; in other planets, including Earth, the magnetic and rotational poles are separated by only a few degrees.
- Temperature readings indicated that the surface of Uranus is about 390 degrees below zero Fahrenheit.

Voyager 2's close flyby—at 45,000 miles per hour—lasted for six hours. Voyager then flew into a trajectory wherein Uranus' immense gravity was utilized as a "slingshot" to hurl the spacecraft toward Neptune, the eighth planet, 2.8 billion miles from Earth. Voyager 2 is scheduled to make a very close approach to Neptune—within 800 miles—on August 25, 1989. That will be the spacecraft's fourth planetary

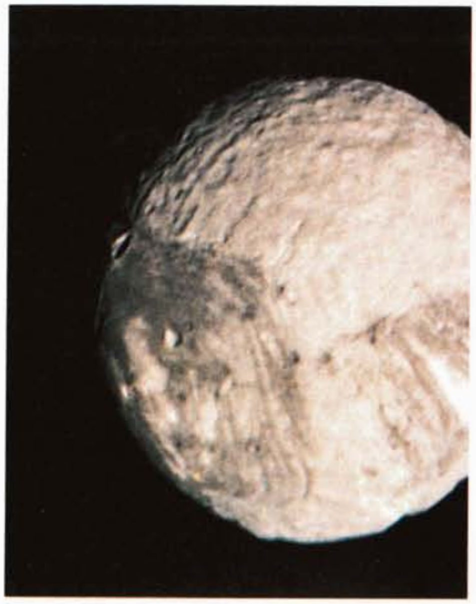


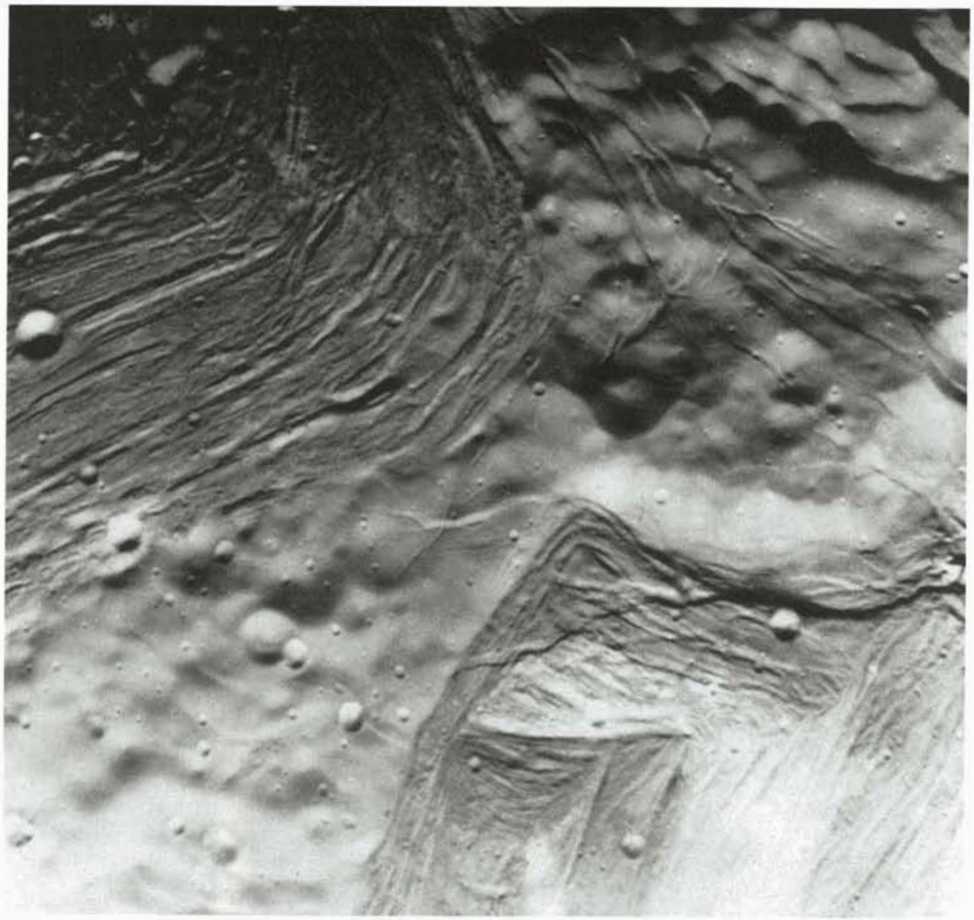


encounter over a 12-year span. Along with a companion craft—Voyager 1—it left Earth in 1977, flew past Jupiter (1979) and Saturn (1981) and returned some 70,000 images of those planets.

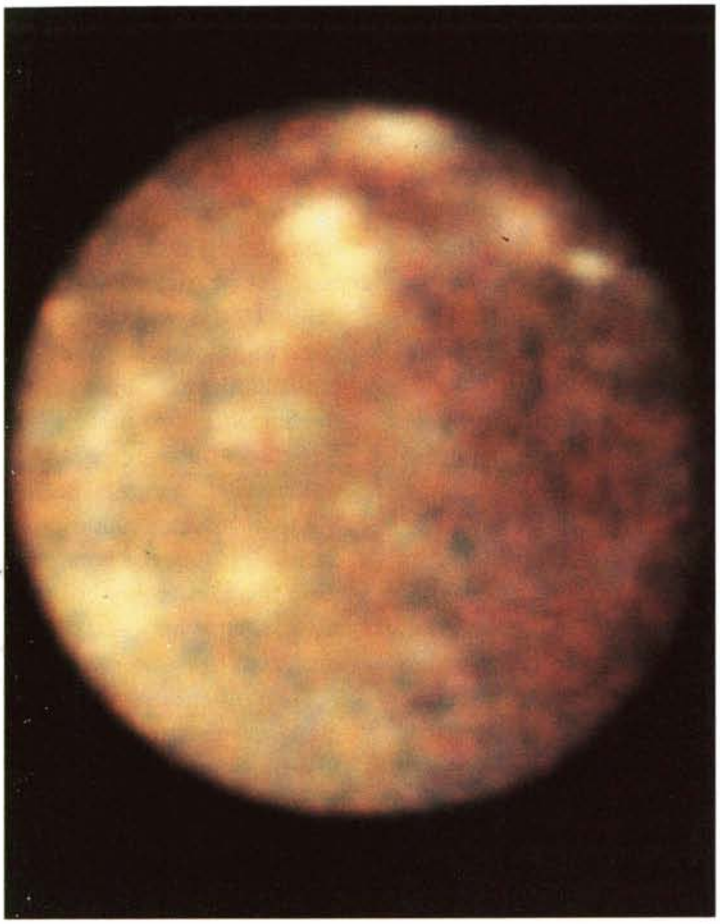
Managed by Jet Propulsion Laboratory, the Voyager project exemplifies one aspect of an area of NASA effort known as space science and applications. The space science program embraces four main avenues of research: solar system exploration, or investigation of the planets, moons, comets, asteroids and other phenomena in the solar system; astrophysics, the study of

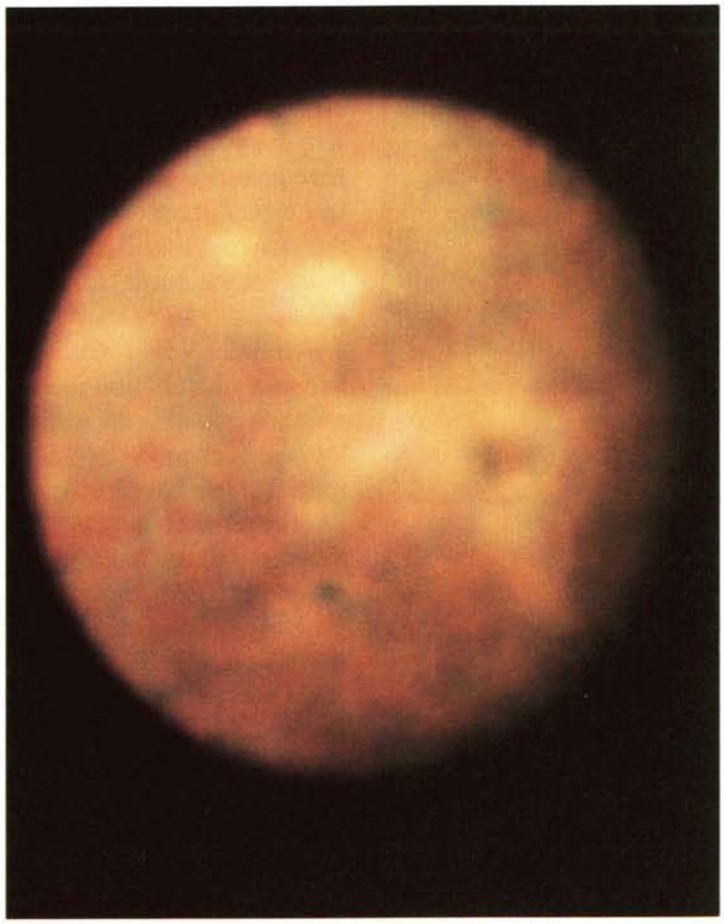
These computer-generated views show Voyager 2 on its historic encounter with the planet Uranus, never before visited by spacecraft and observed only dimly by Earth-based telescopes. At left, Voyager is 2½ hours away from its closest approach to Uranus; above, the spacecraft is flying past Miranda, innermost of Uranus' five major moons. On January 24, 1986, Voyager 2 flew within 50,000 miles of Uranus and 18,000 miles of Miranda.





The above is a color composite of the Uranian moon Miranda, taken by Voyager 2 from a distance of 91,000 miles. The picture was constructed from several images acquired by the narrow-angle camera's green, violet and ultraviolet filters. Smallest of Uranus' major satellites, Miranda is more potato-shaped than spherical and has an unusual surface made up of many different geologic forms. The upper right image is a clear-filter closeup of Miranda taken from 26,000 miles; it shows a variety of grooves, ridges and valleys. There are also many impact craters, the largest about 20 miles in diameter, some of the others ranging from three to six miles in diameter. Taken still closer to Miranda, at 22,000 miles, the lower image covers an area about 150 miles across. Two distinct terrain types are visible: the rugged, higher elevation terrain at right and a lower, striated terrain. The big crater in the lower part of the image is estimated at 15 miles in diameter.





distant stars and galaxies; solar terrestrial research, study of the Sun's energy processes and their interactions with Earth's environment; and life sciences research, aimed at understanding the origin and distribution of life in the universe and at utilizing the space medium to improve Earth knowledge of biology and medicine.

The related applications program involves use of space technology to generate direct public benefit on Earth. Examples include technology for the now-operational systems of communications, weather and Earth resources survey satellites, which NASA pioneered in the 1960s and 1970s. Among more recent examples are a space-based system designed to aid search and rescue operations and, in development, an orbital laboratory for monitoring the upper atmosphere and an ocean dynamics survey satellite of importance to maritime operations. ▲

These are Voyager 2 images of the two largest moons in the Uranus system, Titania at left and Oberon above, both about 1,000 miles in diameter. The Titania picture is a reconstruction of three frames taken when Voyager was about two million miles from the satellite; the Oberon view was made slightly closer, at 1.72 million miles. The surfaces of both moons show areas of lighter and darker material, probably associated with impact craters formed during long exposure to cosmic bombardment. The lack of strong color in both satellites is a distinctive characteristic of the moons and rings of Uranus.

In the scientific quest for understanding how the solar system began and how it evolved, spacecraft and telescopic studies of the planets have provided much important evolutionary data. But the planets, particularly the inner planets, have changed considerably since the solar system was formed some four and a half billion years ago. Scientists need a way of looking back to the beginning. Comets have become priority research targets because they are believed to contain materials relatively unchanged since the formative epoch, hence offer valuable clues to the earliest physical and chemical makeup of the solar system.

The first of a number of planned closeup cometary studies was accomplished on September 11, 1985, when NASA's International Cometary Explorer (ICE) intercepted Comet Giacobini-Zinner, a relatively small comet that makes a pass around the Sun every six and a half years. At a point 44 million miles from Earth, ICE flew through the comet's tail within 4,800 miles of the nucleus. Traveling at 45,000 miles per hour, ICE took 20 minutes to cross the tail, establishing tail width at 14,000 miles, about three times wider than anticipated. The spacecraft reported data without interruption during the encounter and emerged unscathed; scientists at Goddard Space Flight Center, which manages the ICE program, had feared that the spacecraft might be destroyed by a blizzard of high velocity dust particles in the comet's tail.

In its brief encounter, ICE provided a wealth of important data that scientists will be studying for years. Among initial findings, data revealed that no clear-cut bow shock accompanied the comet; the existence or lack of bow shock, a phenomenon like the bow wave that builds up in front of an aircraft approaching the speed of sound, had been a matter of conflicting conjecture among scientists. An unexpected finding was the detection—while ICE was still more than a day and some 1.4 million miles away from the nucleus—of electrical wave (plasma) disturbances coming from the comet; scientists had theorized that first detection might occur just a few hours before ICE reached Giacobini-Zinner.

ICE's instruments discovered ions—electrically charged particles—more than 1.1 million miles from the intercept point; it was believed that gas molecules escaping from Giacobini-Zinner's nucleus were ionized by solar ultraviolet light, then picked up and accelerated back toward the comet by the solar wind, a constant outpouring of magnetized, electrified gas from the Sun. ICE also made the first direct measurement of molecules in a comet, finding mainly water vapor ions and supporting the general view that comets are "dirty snowballs" composed of dust, rock and water ice.

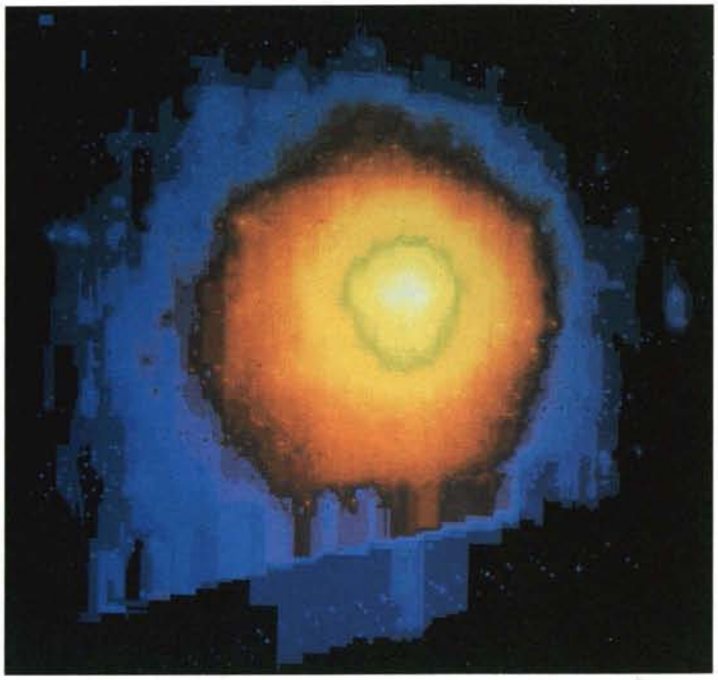
The comet interception climaxed a seven-year odyssey through space for ICE, which began life as the International Sun/Earth Explorer. Launched in 1978, the spacecraft spent four years acquiring data on solar phenomena, in particular the interaction between the solar wind and Earth. ICE was diverted to comet intercept duty at the suggestion of Goddard engineer Dr. Robert Farquhar. After thousands of computer simulations, Farquhar maneuvered ICE past the moon five times in 1983, using lunar gravity to give the spacecraft the additional thrust needed to send it into its interception trajectory. ▲

At right is a false-color ultraweight image of Comet Halley's 12½ million mile long coma, the cloud of gas surrounding the comet. This is a side view of the comet; the concentric colored areas show gradations in comet brightness, declining from the center outward. The image was made by NASA's Pioneer Venus Orbiter, whose ultraviolet telescope made 20,000 scans of the coma over a 72-hour period in February 1986, when the comet was near perihelion —its closest approach to the Sun—on its once-every-76-years swing around the Sun.

The image was part of a 10-week investigation of Comet Halley by Pioneer Venus from its position in orbit around the planet Venus; the spacecraft has been studying the cloud-covered planet since 1978. Pioneer Venus was converted to temporary comet-watching duty because of an important scientific opportunity: from its vantage point in Venus orbit, it was the only observatory able to study Halley at perihelion. The comet was on the opposite side of the Sun from Earth at perihelion, hence not visible to Earth-based telescopes or Earth-orbital spacecraft. The international fleet of four Halley close encounter spacecraft—two Soviet, one Japanese and one European Space Agency—flew through the comet's tail about a month after perihelion.

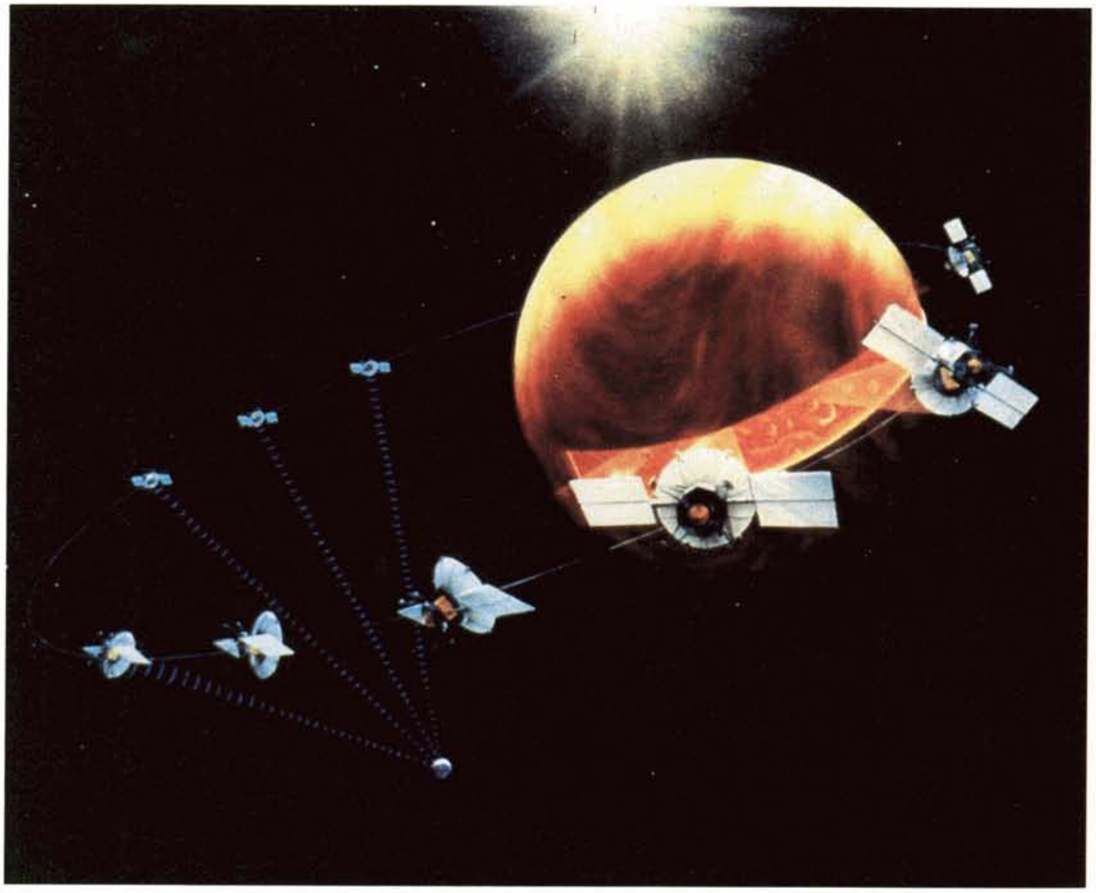
Pioneer's successfully accomplished assignment was to record, by means of its instruments, day-to-day changes in Comet Halley occasioned by mounting heat as the comet came closer to the Sun. In addition to the imagery, Pioneer provided data on water evaporation, jets and outbursts from the comet, the coma's composition and the velocities and lifetimes of atoms in the coma. The Pioneer program is managed by Jet Propulsion Laboratory.

Pioneer Venus was one of three veteran U.S. spacecraft, all launched years earlier for other scientific programs, participating in the concerted international investigation of Comet Halley. The others were the International Cometary Explorer (see opposite page), which provided data on solar wind and the comet's ion tail, and the Solar Maximum Mission satellite, which produced images of Halley and used



its ultraviolet spectrometer to analyze the comet's coma.

In addition to the flight activity, NASA played—and continues to play—a leading role in coordinating the flow of Halley information through the International Halley Watch (IHW). Jet Propulsion Laboratory is one of two lead centers in the IHW, serving the Western Hemisphere, Japan and Australia; the other center, serving Europe, Africa and the rest of Asia, is the Astronomical Institute of West Germany's University of Erlangen-Nurnberg. The 47-nation IHW embraces about 100 observatories around the world, 900 professional astronomers and more than 700 amateur astronomers. The organization made observations from Earth, analyzed data and monitored the operation of ground-based instruments plus the instruments aboard the international fleet of spacecraft, sounding rockets, aircraft and balloons. Halley data is now being collated and organized in preparation for its 1989 publication as a comprehensive archive for study by researchers until Halley makes its next appearance in 2061. ▲

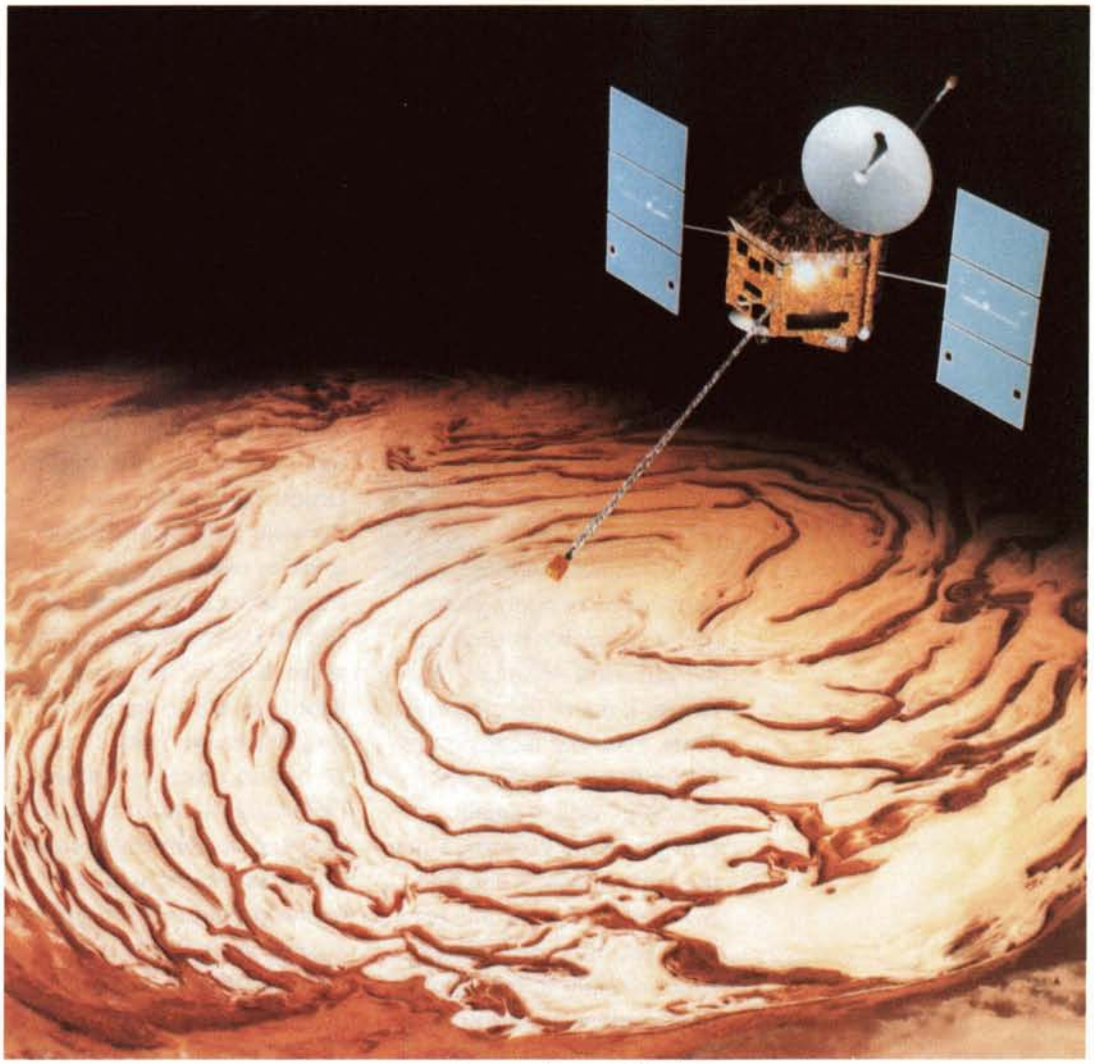


The planet Venus approximates Earth in age, size, mass, density and orbital distance from the Sun. Yet in many other respects—atmosphere, temperature, water content, for example—the two planets differ markedly. Scientists want to know why two similar planets evolved in such dissimilar fashion. The answers are important to the continuing scientific quest for knowledge of the origin and evolution of the solar system. There is, additionally, an underlying practical aspect of more immediate potential benefit: expanded knowledge of Venus may provide clues to greater understanding of the many factors that influence Earth's complex environment.

From Venus flyby missions, from instrumented probes that descended into the atmosphere and observations by the Pioneer Venus Orbiter (see page 25), scientists have acquired information on the planet's atmospheric composition, temperatures, pressures, wind forces and other elements of the Venusian environment. Pioneer Venus also provided the first real look at Venus' topography; its radar altimeter penetrated the planet's permanent cloud cover and measured 93 percent of the surface. Maps prepared from radar data show that about 60 percent of the surface is relatively flat, rolling plain and about one quarter of it is highland, with mountains taller than Everest.

Radar mapping by Pioneer Venus and by Soviet orbiters allows study of the planet from a new informational plateau, but much remains to be learned. The next step is amplification of Pioneer Venus' findings by a new planetary spacecraft named Magellan (left), for the 16th century Portuguese explorer.

The Magellan mission will map 100 percent of the surface, using an advanced instrument called a synthetic aperture radar; it will orbit the planet about once every three hours and dip as close as 150 miles above the surface. Magellan will map with resolutions about 10 times better than were obtained by prior Soviet missions. That will enable identification of such small scale features as volcanos, craters, lava flows, faults, erosion channels and possibly the remnant shorelines of long-ago oceans. Such information will help identify geological processes and establish a geological history of the neighbor planet. Planned for service about the end of this decade, Magellan is managed by Jet Propulsion Laboratory. ▲



Mars, the fourth planet of the solar system, is closely linked to Earth by its volcanic and erosional characteristics and by the fact that, like Earth, it experiences climatic changes. It is the outermost member of the triad of Earthlike planets—Venus, Earth, Mars. Although seemingly very different, the members of the triad exhibit a number of common features. They are the subjects of a continuing program of detailed comparison studies intended to advance understanding of the evolution of the inner solar system and thereby increase knowledge of Earth's own evolution.

Along with the Magellan mission to Venus (see opposite page), the next step in exploration of the triad is a long term investigation of Mars designed to expand the knowledge of the Red Planet acquired by Earth observatories and earlier spacecraft missions. Designated Mars Observer, the mission will be the first of a series of Observer flights to the planets and small bodies of the solar system. To minimize costs, these missions will employ a common basic spacecraft, an adaptation of an existing, proven type of Earth-orbital satellite that can be customized to each Observer mission's requirements.

The Mars Observer will utilize a number of advanced instruments to determine—on a global basis—the elemental and mineralogical character of the planet's surface and to establish the nature and chronology of the surface forming processes that have occurred over millenia. Additionally, the Observer's instruments will investigate the Martian climate, present and past. Managed by Jet Propulsion Laboratory, the Mars Observer is targeted for service in the early 1990s. ▲

Earth's veil of atmosphere filters out or blurs most of the radiation coming from distant parts of the universe. Thus, even the most powerful Earth-based telescopes can "see" only a small portion of the cosmos. Since the early 1960s, NASA has flown a number of increasingly sophisticated observatories designed to surmount the problem of atmospheric distortion by operating *above* the atmosphere. A giant step in this continuing program is the Hubble Space Telescope, potentially the most dramatic single advance in astronomy since the invention of the telescope in 1610.

The Hubble Space Telescope is more than a spacecraft; it is a major long duration astronomy facility intended to operate well into the 21st century with periodic on-orbit servicing and provide astronomers a view of the universe 10-30 times greater than current capability. Viewing in both visible and ultraviolet light, it will be able to peer much farther into space, detect objects 50 times fainter and return images with 10-20 times better clarity than the largest Earth telescopes. Because light from distant galaxies takes so long to reach us, scientists will literally be looking back in time as far as 14 billion years. Estimates of the age of the universe range from 12 to 20 billion years—so, when observing the most distant celestial objects, the Hubble Space Telescope will be capturing light that began its cosmic journey when the universe was in its infancy. This extraordinary capability should provide immensely important clues to the origin and history of the universe.

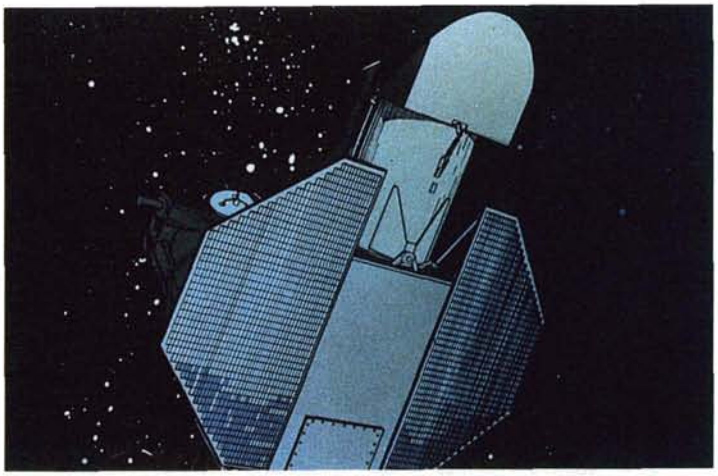
The largest scientific payload ever built, the 12½ ton 43-foot telescope was developed by Lockheed Missiles & Space Company, Sunnyvale, California, spacecraft prime contractor, and Perkin-Elmer Corporation, Danbury, Connecticut, prime contractor for the optical telescope assembly. The European Space Agency furnished the power-generating solar array and one of the five major instruments. The system has been completed and it awaits launch assignment.

Marshall Space Flight Center manages the project. Goddard Space Flight Center led scientific instrument development and will be responsible—when the observatory is in orbit—for controlling the telescope and processing the images and instrument data it returns. Goddard will forward the processed data by land line to the Space Telescope Science Institute, located 30 miles away in Baltimore, Maryland. There astronomers will view the images and get visual and printed readouts of the data flowing from the Hubble observatory's instrument module. The Space Telescope Science Institute is operated for NASA by the 17-member Association of Universities for Research in Astronomy. ▲

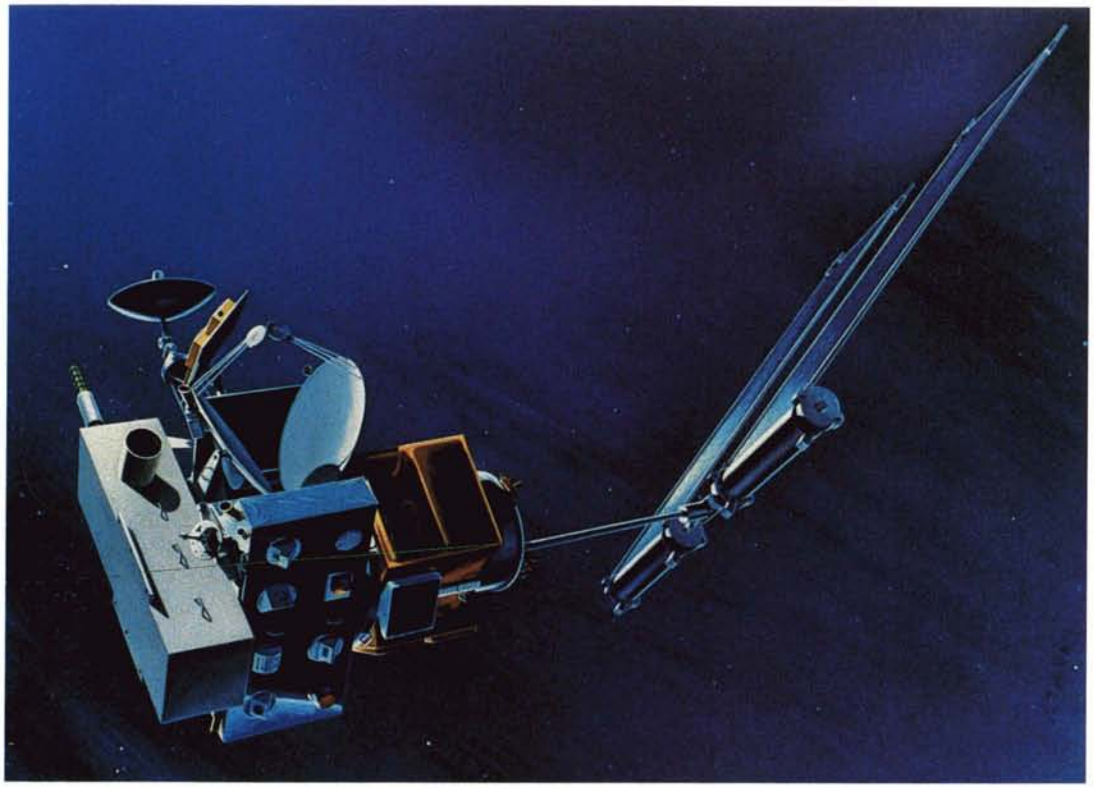
A comprehensive space astronomy program requires observations of the universe not only in visible light but in other forms of radiation that are largely or totally invisible to ground observatories—x-rays, ultraviolet and infrared, for example—because each of these areas of the electromagnetic spectrum offers a different set of clues to the origin and evolution of the universe. One area of investigation that has been particularly productive of valuable information is study of x-ray emissions from celestial objects.

Since the 1960s, NASA has operated a series of orbital x-ray systems that have provided a broad knowledge base about nonvisible emanations from stars, pulsars and galaxies. The knowledge base will be considerably expanded by an advanced observatory planned for service in this decade. Being developed jointly by NASA and the West German Federal Ministry for Research and Technology, it is called ROSAT, for Roentgensatellit (upper right); West Germany is building the spacecraft and x-ray telescope, NASA is providing a high resolution imaging system. ROSAT will conduct a sweeping survey of x-ray sources and make dedicated observations of specific sources for long periods of time, allowing astronomers to study in greater detail many of the phenomena discovered by earlier x-ray satellites. Goddard Space Flight Center and the German Aerospace Research Establishment are the managing organizations for the U.S. and German portions of the program.

For service in the 1990s, NASA is planning the Advanced X-ray Astrophysics Facility (AXAF), a 10-ton observatory intended to operate at least 15 years with on-orbit servicing. AXAF (lower right) will have instruments 100 times more sensitive than those aboard the second High Energy Astronomy Observatory (HEAO-2); launched in 1978, HEAO-2 provided the broadest data yet acquired on x-ray sources. AXAF's instruments will collect data on the entire range of objects known to astronomy, including stars, quasars, galaxies, clusters of galaxies and intergalactic space. An important objective will be imaging and measuring the iron produced and expelled by galaxies, because the amounts of iron detected will tell much about the early history and star formation processes in the galaxies observed.



Managed by Marshall Space Flight Center, AXAF is considered as important an advance in x-ray astronomy as the Hubble Space Telescope (see opposite page) will be in optical astronomy. The two will be operating in the same time frame, along with the Gamma Ray Observatory, in development for launch late in this decade, and the projected Space Infrared Telescope Facility. This family of orbiting telescopes, known as the Great Observatories, will provide the capability for simultaneous observations of cosmic sources at visible, ultraviolet, infrared, x-ray and gamma ray wavelengths. ▲



Since the start of the space program, NASA has devoted a good part of its space science effort to study of Earth and its environment, including such broad areas of investigation as the transfer of solar energy to Earth's land, oceans and atmosphere; studies of the oceans; and examination of the processes that take place in Earth's atmosphere. In the latter area, space-acquired data has produced an enormous volume of scientific knowledge about the various regions of the atmosphere, but all this effort has served to underline that there is still a great deal to be learned about the extraordinarily complex near-Earth environment.

Among a number of NASA environmental programs in being or planned is the Upper Atmosphere Research Satellite (UARS), which is at the same time a scientific satellite for advanced study of the upper atmosphere's physical and chemical processes, and an application system intended to provide direct Earth benefit through greater understanding of weather, climate and the atmospheric effects of man-made pollutants. Formal development of UARS began in 1985 with the award of a contract to General Electric Company's Valley Forge (Pennsylvania) Space Center for development and construction of the observatory. Goddard Space Flight Center has project management responsibility.

Scheduled to enter service in 1990, UARS will operate in a 373-mile circular orbit, well above the air drag level, so that it will be able to report continuously for several years. It will carry a complement of 10 remote sensing instruments that will provide—for the first time—essentially global data about the composition and dynamics of the upper atmosphere. The area of study embraces the stratosphere, mesophere and the thermosphere, regions of the atmosphere extending from about six miles altitude to an indefinite boundary in near-Earth space.

Among the major objectives are understanding of the mechanisms that control the structure and variability of the upper atmosphere and the role of the upper atmosphere in climate and climatic changes. In addition, UARS will explore how the upper atmosphere responds to natural and human-related perturbations. The observatory is expected to provide previously unavailable insight as to whether man's industrial and technological activities adversely influence the layer of ozone that protects Earth from the potentially harmful ultraviolet rays of the Sun, and how the stratosphere reacts to such natural particle injections as those caused by volcanic eruptions. ▲

In 1978, NASA launched and operated for three months a satellite called Seasat, a brief but highly successful experiment in collecting ocean surface data using microwave remote sensing techniques. Seasat was a companion project to the Landsat Earth resources survey satellites developed by NASA and operated continuously since 1972, initially by NASA, later by the National Oceanic and Atmospheric Administration (NOAA) and, beginning last year, by the commercial Earth Observation Satellite Company (EOSAT), a joint venture of Hughes Aircraft Company and RCA Corporation. EOSAT has assumed responsibility for further U.S. development of land observation satellites. NASA, accordingly, is placing renewed emphasis on systems for monitoring the oceans from space, for scientific study and for practical benefit in such areas as weather and climate prediction, coastal storm warning, maritime safety, waste disposal, ship design, ship routing and food production from ocean sources.

Shown in the accompanying illustration is a planned ocean observation satellite known as TOPEX, for Ocean Topography Experiment. Intended for service in the early 1990s, the radar altimeter on TOPEX is a much more advanced successor to the one that flew on Seasat. It is designed to make highly accurate measurements of sea surface elevations over entire ocean basins for several years. Integrated with subsurface measurements, this information will be used in models to determine ocean circulation and its variability. Reporting continuously on such changing factors as wave heights, surface wind speed, current and tide patterns, TOPEX will provide improved knowledge of ocean dynamics for scientific studies and will establish an information base for practical applications.

In a related project, NASA is participating—in cooperation with the Navy, Air Force and NOAA—in the Navy Remote Ocean Sensing System (NROSS) program, planned for initial service in 1990. NROSS will provide oceanographic measurements on a continuous, near-real-time, all-weather, global basis for fleet operation requirements and for fundamental research. NASA's contribution to NROSS involves development of a key component of the satellite system called a "scatterometer," a microwave radar that enables calculation of wind speeds and directions by measurement of reflections from the waves on the ocean surface. NASA pioneered that technique with the Seasat scatterometer and is using the Seasat technology as a base for developing the more advanced NROSS scatterometer, called NSCAT. NSCAT data will provide a basis for research studies of waves, ocean circulation, and the interaction between the oceans and the atmosphere. Together with surface elevation data from TOPEX, oceanographers will have a first-ever view of the oceans' primary driving force (winds) and their response (surface elevations) to that force. This will permit a fundamental breakthrough in man's understanding of how the oceans work as a dynamic system and the oceans' role in climate and climatic variability. ▲

Recommendations of the National Commission on Space offer an exciting glimpse of the next half century in space

Human settlements on Earth's moon and on Mars, robot-manned extraterrestrial prospecting, mining and manufacturing, a network of orbiting spaceports serving as way stations for routine travel in the inner solar system—these are a few of the prospects for the 21st century, according to a report by the National Commission on Space. It sounds like science fiction but it is actually a matter-of-fact statement prepared by a group of highly respected space experts, including a former NASA administrator, government and industry scientists and engineers, past and current astronauts. Entitled *Pioneering the Space Frontier, Our Next Fifty Years in Space*, the report—released in May 1986—recommends a series of exciting space goals for 21st century America and offers a step-by-step program for their attainment.

The commission's scenario begins with the assumption that the U.S./international manned Space Station will be initially operational by 1994 and goes on from there. A first requisite, to be accomplished within the next 15 years, is cheaper transportation to space of both cargo and people, the report says. "It is especially important that the cost be dramatically reduced for free enterprise to flourish with commercialization of space operations. The commission is confident that the cost of transportation can and should be reduced below $200 per pound (1986 dollars) by the year 2000." The $200 figure represents a small fraction of current cost.

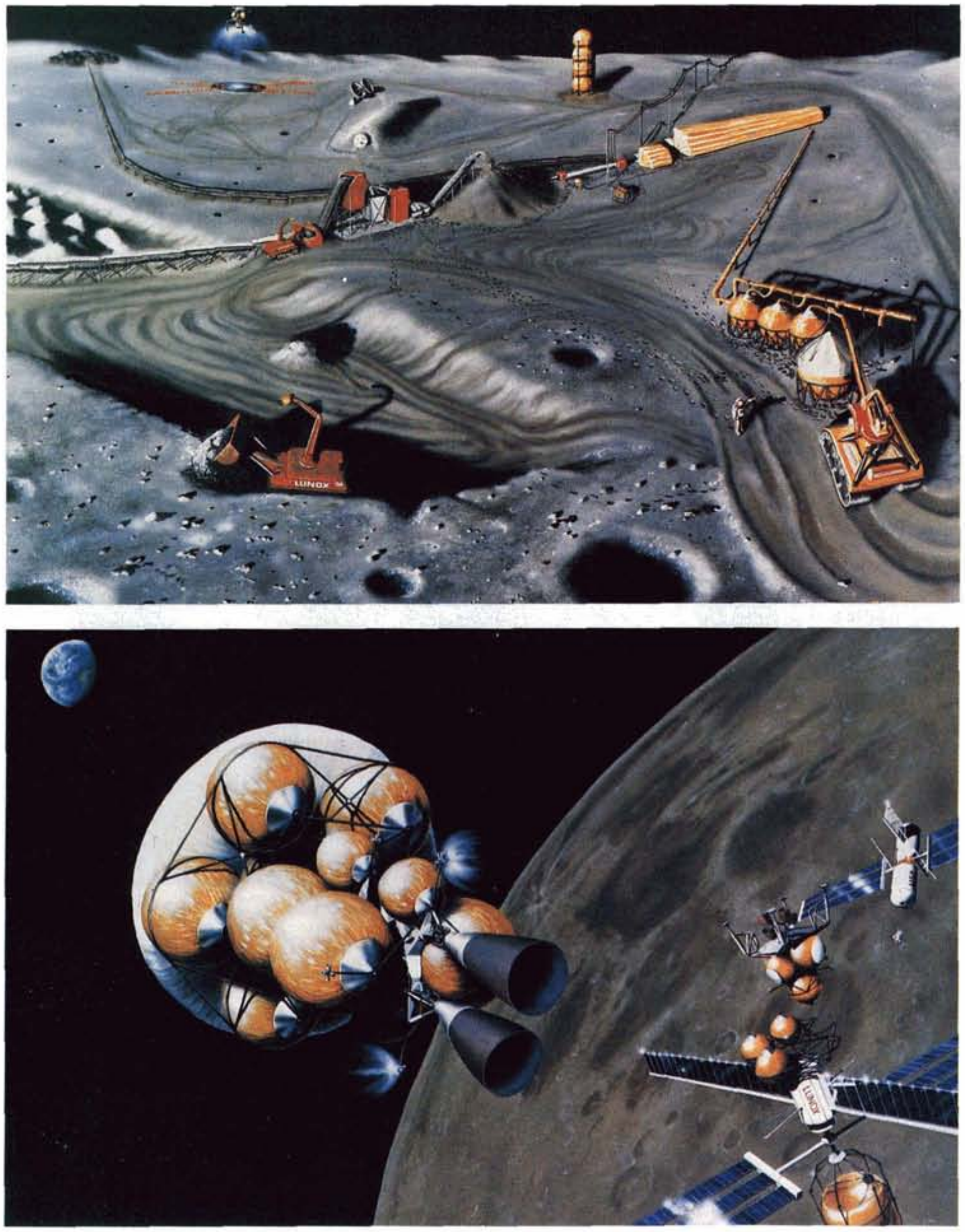
The first steps on what the commission calls the "Highway to Space" are a low cost Earth-to-orbit cargo vehicle and a companion passenger craft, to be flight ready around the turn of the century. Among other foreseeable vehicle developments are an electric propulsion cargo ship for transfer to destinations beyond Earth orbit, to be flying early in the 21st century; a manned Mars exploration spacecraft, about 2010; and, after 2015, large nuclear powered spaceships capable of delivering great amounts of cargo and, presumably, people, because the report predicts vast expansion of space travel and commercial development.

The commission sees the Space Station expanding around the year 2000 to an "initial spaceport," meaning a growth version including laboratory, factory, servicing facilities and a supply depot. Continuing growth would produce, around 2010, an even larger, more mission-capable "full spaceport" in Earth orbit.

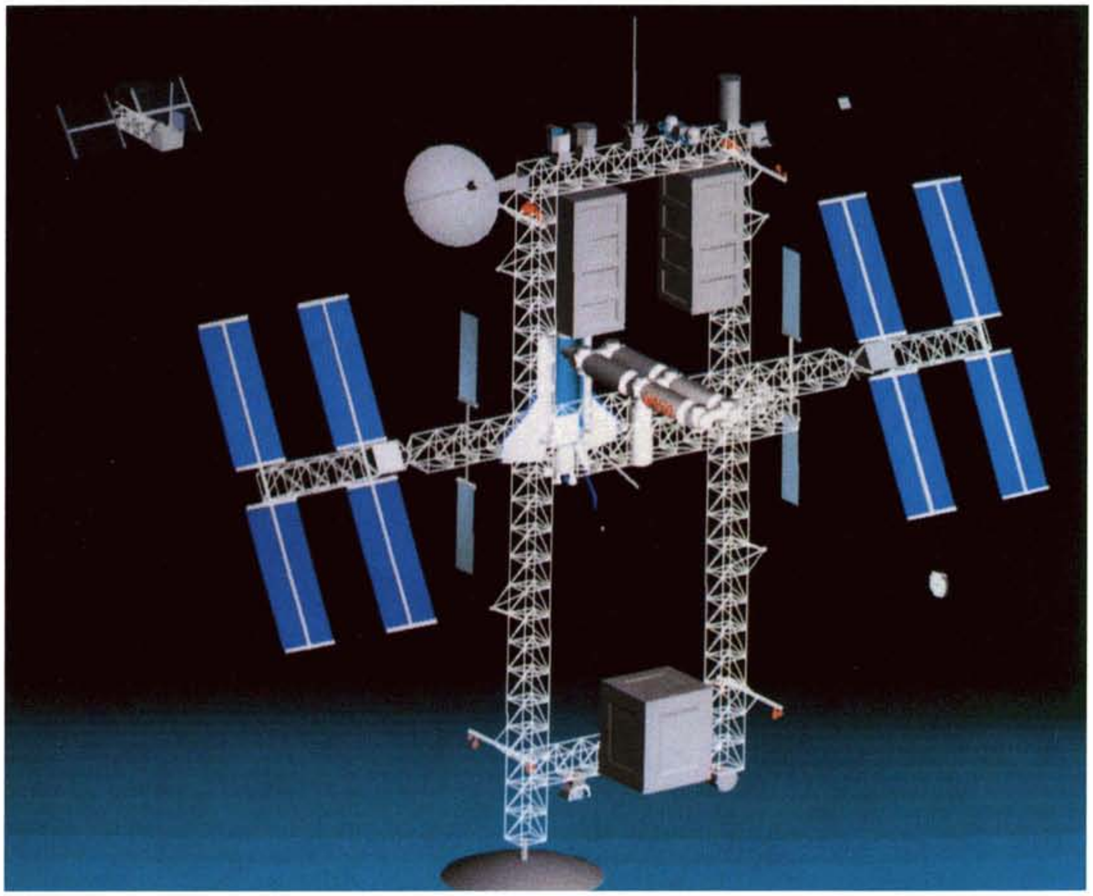
The "Bridge Between Worlds," a phased expansion of operations in the inner solar system, would begin modestly with an unmanned lunar sample return mission in the late 1990s to assay lunar mining possibilities. That would be followed by establishment of a manned lunar outpost, a scientific/prospecting base, around 2005. The base would grow, in a few years, into a pilot plant producing rocket propellant from moon materials and, about 2020, a full-scale lunar manufacturing facility. During this time frame, there would be expanded study of accessible asteroids, followed by unmanned prospecting missions to selected asteroids and, finally, robotic mining of asteroids for mineral and other resources.

Development of bases beyond Earth would include construction of a full lunar spaceport around 2012; a station between Earth and lunar orbit, some time about 2015; and finally, between 2020-25, a Mars spaceport. Habitation of Mars would precede the full spaceport, beginning with a robot-operated facility about 2012, a manned outpost in 2015, followed by a gradually expanding settlement that would reach "full base" status before 2030. The ultimate goal within the 50-year span is permanent settlements on the moon and on Mars that would use local resources for human-supervised robotic fabrication of products to sustain the activities of the settlements and the network of spaceports.

It all sounds "far out" but 50 years in an era of snowballing technology advancement is a long time. The commission is not offering fanciful notions of what *might* happen in space but what *should* occur over the next 50 years. The report sums the potential in succinct manner: "Technically challenging but feasible." ▲



This artist's conception shows a 21st century lunar operation in which crews are mining ilmenite,a moonsoil component from which oxygen can be produced to support the lunar base and other facilities in space. Ferry vehicles, such as the one in the lower illustration, would link the moon base with other spaceports in the inner solar system.



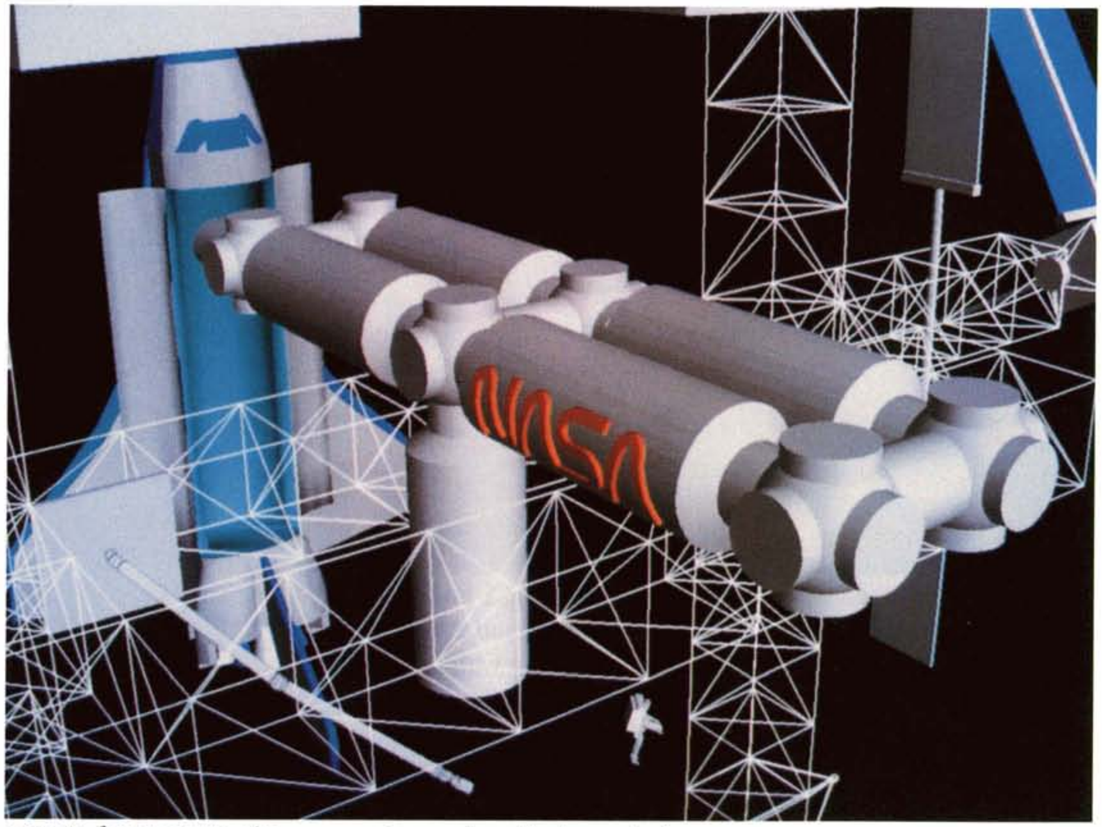
Shown above is a computer-generated representation of a new NASA reference configuration for the permanent multipurpose Space Station being developed for initial occupancy in the mid-1990s. The new "dual keel" design features two vertical keels, or latticework beams (center photo), each the length of a football field, joined at top and bottom by connecting beams to form a rectangular structure. The two keels are crossed near midsection by a single large horizontal beam that supports the solar cell arrays and radiators.

Intended to increase the structural area, the dual keel configuration is a refinement of an earlier "power tower" design. The change stemmed from a study of user requirements, including the types of payloads and station growth that must be accommodated well into the 21st century. It was felt that a larger structure with greater stiffness would be needed for mounting more station systems and experiments. The rectangular structure and the larger latticework beams—now more than 16 feet wide—provided the requisite stiffness and the 361-foot-long vertical keels, plus their connecting beams, substantially increased the area available for exterior mounting of payloads and equipment.

At right is a closeup view of the station's pressurized modules, which are arranged in a raft pattern and connected by a series of external airlocks and tunnels. The design refinement moved the modules closer to the station's center of mass, the most advantageous spot for conducting experiments that require a microgravity environment. The effective volume of the modules has been substantially increased, first by extending their length 9.5 feet and second by taking the airlocks out of the module itself and putting them outside, increasing the usable interior area. Modules are now 44.5 feet long and approximately 13.8 feet in diameter, about the size of a large bus.

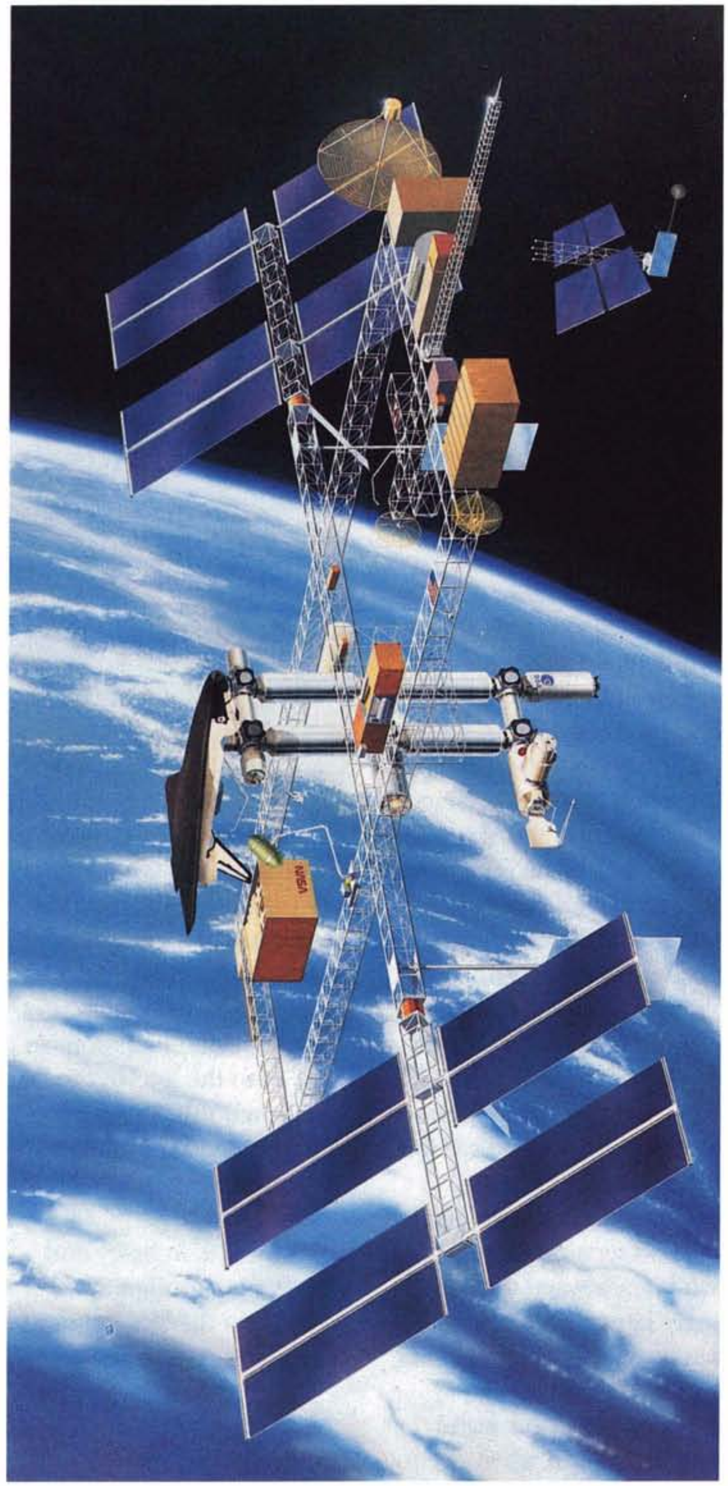
Operating in low Earth orbit at an altitude of about

300 miles, the Space Station will serve as a laboratory for basic research, a "look up" observatory for astronomy/ astrophysics and a "look down" observatory for Earth studies, a plant for manufacture of many important products not producible on Earth and a facility for such Earth applications as communications, weather observation and remote sensing. In all these areas, man's presence will afford an extra measure of capability for observations where human judgment and skill are important, for example, in instrument selection and adjustment, in managing the data required by the instruments and in overall system operation and maintenance.



Additionally, the Space Station will be an operations base, allowing continuous rather than intermittent operations in orbit, thereby significantly increasing the amount of useful work that can be performed. It will be an assembly center for structures too large to be carried in the Shuttle Orbiter's cargo bay; a depot for servicing and repairing free-flying satellites; a warehouse for spare parts or replacement satellites; a base for vehicles capable of delivering payloads to higher orbit and returning them when necessary. In future years, the Space Station can become a departure point—like the base camp of a mountain climb—for such activities as building a permanent moon station, manned missions to Mars or to the asteroids, and unmanned missions for collecting and returning to Earth samples from the distant planets.

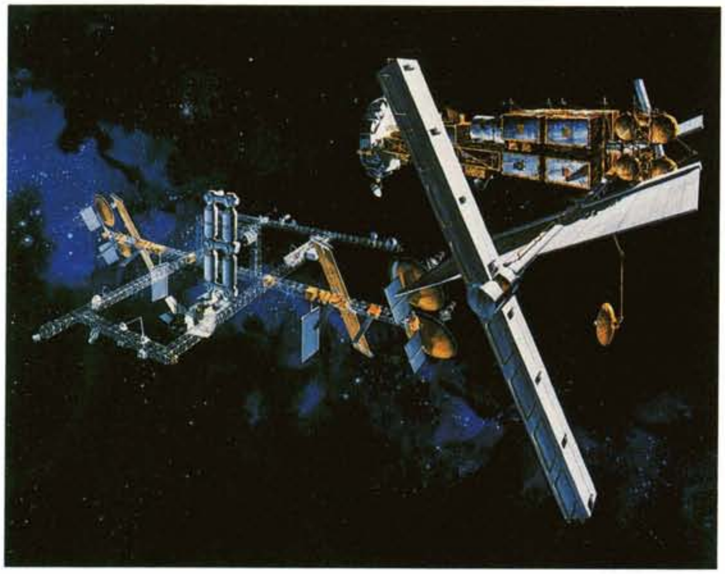
NASA, U.S. industry and cooperating foreign nations are now in the late stages of a 21-month Phase B definition and preliminary design study, during which designers will identify and evaluate alternative systems, components and philosophies to arrive at a Space Station configuration that best meets the needs of potential users, is cost-effective in operation and maintenance, and is flexible in terms of eventual growth in size and capability. Phase B is scheduled for completion next January and hardware contracts will be awarded later in 1987. Plans call for assembly of the Space Station in orbit during 1993-96. ▲



In keeping with NASA's long term policy of promoting cooperation with other nations in space projects, the Space Station is an international endeavor. NASA has signed agreements with the European Space Agency (ESA), Canada and Japan that provide a framework for cooperation during the current Phase B definition and preliminary design activity.

ESA is contemplating two types of unmanned platforms and a pressurized module that could be used as a laboratory portion of the Space Station proper with facilities for materials processing and life sciences experimentation. Above is a full-scale mockup of the ESA module, named *Columbus*, at the Aeritalia plant in Rome, Italy.

Japan is studying a multipurpose research and development laboratory with a pressurized segment and an exposed workdeck fitted with a remote manipulator. Canada is focusing its study effort on a Mobile Servicing Center that builds upon Canada's experience in developing the Space Shuttle Orbiter's robot manipulator arm. The illustration at right, a Johnson Space Center concept, shows the international elements in place; in addition to the U.S.-built central modules, there is the *Columbus* module (center right) with the ESA insignia and, also at center right, the

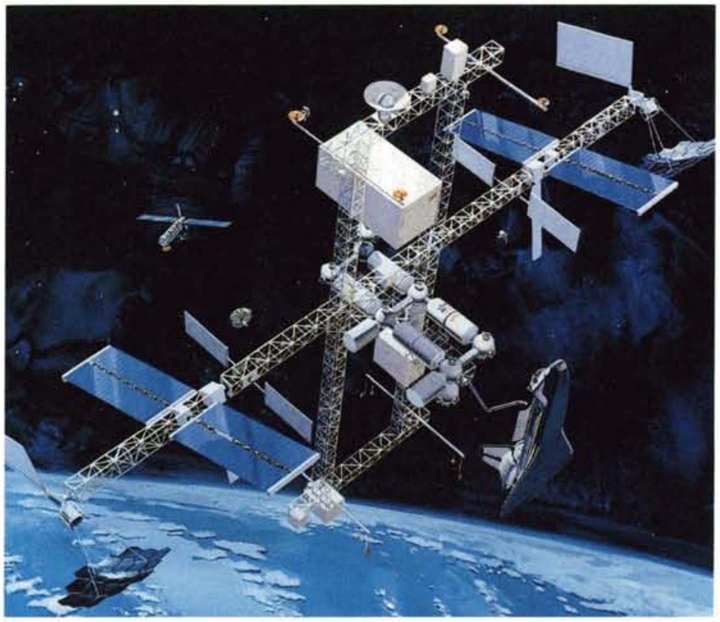


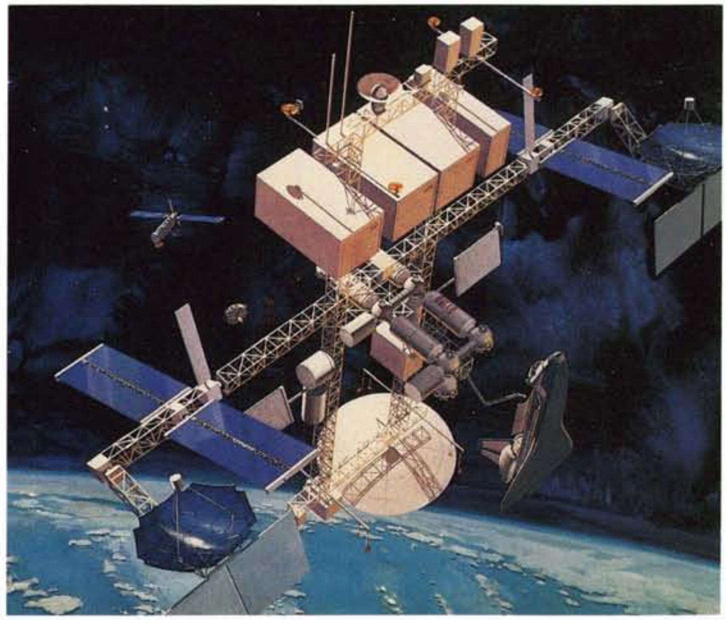
Japanese module with the Rising Sun emblem. On the underside of the top boom is the Space Station Remote Manipulator System, an element of Canada's Mobile Servicing Center.

In the above concept provided by TRW, Inc., an Orbital Maneuvering Vehicle is tugging an unmanned space platform toward the manned base; the solar array that generates power for the platform in normal operation is folded during towing. The Space Station plan contemplates a number of free-flying platforms carrying instruments and experiments for scientific, technological and product research.

One of them will operate in the same orbit as the main base, an orbit inclined 28.5 degrees to Earth's equator, but it will be some distance removed to avoid disturbance or contamination from main station activities. For routine inspection and maintenance, the co-orbiting platform can be visited by astronauts equipped with Manned Maneuvering Units; when payload changeout is necessary, the platform is brought to the main station as pictured. This process of tending, servicing and repairing unmanned platforms and other satellites in compatible orbits increases the lifetimes of expensive assets and allows periodic upgrading of such space systems as technology advances. There will be other unmanned platforms in high inclination or polar orbits; they will be launched and serviced by the Space Shuttle.

A Marshall Space Flight Center concept (above) illustrates another Space Station capability: orbital assembly of structures too large to be delivered in one piece by the Shuttle, future systems such as unmanned platforms, telescopes or large antennas. At the bottom of the illustration, two astronauts wearing Manned Maneuvering Units are completing assembly of a very large antenna that may become part of the Space Station or may be deposited in orbit as a free-flyer. ▲



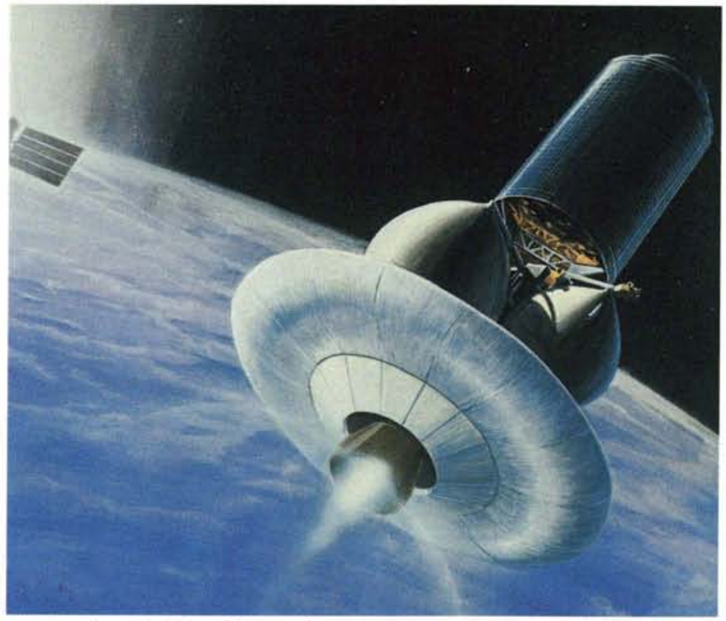


The above concept shows the power generating system planned for the Space Station, a hybrid that combines the familiar photovoltaic solar arrays, which convert sunlight directly into electricity, with a new thermal dynamic heat engine. In the latter system, the large dishes at either end of the central boom contain a number of hexagonal mirrors that collect solar heat, which is used to drive an electricity-generating turbine. The combined system will produce 75 kilowatts of electricity. The hybrid design was adopted because the heat engine is a more efficient way of generating power and the use of solar panels alone would have required an enormous array, increasing drag and necessitating more frequent adjustment of the Space Station's orbital position.

The Rockwell International concept at left center depicts a growth version that goes well beyond the Initial Orbiting Capability. This advanced station includes, among other equipment, a number of large enclosed bays (above the core of pressurized modules), which are servicing garages for repair of satellites in an enclosed environment and hangars for two types of vehicles planned for use with the Space Station. One is the Orbital Maneuvering Vehicle (OMV) shown approaching its hangar at left center in the illustration.

At center right is a close-up artist's rendering of an OMV as seen by Martin Marietta Denver Aerospace, one of three manufacturers competing for a contract to build the vehicle; the others are TRW Inc. and LTV Aerospace and Defense.

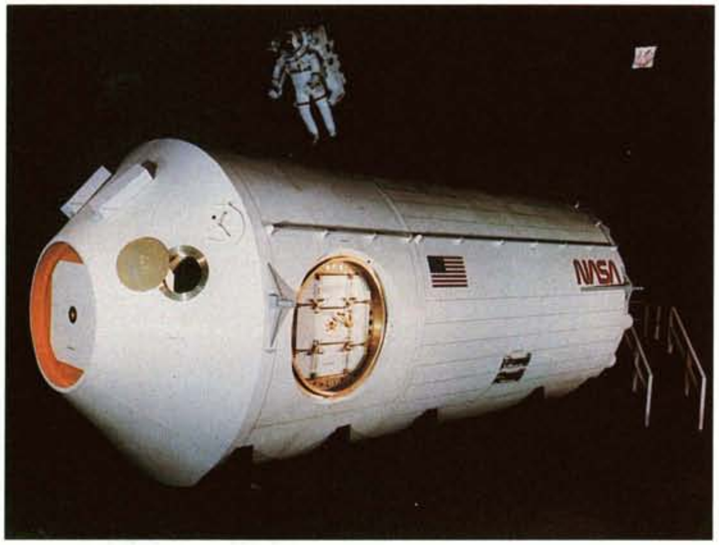
The OMV is a reusable, free-flying spacecraft operated by remote control after deployment from the Space Shuttle or the Space Station. A "smart tug" capable of moving satellites and other objects from one orbit to another, the OMV is a versatile spacecraft that can be configured—by use of modification kits—to perform as many as 17 different missions. For delivery of payloads, for example, it can propel a satellite as far as 1,200 miles from the Space Station or it can extend the Shuttle's reach by that distance. When mated with a modular "servicer," the OMV can provide routine or contingency on-orbit servicing, maintenance or payload changeout. It will also be a useful system for construction of large space structures, including the Space Station. First flight is planned for 1991; Marshall Space Flight Center is OMV project manager.

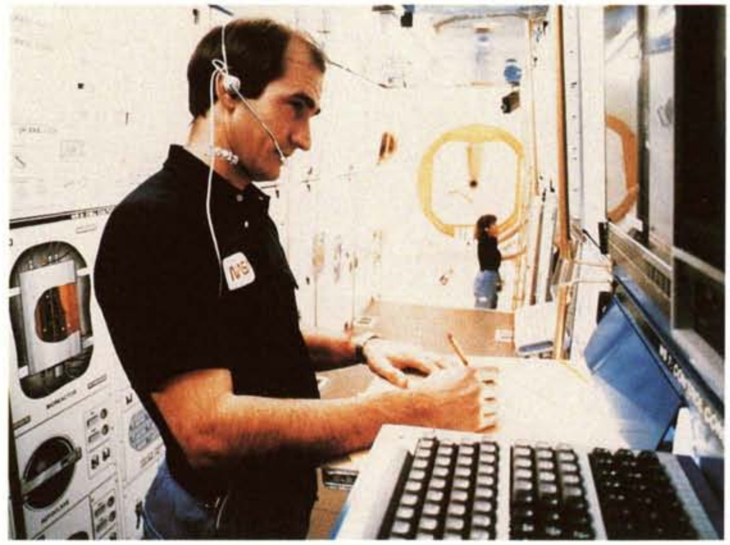


At far right is a Martin Marietta Denver Aerospace concept of an Orbital Transfer Vehicle (OTV) that would be used to transfer payloads between low and high Earth orbit, particularly geosynchronous orbit (22,3000 miles), where spacecraft are figuratively stationary with respect to a point on Earth. In Shuttle operations, such transfer is now a two-step process; the payload is deployed from the Shuttle Orbiter in low Earth orbit, then boosted to the higher altitude by an upper stage propulsion unit. Existing upper stages are not reusable, nor can they retrieve payloads.

Targeted for operational service in the 1990s, the OTV would be a reusable system that could deliver payloads to high orbit and, when necessary, return them to the Space Shuttle or the Space Station for refurbishment.

The OTV may be permanently based at the Space Station or it may be ground-based, operating as an adjunct of the Space Shuttle. Initially it will be an unmanned system but the ultimate goal is development of an OTV that can ferry a manned capsule to and from geosynchronous orbit, allowing on-orbit servicing of spacecraft or multipayload platforms in orbits beyond the Shuttle's reach. Martin Marietta and Boeing Aerospace are conducting OTV studies for Marshall Space Flight Center. ▲





The core of the Space Station consists of a series of pressurized cylindrical common modules serving as living quarters and laboratories. The exact number of U.S. modules will be determined in the course of Phase B studies now under way, but the initial Space Station will probably have two to four, interconnected by airlocks and tunnels.

The atmosphere inside the modules will be nearly identical to Earth's, so that scientists will be able to compare data acquired from Earth-based testing with data gathered in orbit. An environmental control and life support system will provide the crew with oxygen for breathing; supply water for drinking, bathing and food preparation; remove contaminants from the module's artificial atmosphere; and process biological wastes. It will be a closed cycle system that will enable recovery of oxygen from carbon dioxide expelled by the crew and will allow reuse of wash water, urine and condensate. Only food and nitrogen will have to be periodically resupplied.

The aerospace companies working on Phase B definition and preliminary design of the Space Station have conducted extensive studies of interior arrangements and built mockups of variously configured modules. At upper left is Martin Marietta's mockup, showing an exterior view with hatches for interconnection with other modules and a space-suited astronaut for size comparison. At lower left is an interior view of the same mockup, configured as a manufacturing technology laboratory.

Above is Boeing Aerospace Company's mockup of an interior configured as a microgravity and materials processing facility, with all the equipment needed for the types of experiments envisioned compactly stored in wall cabinets.

At upper right is a Rockwell International mockup of a common module that would serve as both living and working quarters. The lower right illustration shows a McDonnell Douglas Corporation concept of what the company calls a "quiet module," wherein crew members would work

and sleep; the sleeping facility is the small partitioned area from which the astronaut is emerging.

The initial Space Station will probably have a crew of eight; they will serve for periods of approximately three months at a time. The Space Station will have a docking hub in the pressurized module complex to allow Space Shuttle docking for rotating crews and for periodic resupply. ▲

NASA seeks to stimulate private investment in space-related ventures to assure U.S. leadership in a promising new field of space endeavor.

In 1985, NASA launched a new program intended to stimulate interest and investment in commercial space activities. The program involves establishment of Centers for the Commercial Development of Space, not-for-profit joint research undertakings composed of industrial firms, academic institutions and government organizations.

NASA seeks to encourage space related research and development in the interest of the U.S. economy, because such activity holds promise for development of new products and processes with commercial potential, for example, superior crystals for improved electronic systems; metallic superalloys for construction and manufacturing use; pure glass, free of container contamination, for laser, optical and other uses; a new class of high purity biological materials for more effective health care; and a variety of industrial process equipment and instrumentation.

The program also seeks to expand interest in space-based services, such as remote sensing for land and ocean observations and types of satellite communications not yet available to the public—mobile communications for road vehicles, for example, or electronic mail for remote areas.

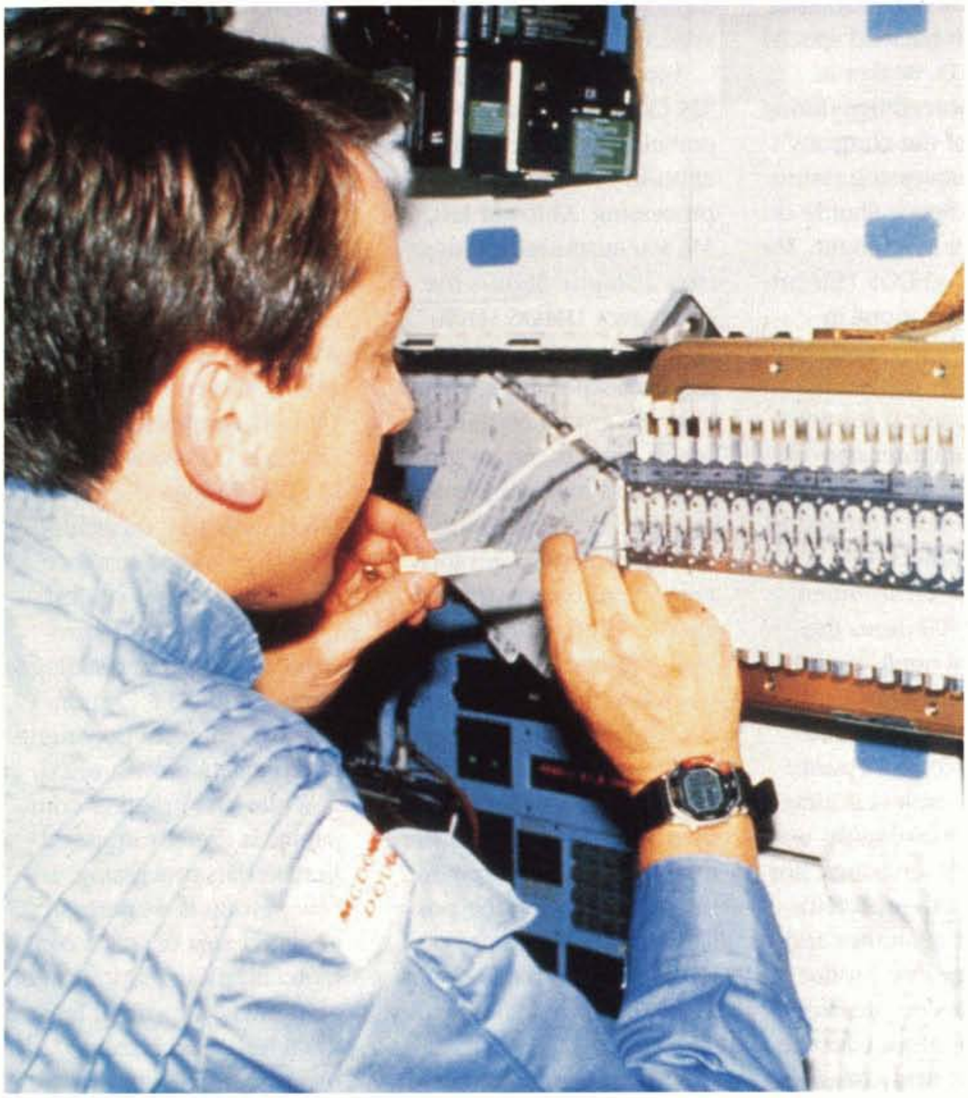
In August 1985, NASA selected five industry/academic/government teams to establish Centers for the Commercial Development of Space. The Centers will work closely with NASA field centers in developing and executing research programs; each will concentrate in a particular area of research activity, although there will inevitably be some overlap. The Centers, and their areas of focus, are:

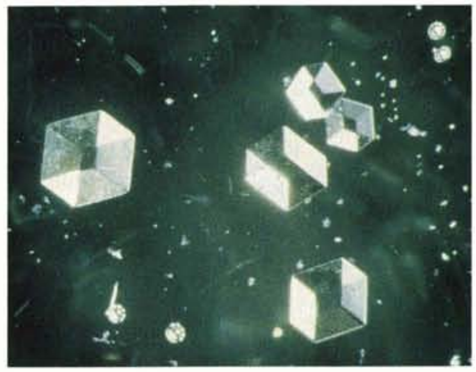
Battelle Columbus (Ohio) Laboratories, multiphase materials processing; University of Alabama, Birmingham, macromolecular crystallography; University of Alabama, Huntsville, materials processing; Institute for Technology Development, National Space Technology Laboratories, Jackson, Mississippi, space remote sensing; and Vanderbilt University, Nashville, Tennessee, metallurgical processing.

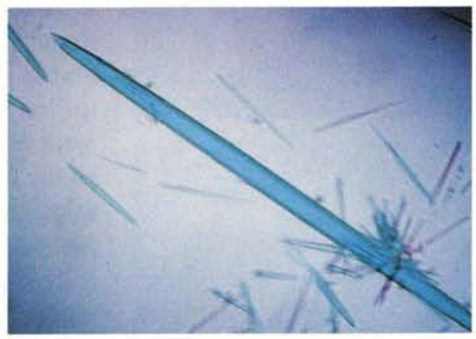
NASA will initially—for a period not exceeding five years—provide funding for the Centers, the amounts ranging from $750,000 to $1.1 million a year; continued funding will depend on a favorable annual review of progress. After five years, the Centers are expected to be self-sustaining.

In the spring of 1986, NASA was evaluating proposals submitted by a number of other teams preparatory to a planned second round of selections for Center establishment.

The Centers for the Commercial Development of Space represent the latest step in NASA's program to encourage and facilitate commercial use of space. NASA provides technical assistance to companies interested in pursuing commercial space ventures and offers reduced rate space transportation for some high technology endeavors. NASA also conducts workshops and seminars that bring together government, industry and academic researchers and other interests, such as the







investment banking and insurance communities. NASA's aim is to promote expanded private sector investment and involvement in space activities, the key to exploiting space for Earth benefit. ▲

Above, a Space Shuttle payload specialist is readying an experiment in growing crystals in orbit. The experiment was developed by the Center for Commercial Development of Space at the University of Alabama, Birmingham, one of several such NASA-sponsored centers. In the upper right photos are examples of crystals grown by the Birmingham Center aboard the Shuttle. The low gravity environment of space allows growth of crystals much larger and with fewer defects than Earth-grown crystals, offering advantage in production of improved electronic systems.

At left, McDonnell Douglas Corporation payload specialist Charles D. Walker is checking procedures during operation of the company's materials processing system aboard the Space Shuttle on a December 1985 flight. The system, called EOS (Electrophoresis Operations in Space), separates materials in solution by subjecting them to electrical stimulation in a computer controlled process. The EOS system has demonstrated its ability to produce in a microgravity environment more than 700 times the material that could be extracted from similar Earth-based processing, with a fourfold increase in purity.

The EOS project is aimed at separating biological materials—cells, enzymes, hormones and other proteins—in sufficient quantities and purities to enable production of advanced pharmaceuticals for more effective treatment of many diseases. On the flight pictured, the seventh orbital operation of EOS, the system was used to produce quantities of a hormone for advanced testing. When Shuttle flights resume, McDonnell Douglas plans to introduce an advanced, fully-automated EOS-1 manufacturing unit that will have 24 times the capacity of the initial EOS system.

Another major U.S. firm—3M Company—has been pursuing a different type of effort in orbital materials processing. At lower left, 3M scientists are opening—after a Shuttle flight—the company's DMOS (Diffusion Mixing of Organic Solutions) experiment, a study of space-grown crystals. In space, crystals can be grown larger and more nearly flawless than on Earth, hence have potential for advantageous applications in such areas as electronics, optics and communications. 3M has flown the DMOS system twice and another type of crystal growing apparatus once. The company's emphasis is on research rather than product development, but it is exploring the possibility of eventual use of space-grown crystals in imaging, electronic and health care systems.

A recent magazine survey disclosed that there are about 20 U.S. companies engaged in some form of microgravity materials processing research, including ground-based experiments and planned flight projects: research areas include biological processing, crystal growing, metallurgy, pure glass processing and research in fluid dynamics. Among those who have signed agreements with NASA, in addition to McDonnell Douglas and 3M, are Microgravity Research Associates (crystallography); Martin Marietta Corporation (fluid dynamics research); Deere & Company (research in alloy formation); Honeywell Inc. (crystallography); Boeing Aerospace Company (electro-optical crystals); Grumman Aerospace Company (crystallography); and GTE Corporation (organic and polymeric microgravity growth tests).

While one group of companies is directly engaged in materials processing, another group is working in a related area of space commercialization: fabrication of equipment for sale or lease to materials processing experimenters.

Rockwell International, for example, has developed a Fluids Experiment Apparatus (FEA) designed to handle a range of processing applications, including liquid chemistry, fluid physics, thermodynamics, crystal growth and biological cell culturing. About the size of a TV set, the FEA can heat, cool, expose to vacuum and manipulate experiment samples, which may be gaseous, liquid or solid. Grumman Aerospace is developing a processing furnace for use on the Space Shuttle.

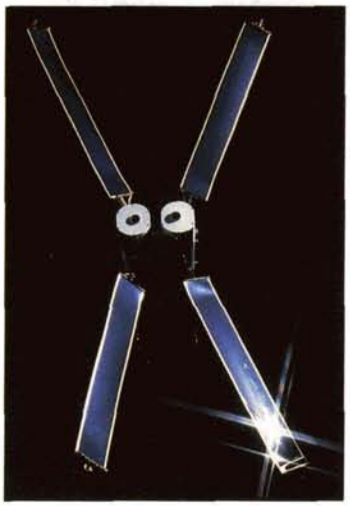
At right, John M. Cassanto, president of Instrumentation Technology Associates (ITA) displays another kind of Shuttle-use equipment for materials processing: cylindrical canisters (here shown without their outer casings) for Shuttleborne Getaway Special experiment packages. Getaway Specials are small, self-contained payloads flown on Shuttle missions where there is leftover space after primary payloads have been accommodated. Managed by Goddard Space Flight Center, the Getaway Special program offers low cost opportunities for orbital research projects to experimenters who could not justify or could not afford the cost of a primary payload—educational institutions, research organizations, industry researchers or private individuals. Getaway Special experiments require no use of Shuttle resources or crew tending; they are exposed to the space environment in the open payload bay, then returned to Earth for analysis.

The photo shows two sizes of canisters offered by ITA, the five cubic foot module at left and a 2.5 cubic foot module; each provides basic electronic equipment in the bottom bay, as shown in the photo of the small canister. Avionics include a power supply, a data recorder, pressure and temperature sensors and a programmer/sequencer; additional equipment—such as a video recorder—can be included at the experimenter's option.

ITA is developing a larger experiment module for use with NASA Hitchhiker payloads, which are Shuttle bay experiment packages weighing up to 1,000 pounds, more complex than Getaway Specials and generally requiring use of Shuttle resources, such as power, commands, recording and telemetry. The ISEM-H (ITA Standardized Experiment Module for Hitchhiker) will consist of an exterior pressure vessel capable of being pressurized or vented into space and an interior structure for mounting experiments or hardware for production of space processed materials. The unit also

provides avionic equipment for tapping into Shuttle resources.

ITA typifies a number of companies that are not only providing equipment for materials processing but also offering a full range of related services. For experimenters who have a research idea but are new to the field, they can design and assemble an experiment apparatus, install it in a module, deliver it to NASA for Shuttle integration and handle all the requisite safety tests and administrative detail. ▲



Although materials processing activities constitute the broadest area of commercial space development thus far, some companies are focusing their attention on another area: development of flight systems intended primarily for commercial space operations.

One such system is the Industrial Space Facility (ISF) shown in cutaway view at upper left. Being developed by Space Industries, Inc. for service around the end of the decade, the ISF is designed as a Shuttle-serviced orbiting facility for experimental or operational materials processing, alternatively as a scientific laboratory or a technology development facility for testing new space equipment and procedures.

In the basic form shown in the cutaway view, the ISF is a single module, 35 feet long and 14½ feet in diameter, with a large solar array power source being developed by Lockheed Missiles & Space Company. The module has built-in power storage, temperature control, communications and data management equipment, along with laboratory/factory equipment customized to the job the facility is to accomplish. As many as six modules can be docked together to create what the developers call a "space industrial park." The lower left photo shows a mated two-module system.

The ISF is designed as an unmanned automated station, but a unique aspect of the design is provision of 2,500 square feet of pressurized volume in each module. Thus, Shuttle-delivered servicing crews will be able to work in shirtsleeves for the two or three days it might take for repairs or adjustments, equipment changeouts, product harvesting and cleaning/restocking production hardware.

In a shuttle/ISF resupply and servicing operation, the Shuttle Orbiter is docked to the ISF by means of a berthing adapter. Astronauts enter the pressurized part of the facility through a docking tunnel. Connected to the facility module is a separable supply module containing oxygen for pressurization and other consumables; resupply modules, six to 11 feet long, will be delivered every three or four months and depleted modules returned to Earth. The periodically man-tended ISF will operate in the same orbit as that of the U.S./international Space Station and it will also be able to dock with the Space Station for servicing. By agreement, NASA and Space Industries will work together on technical matters and operational support requirements, and will exchange non-proprietary data.

Another area of privately funded space activity is development of upper stage propulsion systems for boosting payloads to higher orbits, for example the 22,300 mile high geosynchronous orbit where commercial communications satellites and other "geostationary" satellites operate. This is a two-step process wherein the payload is first deployed from the Shuttle Orbiter in low Earth orbit, then transferred to geosynchronous orbit by a secondary boost from an upper stage launch vehicle affixed to the satellite.

The first privately developed upper stage was the PAM (Payload Assist Module) built by McDonnell Douglas Astronautics Company and employed for all Shuttle launches of commercial communications satellites thus far. The company has developed an advanced PAM-DII that can boost 4,160 pounds to geosynchronous orbit.

A new medium capacity upper stage is under development as a commercial enterprise in cooperation with NASA. Known as the Transfer Orbit Stage (TOS), it is being developed by Orbital Sciences Corporation (OSC) with private capital. NASA is not contributing any direct financial support but provides technical monitoring of TOS progress through a project office at Marshall Space Flight Center. This arrangement will make a new space transportation system available for government as well as commercial service while saving the government the estimated $50 million required to develop the system.

In March 1986, NASA selected the TOS system as the upper stage vehicle to be used after Space Shuttle deployment of the Mars Observer mission in 1990.

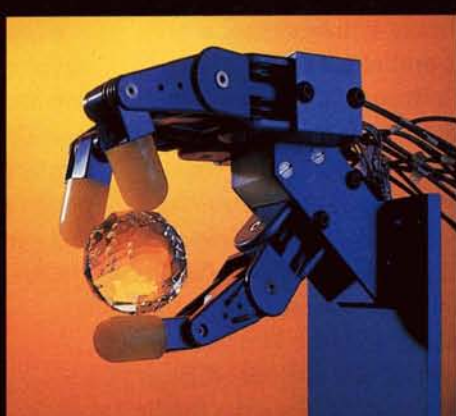
TOS is being built by Martin Marietta Denver Aerospace, prime contractor to OSC. Powered by a solid propellant rocket motor, TOS is being developed under a design philosophy that combines extensive use of space-qualified hardware with selective application of new technologies. The stage is expected to be ready for service by late 1986.

OSC and Martin Marietta are also developing a complementary upper stage called the Apogee and Maneuvering Stage (AMS), which employs space storable liquid rocket technology. Used as a combined two-stage vehicle, the TOS/AMS can deliver a 6,500-pound payload to geosynchronous orbit. On such missions, the TOS stage delivers a high-thrust, short-duration injection into elliptical transfer orbit; the AMS provides insertion into circular orbit and precise final positioning of the payload. The photo above shows AMS boosting a large satellite following separation of the TOS stage. TOS/AMS is targeted for initial service availability in December 1987. ▲

Technology Twice Used

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 development.

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



Space Technology for the Fire Department

A NASA-developed breathing system for firefighters exemplifies the benefit potential of aerospace technology transfer

Firefighting and fire prevention are areas of activity that seem to be especially productive of aerospace spinoffs. In recent years, for example, aerospace technology has been beneficially transferred to such civil-use applications as a portable firefighting module; protective outergarments for workers in hazardous environments; a broad range of fire-retardant paints and foams; fireblocking ablative coatings for outdoor structures; and a number of types of flame resistant fabrics for use in the home, office, or in public transportation vehicles.

Perhaps the broadest fire-related technology transfer is the breathing apparatus worn by firefighters for protection from smoke inhalation injury. Breathing equipment widely used throughout the United States is based on a NASA development of the 1970s that coupled NASA's design expertise and lightweight materials developed for the U.S. space program. That project was the first concerted effort to improve firefighter breathing systems, which had not changed appreciably since the World War II era.

It started in 1971 in response to a need expressed by many of the nation's fire chiefs. The traditional breathing system was heavy, cumbersome, mobility-restricting and so physically taxing that it often induced extreme fatigue. Many firefighters preferred not to use the equipment, electing to take their chances of being overcome by smoke rather than risk collapse from heat and exhaustion. As a result, smoke inhalation injuries were on the rise.

In cooperation with the Fire Technology Division of the National Bureau of Standards, NASA established a public interest technology utilization project under the direction of Johnson Space Center (JSC). JSC embarked on a multiyear design and development effort centered on application of technology developed for portable life support systems used by Apollo astronauts on the moon. Specifications were drawn from input provided by a User Requirements Committee made up of fire chiefs and city managers. In addition, such fire service organizations as the National Fire Protection Association, the International Association of Fire Fighters and the International Association of Fire Chiefs periodically reviewed the program. Two companies—Martin Marietta Corporation and Structural Composites Industries, Inc.—were awarded contracts to build lightweight air cylinders patterned on technology originally developed for rocket motor casings. Scott Aviation, Lancaster, New York, received the contract to build the other components of the breathing apparatus. JSC conducted its own extensive testing of the new system and this was followed by a series of field tests—in 1974-75—by the fire departments of New York (the nation's largest), Houston and Los Angeles.

What emerged from the four year development effort was a breathing system weighing slightly more than 20 pounds, about one-third less than predecessor systems, with a reduced profile design intended to improve the mobility of the wearer. The system included a face mask, frame and harness,

At left, the firefighters are wearing a protective breathing system designed and developed by NASA's Johnson Space Center (JSC). The project adapted materials and technology from the space program to a national need for lighter, less bulky breathing apparatus. Shown above is the original JSC design, which served as a departure point for new systems developed by major manufacturers of firefighting equipment.

a warning device and the air bottle with its associated valves and regulator. The basic air cylinder offered the same 30-minute operating time as predecessor systems, but it was lighter and slimmer; this was accomplished by using aluminum/composite materials and by pressurizing the cylinders at 4,500 pounds per square inch, roughly twice that of earlier tanks. NASA also provided an optional 45-minute duration special use cylinder that was still within the allowable weight. The frame and harness was made easier to put on and take off and the system's weight was shifted from shoulders to hips to improve wearer comfort. The new face mask offered better visibility and closer fit, and the air depletion warning device was designed so that the beeping alarm could be heard only by the wearer, to minimize confusion in the hectic environment of a fire scene.

"It was a major improvement in firefighting equipment, no question," says Chief James Manahan of the New York City Fire Department's Safety Operating Battalion. He qualifies as a leading expert on breathing apparatus. A veteran of 29 years service, he has worn both the old and new systems in actual firefighting operations. As a captain with Squad Company Four, he was project officer for the NYFD participation in the 1974-75 field tests. And in his current work with the safety battalion, part of his job is observing the use of breathing systems at fire scenes and looking for problems that may crop up in breathing system operation and maintenance. "The NASA technology definitely made a contribution toward reducing firefighter fatigue."

(Continued)

At a fire in a New York City office building, NYFD firefighters group in the lobby awaiting assignment (above), their breathing apparatus stacked for use if needed. It was—the upper floor electrical fire generated much smoke. At right, one firefighter helps another adjust his breathing system.

At his office on Randall's Island, New York, safety battalion Chief James Manahan compared the modern firefighter's breathing apparatus, based on NASA technology, with pre-NASA equipment.

"This one," he said, tapping a metal case containing the old system, "was heavy, bulky, had narrow eye pieces and the weight pulled down on the shoulders. When you wore that thing for 15 minutes, you couldn't wait to get out of it. And this"—he indicated an adjacent case—"is the current system we use, with a smaller, lighter air cylinder, better mask and harness." Aside from the lighter weight, firefighters consider the waist-mounted harness a big plus; it shifted the weight from shoulders to hips, provided better weight distribution and therefore makes the pack seem lighter than it is.

Has the NASA technology met the original objective of inspiring greater use of breathing systems? Firefighters are generally more hazard-aware today, Chief Manahan said, because greatly expanded use of exotic chemicals, plastics and other synthetics in industrial operations, building materials, home and office furniture has increased the incidence of toxic fume generation in fires. There is greater readiness to use protective gear, and no doubt the availability of a more comfortable breathing system contributed to that attitude.

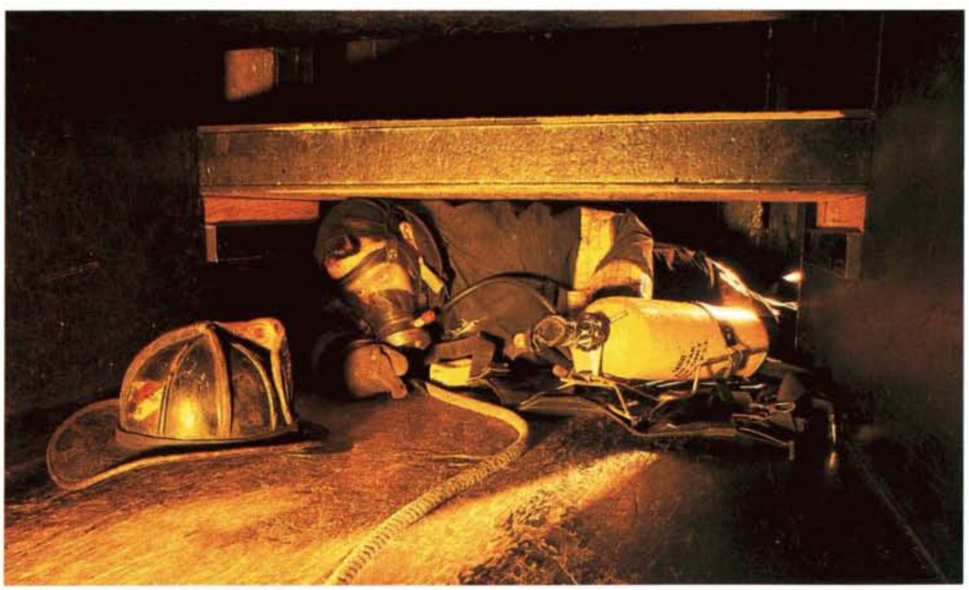
After completion of the field tests a decade ago, the New York City Fire Department became one of the first of the nation's fire services to adopt the new technology on an operational basis. Use of the lightweight apparatus spread quickly across the country as producers of firefighting equipment used the NASA technology as a departure point for their own development of new breathing systems. Each com-

A NYFD firefighter is disposing of hazardous material, protected by a "hazmat" suit. In Level One work, where the material is known or suspected to generate toxic fumes, the breathing apparatus is worn under the hazmat outer gear.

At the NYFD Randall's Island training facility, firefighters undergo "mask confidence training," carrying out such fire operations as hosing (above) and probing building interiors (right), squeezing through narrow areas as might be necessary in a real fire with their breathing units attached and (below) momentarily detached. The NASA-developed breathing system was designed with reduced profile wherever possible to improve mobility in tight confines.

pany made its own modifications and refinements to the original design, and new features are continually being added, but today every major manufacturer of breathing apparatus is producing units that incorporate the NASA technology in some form.

"The existence of these units offers the fire services a wide variety of breathing systems that would not have been available without NASA's efforts," says J. Tom Smith, Firefighter Health and Safety Specialist of the U.S. Fire Administration. "As a result of the introduction of lightweight breathing systems, inhalation injuries to firefighters have been drastically reduced." ▲

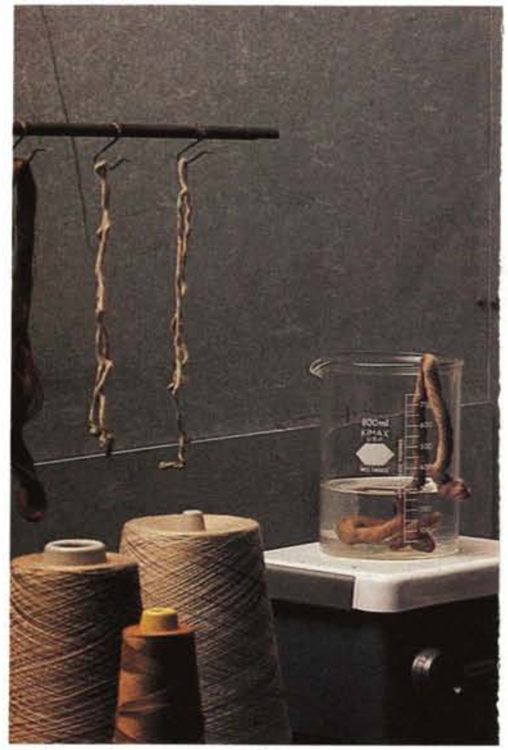


A fire resistant textile ingredient highlights a sampling of spinoffs in the field of public safety

Sometimes an aerospace spinoff product is a "late bloomer," meaning that its adaptation to civil uses may not happen until years, even decades, after the original development. An example is the fireblocking fiber known to chemists as polybenzimidazole and to everyone else as PBI. It was almost a quarter century ago that Celanese Corporation of New York developed PBI for NASA and the Air Force Materials Laboratory, but it was not until the 1980s that PBI's real commercialization began. Now PBI is a full-fledged commercial product in wide use and its range of applications is broadening rapidly.

PBI fiber emits very little smoke or "offgassing" at temperatures up to 1040 degrees Fahrenheit. Fabrics made from PBI are durable and comfortable, they do not burn in air or melt, they have very low shrinkage at high temperatures and they retain their flexibility after exposure to heat or flames. They also resist strong acids, solvents, fuels and oils. This combination of properties makes them attractive candidates for a broad spectrum of thermal protection and related applications.

PBI's development was originally intended to provide a flight suit material that would afford astronauts and military pilots maximum protection against fire. After successful development of the fiber, Celanese designed a manufacturing process and produced PBI in limited amounts for military and space applications; it was used, for example, in Apollo and Space Shuttle astronaut gear and in webbings and tethers on Apollo Skylab flights. But during most of the 1970s, PBI found no large-scale civil applications.



That changed in 1980 when Celanese moved to full commercialization and announced plans to build a new plant for PBI production. One reason for the company's decision was that a market had opened for an alternative material to asbestos. Another was stricter government anti-pollution standards; PBI's ability to resist corrosive gases and chemicals made it an attractive material for filtering stack gases. There were also applications in thermal protective wear for foundry workers, chemical plant employees, firefighters and others whose occupational activities expose them to flame and intense heat.

Located at Rock Hill, South Carolina, the Celanese PBI plant started production—in 1983—of fibers for conversion

At left, a Celanese Corporation laboratory technician is acid bath-testing a batch of PBI fibers. Originally developed as material for fire resistant flight suits, the fibers are now being used in a widening range of civil applications.

into fabrics by other manufacturers for both military and industrial applications. The company has since increased production substantially and also expanded its market through agreements with Teijin Limited, Osaka, Japan to market PBI in the Far East and Hoechst A.G., Frankfurt, Germany for European marketing.

The range of PBI uses is similarly expanding. Last year, the fiber found a new application in fabrics for a new line of auto racing driver suits manufactured by Pyrotect, Inc., Minneapolis, Minnesota. And, since 1984, Celanese has been working on what could become the most important application from the standpoint of public safety: a fireblocking covering for the foam cushions in commercial airliner seats (see page 56).

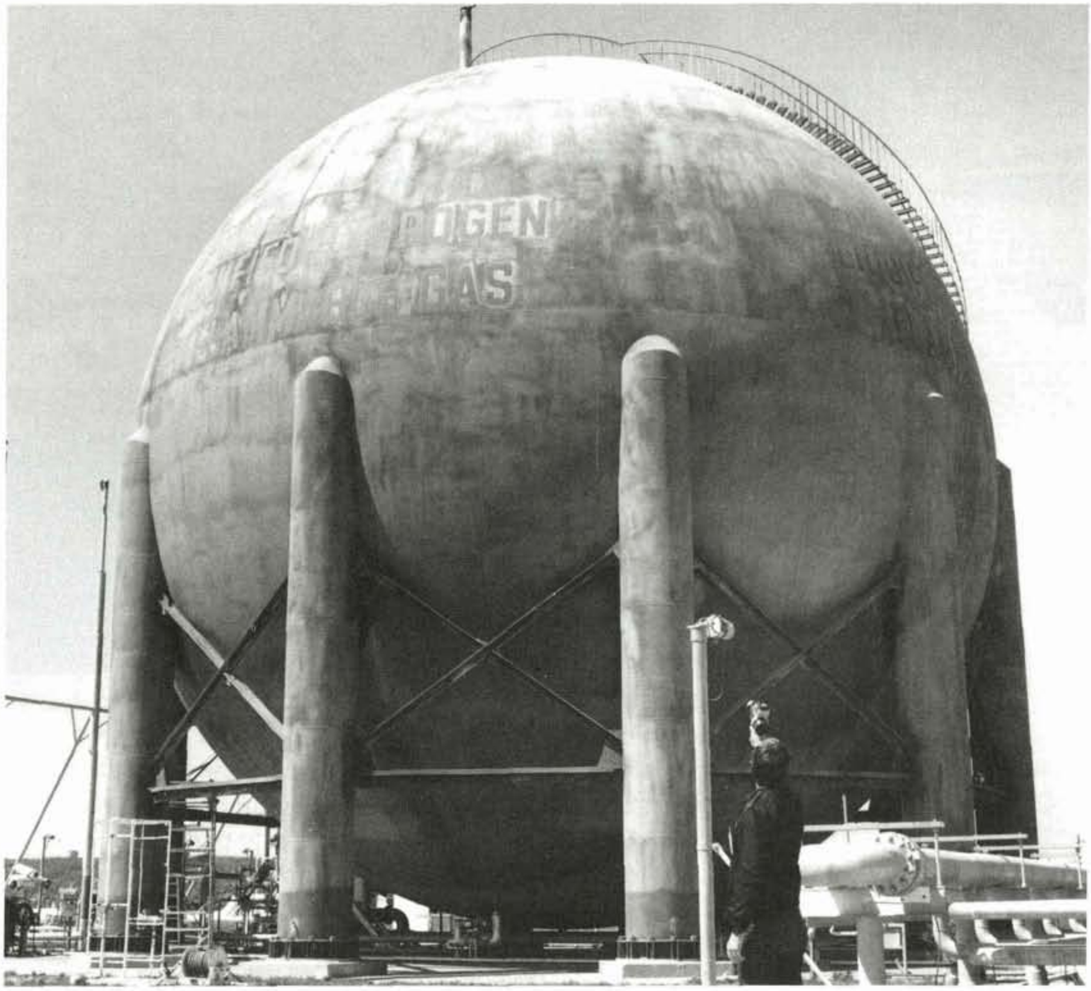
The firefighter pictured above is wearing a jacket whose fabric incorporates PBI fibers. The fabric does not burn or crack, thus providing flame protection to its wearer, and it is lightweight, allowing greater maneuverability with less fatigue. These and other properties make PBI attractive for a variety of thermal protection applications, such as the gloves and outer garment worn by the foundry worker at left.

The first two photos show a seat burn test of a fabric that does not contain Celanese PBI; the far left photo shows the seat after 30 seconds exposure to a temperature of 1900 degrees Fahrenheit, the adjacent photo at 90 seconds. The latter two photos illustrate the dramatically reduced flame involvement, at the same time intervals and temperature, in seats incorporating PBI.

In October 1984, the Federal Aviation Administration (FAA) issued new and more stringent flammability requirements for aircraft seat cushions, a source of flame and smoke propagation in the event of an aircraft fire. Designed to give commercial airline passengers an extra 40 to 60 seconds to evacuate a burning airplane by delaying the spread of fire, smoke and toxic fumes, the new rules required that airliners carrying more than 30 people must—within three years—install burn-resistant seats.

Just two days later, Celanese Corporation announced that fabrics made of its PBI fiber meet the FAA requirements: no more than 10 percent cushion weight loss and no spread of flame across the full width of the seat after exposure—for two full minutes—to a temperature of 1900 degrees Fahrenheit. Prior to the FAA's issuance of the new guidelines, Celanese Fiber Operations, Charlotte, North Carolina, had set up its own seat burn facility for advanced research and testing of PBI in cooperation with airlines, seat manufacturers and fabric manufacturers.

PBI, which does not burn in air, is used in a fabric covering around the polyurethane foam seat cushion, creating a fireblocking layer between the seat's upholstery and the foam, thus all but eliminating the toxic fumes and fire-spreading gases emitted by burning foam. PBI fabrics have consistently displayed superior fireblocking performance in tests and additionally have impressed airline officials with their durability, ease of fabrication, comfort, weight and in-service maintainability—all big factors in selecting coverings for thousands of airliner seats. A range of PBI airline seat fabrics has been designed and a number of airlines have specified or are testing PBI fireblocked seats. ▲



For use in the Space Shuttle's main engines and other rocket systems, NASA stores liquid hydrogen in large spherical tanks at Kennedy Space Center (KSC) and feeds it to launch pads through a network of pipes, valves and return lines. A high energy propellant, hydrogen is important to space operations but it requires careful handling on the ground; it is easily ignited and a spark could touch off an intensely-burning fire that is especially troublesome because hydrogen burns with an invisible flame. NASA thus saw a need for a portable hydrogen fire detector that would enable technicians to monitor regularly the spread-out propellant storage and delivery system.

The answer was a hand-held ultraviolet fire detector, developed under NASA contract by Detector Electronics, Minneapolis, Minnesota, manufacturer of a wide array of permanently-mounted ultraviolet and infrared fire detectors. Shown in use at KSC (above) and in closeup (far right), the system developed for NASA has become a commercial product for use in hydrogen generating plants, pipelines and other hydrogen handling facilities.

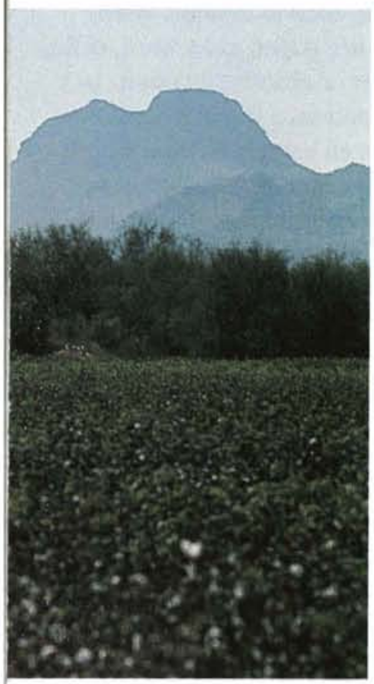
The hand-held detector has sensors that can spot an invisible hydrogen flame at distances up to 100 feet. It has a visual readout that shows the level of ultraviolet radiation and it also provides an aural fire alert, a buzzing sound in the operator's earphones. Because the sensors are designed to react only to a narrow band of ultraviolet radiation, the detector cannot be fooled by sunshine, reflections, incandescent or fluorescent lights. Detector Electronics delivered the first commercial units in 1985. ▲

At left above, Arizona crop duster Gary Owens is about to board his agricultural airplane. In Arizona, most crop dusting work is done in the late afternoon or evening, so Owens' plane has been exposed to hot sunlight for hours and the cockpit temperature may be as high as 125 degrees Fahrenheit. And the plane's cockpit is not air conditioned—few are, because of the expense.

Cockpit heat poses a major problem for Gary Owens and others of his profession because elevated body temperature can cause fatigue, dehydration and even collapse, extremely dangerous possibilities to a pilot flying at times only two to four feet above the vegetation (above). But Gary Owens has an answer; in July 1985 he became the first crop duster to purchase a Cool Head™ personal cooling system from Life Support Systems, Inc. (LSSI), Mountain View, California.

At far right, Owens models the Cool Head system. He is wearing a lightweight vest unit through which cooling liquid circulates and, under his flight helmet, he has a companion cooling headliner. Visible in the cockpit is the portable cooling package, which includes a heat exchanger that cools the working fluid circulated through vest and headliner, and a control display unit containing a pump, a liquid reservoir, temperature control and power unit. Cool Head can operate from its own rechargeable battery or from the airplane's—or other vehicle's—power system. With Cool Head, says LSSI, 40 to 60 percent of body heat storage caused by high temperature can be eliminated and heart rate can be lowered by 50 to 80 beats a minute.

Cool Head user Gary Owens calls it "a winner." In a letter to LSSI, he wrote: "I



don't sweat at all with the Cool Head system. This makes me more comfortable, more alert, less fatigued and provides much greater safety in flight. For the first time in my (eight year) crop dusting career, I am fresh, alert and without mental pressure."

The Cool Head technology originated in a 1968 NASA development program that produced a channeled cooling garment for space wear. In 1971, NASA's Ames Research Center awarded a contract to Acurex Corporation for an extension of the technology involving development of a heat stress alleviating liquid-cooled headliner for helicopter pilots. In the mid-1970s, NASA and the Bureau of Mines jointly sponsored an Acurex program for development of a self-contained cooling system for mine rescue workers. In 1980, William Elkins, formerly with Acurex and long associated with cooling system research, formed LSSI to pursue commercial uses of the technology.

Cool Head personal cooling systems have been acquired by the Army and the Air Force for use by personnel who must perform arduous work while wearing hot and bulky protective gear, such as garments to prevent contact with chemical/bacteriological warfare agents. Cool Heads have also been bought by the U.S. Navy for evaluation in helicopters and light aircraft, and by military units of foreign governments.

Among commercial applications are use by employees susceptible to on-the-job heat stress in such industries as primary metals reduction, deep mining, chemicals, paper and glass. Other commercial uses include personal cooling for heavy equipment operators and workers wearing toxic waste clean-up suits. Cool Head is also being used by a number of auto racing drivers, notably Paul Newman of motion picture fame and Bill Elliott.

Additionally, Cool Head is being evaluated by NASA's Research Triangle Institute (North Carolina) Technology Applications Team, which is conducting a program to utilize aerospace-derived technology to improve on-board equipment in public service helicopters, such as those engaged in law enforcement, search and rescue, drug enforcement, border patrol and forest service activities. The NASA application team and LSSI are working to identify possible improvements in the Cool Head system that would enhance its utility in the public service helicopter application. ▲

TM Cool Head is a trademark of Life Support Systems, Inc.

AID FOR THE MEDICAL LABORATORY

Among spinoff innovations in medicine is a line of efficiency enhancing products for separating chemical compounds in fluids

In the early 1970s, Jet Propulsion Laboratory (JPL) undertook a community service project to meet a need of the Los Angeles Police Department. The department's forensic chemistry laboratory needed a reliable but more rapid way of detecting drugs in blood or urine samples taken from suspected narcotics users. JPL applied its world renowned technological expertise, invented a technique for speedier separation of biological compounds, then advanced the technique another step by developing a method of automating the process. The JPL effort provided a technology base for a line of sample preparation products developed by Analytichem International, Harbor City, California and sold all over the world.

Liquid/liquid extraction is a term used in chemistry to describe a method of separating chemical compounds contained in blood, urine or other biological fluids for research or forensic work, medical treatment or pharmaceutical manufacture. At the time JPL began its research, the conventional extraction process involved transferring the compounds to be separated into a solvent liquid in a series of complicated operations—agitation, emulsion formation, centrifuge spinning, mechanical filtration and other steps, each step time-consuming and each requiring certain special equipment.

Looking for a simpler, easier way, JPL developed a new single step extraction process that sharply cut processing time, reduced cost and eliminated much of the equipment requirement. The technique involved use of disposable tubes called "extraction columns" partially filled with an absorbent packing material, such as ceramic wool, shredded filter paper, glass wool, cellulose powder or absorbent cotton. In a typical extraction, a liquid sample was poured into an extraction tube where the packing material absorbed water and impurities from the sample and spread the specimen as a very thin film over a large area; this made the drug-bearing components easily separable through contact with organic solvents. To extract a particular compound, an appropriate liquid solvent was introduced to the tube. As the solvent passed through the packing material, the desired compound became dissolved in the solvent and exited through the tube's bottom stem, to be collected for further processing. By introduction of another solvent, a different compound could be extracted from the remaining sample.

JPL then developed an automated system for analyzing the extracted compound. Called AUDRI—for Automated Drug Identification—the device combined computer, spectrographic and gas chromatograph technology in a system that removed the solvent from the extract, vaporized the extract, then directed the vapor into a series of gas chromatographs, instruments that separate and identify the various gases in a mixture and their amounts (AUDRI had a separate gas chromotograph for each family of compounds to be identified). The data from the chromatographs and other AUDRI instruments was sent to a computer, which compared the data with a repertoire of drug characteristics stored in its memory and thus made a final drug identification.

NASA waived title for the extraction tube and AUDRI technology to JPL's parent organization, California Institute of Technology (Caltech) and Caltech granted licenses for commercial use of the technology to three companies, one of them Analytichem International. Analytichem initially introduced the JPL disposable extraction column under the trade name Extube™ and is still producing it in two forms: Chem Elut™ columns for applications demanding exceptional purity and Tox Elut®, specifically designed for urine drug abuse screening.

Analytichem has advanced the original technology by developing—for applications in sample preparation, analysis and pharmaceutical manufacturing—a range of Sepralyte® chemical isolation products based on silica adsorbing materials, or sorbents. A key Sepralyte product is Bond Elut®, a liquid/solid extraction column designed for fast, efficient, economical processing. The company also produces a variety of Bond Elut accessories, including a Vac Elut™ processing station that can handle up to 10 Bond Elut columns simultaneously and provide results in a few minutes.

In addition, Analytichem used the JPL/AUDRI technology as a departure point for company development of an automated sample extraction and analysis system known as AASP®. The instrument is manufactured by Varian Associates and Analytichem produces AASP Cassettes with 10 sorbent cartridges for 10 simultaneous sample extractions; the cassettes embrace the complete spectrum of Sepralyte sorbents to accommodate virtually any separation application. Analytichem's products have found wide and growing acceptance; thus, JPL's community service effort of a decade and a half ago played an important part in bringing new, efficiency-enhancing products to the marketplace and in generating sales running into the millions of dollars. ▲

™ Extube, Chem Elut and Vac Elut are trademarks of Analytichem International, Inc.
® Tox Elut, Sepralyte, Bond Elut and AASP are registered trademarks of Analytichem International, Inc.

At left, a National Institute of Health technician is assaying a laboratory sample prepared by use of the equipment in foreground, a processing unit and a series of "extraction columns" that make possible rapid separation of the compounds in biological or other fluids. Developed by Analytichem International, the equipment and technique derive from technology originally developed by Jet Propulsion Laboratory to detect drugs in blood or urine samples.

Shown in closeup are two members of the Analytichem family of products for sample preparation and analysis: the Bond Elut (top) and Tox Elut extraction columns, the latter specifically designed for drug abuse screening.

Image analysis is the art of obtaining information from pictures, for example, through visual examination of a photograph or x-ray. But visual extraction and interpretation of information is slow, tedious and error prone because it is subjective. To support space requirements, NASA—in particular Jet Propulsion Laboratory (JPL)—developed the technique of digital imaging, computer-processed numerical representation of physical images, such as the planets and moons of the solar system. JPL also played a lead role in developing digital image processing, or enhancement of images to improve their quality and make them easier to interpret. Quantitative digital image analysis goes a step further and includes location of objects within an image and measurement of each object to extract quantitative information.

In the decade of the 1980s, these technologies are finding scores of non-aerospace applications. In medicine, for example, CAT scanners and diagnostic radiography systems are based on digital imaging; three-dimensional reconstruction techniques are proving a valuable aid to microscopy; and computerized image analysis of cardiological x-rays is providing quantitative data on heart valve and artery functions. In industry, digital imaging is notably employed in quality control inspection systems; it also has applications in chemistry, cartography, manufacture of printed circuitry, metallurgy, ultrasonics and seismography, in addition to many aerospace uses.

Shown in the accompanying photo is the PSICOM 327, a stand-alone work station designed to perform all of the commonly used functions in quantitative digital image analysis. The photo shows a medical application—quantitative measurements of a microscope specimen—but PSICOM 327 is a general purpose system with broad industrial and scientific uses in addition to its clinical applications.

Introduced to the commercial market in 1985, the PSICOM 327 is manufactured by Perceptive Systems, Inc. (PSI), Houston, Texas. PSI is a NASA technology transfer company employing a number of personnel with NASA-acquired technical expertise, operating under a NASA patent license, and incorporating in its products digital imaging technology developed by JPL. The company was founded in 1984 by Dr. Kenneth Castleman, now vice president—research and development, and Don Winkler, vice president—engineering. Both are former NASA digital imaging experts, Castleman with JPL and Winkler with Johnson Space Center.

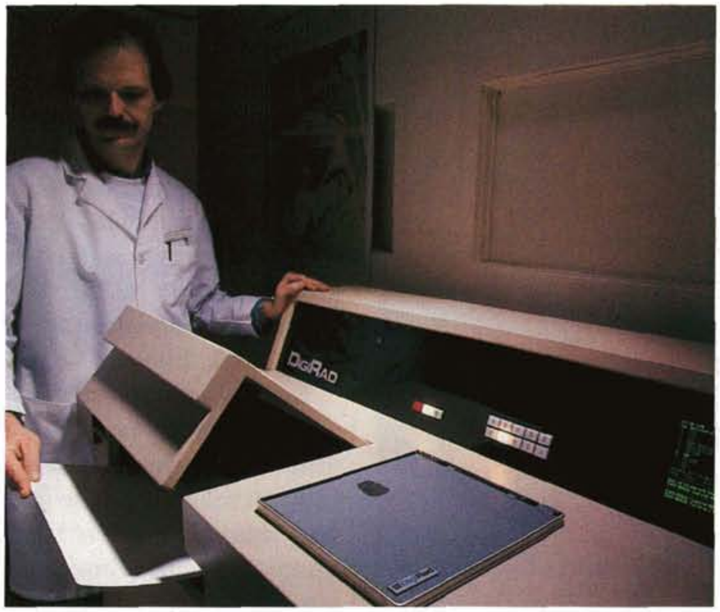
The PSICOM 327, now in use at several universities and industrial facilities, is PSI's first product. The company recently introduced a new PSICOM 427 high resolution imaging system to meet market demand for greater accuracy and image resolution in some applications, and it also developed the first model of a 200 Series that will feature lower cost, smaller, more mobile systems designed for specific rather than general purpose applications. ▲

The accompanying photographs show components of a new digital radiography system designed for improved efficiency, flexibility and cost-effectiveness in hospital radiographic examinations. Developed and built by DigiRad Corporation, Palo Alto, California, it is called System One and is intended to reduce hospital operating costs by eliminating the expense of film in x-rays and other image acquisition procedures.

With System One, patient radiographic examinations are conducted in the standard manner except that body images are not recorded on film but on the DigiRad RIM®, or Reusable Image Medium, essentially an intensifying screen that is capable of retaining an image. System One "reads" the RIM with a laser scanner (not pictured) and uses the scan information to produce a digital image in the image processor shown at upper right. The image is then stored in the computer's memory; the RIM, meanwhile, is automatically erased so that it can be used again. Images are stored on optical disks that can accommodate 400 images on a platter the size of a phonograph record.

In the reading room, a radiologist selects images from System One's directory for display on the physician's console (lower photo). A key element of System One is what DigiRad calls "energy selective imaging," an image enhancement feature that improves diagnostic capability by enabling the system's operator to subtract certain features. For example, the radiologist can "dial away" the ribs in a chest picture or remove soft tissue from the image; this permits the physician to compare—on the three image screens of the console—standard, bone-subtracted or soft tissue-subtracted views.

Filmless radiography, says DigiRad, substantially lowers the direct cost of making images (film cost) and provides additional indirect savings of significant order by eliminating the need for film accessory equipment, by compressing image storage space and by improving productivity in calling up images. System One is compatible with all existing radiographic equipment and it produces high resolution



images, resolving the problem of image quality loss incurred in prior attempts to eliminate film.

System One incorporates digital imaging technology —specifically the energy selective technology—developed by Stanford University with support from NASA grants. One of the participants in the Stanford research program, Dr. Robert E. Alvarez, now chairman of the board of DigiRad, obtained a license from Stanford for commercialization of the digital radiography system, which was introduced to service in 1984. ▲

® RIM is a registered trademark of DigiRad Corporation.

The unit pictured is a FluoroScan™ Imaging System, a high resolution, low radiation device for continuous real-time viewing of stationary or moving objects. Intended primarily for medical applications, it is produced under NASA license by HealthMate, Inc., Northbrook, Illinois.

The FluoroScan system is a second generation spinoff from NASA technology originally developed for use in x-ray astronomy, where imaging at extremely low x-ray intensity is required. The technology was subsequently applied—by Goddard Space Flight Center—to development of an isotopic, portable, minimal radiation x-ray instrument known as the Low Intensity X-ray Imaging Scope, designed principally for emergency medical use. One of several NASA licensees, HealthMate replaced the isotope penetrating source with a variable power x-ray tube and added a number of improvements while retaining the small size, light weight and maneuverability advantages of the original system.

Major components of the FluoroScan system include an x-ray generator, an x-ray scintillator, a visible light image intensifier and a video display; in the photo, the cylindrical tube contains the detector, intensifier and video camera, while the x-ray housing, tube and power supply are in the "C-arm" from which the cylinder is suspended. X-rays from the generator cast a shadow of the object being examined—a bone, for example—on the scintillator, which converts the x-ray image to a visible light image. Intensified by the high gain light intensifier, the image can be viewed directly through the tube or on the closed circuit television (CCTV) monitor; use of CCTV allows images to be recorded and stored.

Easy mobility is provided by the wheel-and-caster base and by the primary arm/C-arm arrangement shown, allowing the examining physician to position the unit rather than position the patient. Moving the unit closer to the patient is not dangerous because radiation levels are far below those of conventional x-ray equipment, and such movement allows magnification of the image up to 4½ times with higher resolution. For all its capabilities, FluoroScan occupies only two square feet of space and weighs about 20 pounds. It can be plugged into an electrical outlet or, in portable use, operated by power from a rechargeable battery.

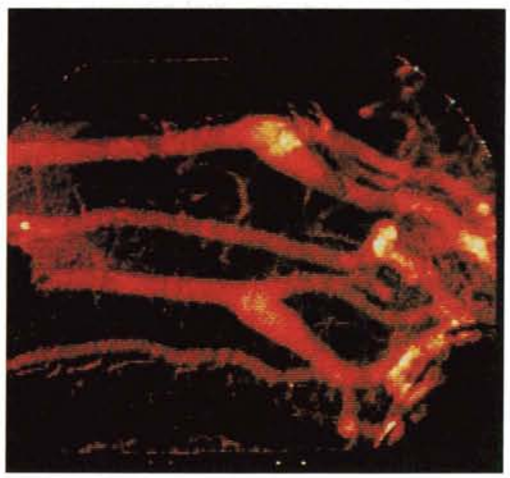
In medical applications, FluoroScan has particular utility in examination of fractures, dislocations and foreign objects and in placement of catheters. In surgery, its continuous real-time imaging capability offers continual monitoring; for example, an orthopedic surgeon can set a fracture while viewing the insertion of pins. In attending newborns, especially those requiring intensive care, it offers the dual benefits of lower radiation for tiny patients and higher resolution of the area being viewed. In veterinary medicine, FluoroScan permits examining animals without sedation because it does not require a still patient to produce a quality image. ▲

™ FluoroScan is a trademark of HealthMate, Inc.

A unit of the Washington University School of Medicine, the Mallinckrodt Institute of Radiology (MIR) is engaged in medical research in such areas as computerized tomography, positron emission tomography, nuclear imaging, high energy radiation therapy and angiography. With more than 125 terminals, MIR's computer system is the largest radiology computer facility in the world.

Since 1979, the institute has been developing the MIR Digital Image Processing System, a transportable system for medical image enhancement. The system has many potential applications in diagnostic imagery analysis and has been used in digital vascular imaging studies of the coronary arteries. For these studies, blood vessels are injected with x-ray dye and images are produced over a period of time to analyze whether the arteries have narrowed, an indication of atherosclerosis (hardening of the arteries).

The accompanying illustrations exemplify digital image processing, which allows visualizing features that would otherwise not be visible. At upper right is a digital image of coronary arteries in a two-year-old child with congenital heart disease. In the lower photo, the image shows the carotid arteries of a 50-year-old being evaluated for atherosclerosis. Comparison tests of the MIR Digital Image Processing System with routine cardiac examinations indicate that the system offers great potential in determining whether cardiac surgery is necessary.



The MIR system employs NASA-developed digital image processing technology, used to improve the quality of diagnostic examination by clarifying the images and extracting specific quantitative information on blood flow in the arteries. As a basis for developing the computer imaging routines for data processing, contrast enhancement and picture display, Mallinckrodt radiologists relied on a computer program, developed by NASA's Jet Propulsion Laboratory at the California Institute of Technology, known as Mini-VICAR/IBIS, for Video Image Communication and Retrieval/Image Based Information System. The program was supplied to MIR by the Computer Software Management and Information Center (COSMIC)®, a unit of NASA's technology transfer network. Located at the University of Georgia, COSMIC collects and stores government-developed computer programs that have secondary applicability and makes them available to industrial firms, government agencies and other organizations. ▲

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

At left, Dr. Bonny Specker, an epidemiologist at the University of Cincinnati Medical Center, holds an infant who is wearing a sunlight-measuring device known as a solar dosimeter. A spinoff from NASA solar cell technology developed to provide spacecraft power, the solar dosimeter played a part in an important study conducted last year by Dr. Specker and her Medical Center associates, bioengineer Neil Edwards, research assistant Sean Lyon and director of neonatology Dr. Reginald Tsang.

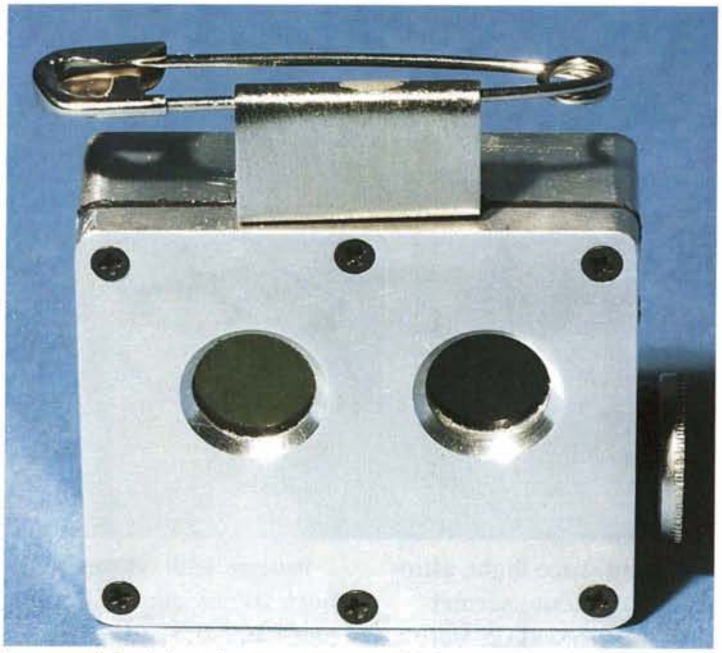
The group investigated the effect of sunlight exposure on maintaining vitamin D status in infants. Vitamin D is derived from dietary sources or produced by the skin after stimulation by ultraviolet light. The effect of sunshine on vitamin D is particularly important to exclusively breast-fed infants who are not receiving supplements, because the vitamin D content of breast milk is low.

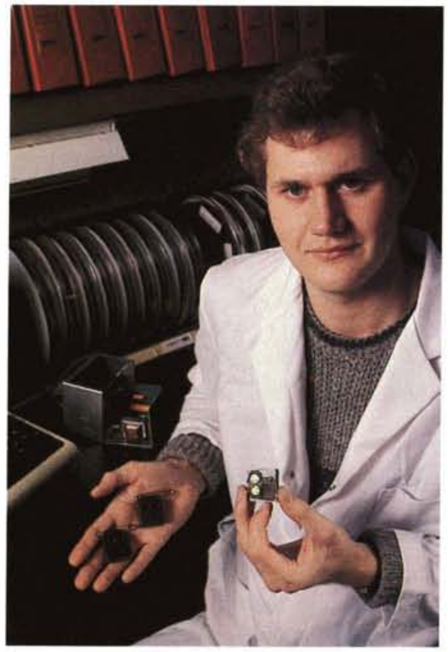
In order to investigate the relationship between sunshine exposure and vitamin D, it was necessary to develop a method of quantifying sunshine exposure in infants. This was accomplished in part by a specifically designed "sunshine diary," in which volunteer mothers recorded—each day for a week—how many minutes the infant was outdoors and what type of clothing was worn.

Looking for a way to double check the diary, engineer Neil Edwards read an article in the NASA publication *Tech Briefs* (see page 127) that described the solar dosimeter, a miniature integrating light meter originally developed by Langley Research Center for measuring accumulated radiation in the ultraviolet and other regions of the spectrum.

Biomedical researchers at the University of Virginia, conducting long-term studies to clarify the role of sunlight in inducing skin cancer, expressed a need for a miniaturized solar dosimeter that could be worn by study participants throughout a day's activity and provide data on the amount of solar radiation to which the wearer was subjected. Langley adapted the technology to the simple, personal-use dosimeter shown at right center. The two circular "eyes" are silicon photovoltaic detectors that collect incident solar energy after passage through filters. The received energy is converted to electrical signals that are proportional to the amount of radiation absorbed. The electric charge is transmitted to E-cells that record the charge by plating silver ions onto an electrode; on completion of an activity period, the total radiation received by the wearer of the device can be determined by measuring the time required to replate the silver. The dosimeter was used in the University of Virginia study and later in another sunshine exposure study conducted by Virginia Polytechnic Institute and State University.

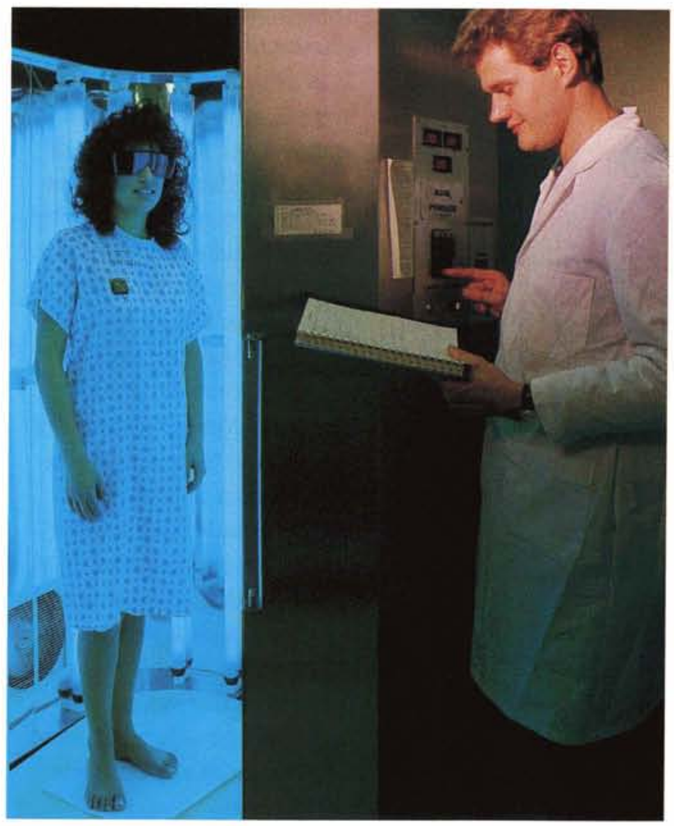
The University of Cincinnati's Edwards followed up on the *Tech Briefs* article by obtaining from Langley Research Center a Technical Support Package that provided details of the solar dosimeter's construction and operation and by conferring with Langley officials. Satisfied that the device was the answer to its need, the Medical Center sought and received a license from NASA, and Edwards' engineering group fabricated about 70 units of the dosimeter for the vitamin D investigation. The Cincinnati team employed the basic technology

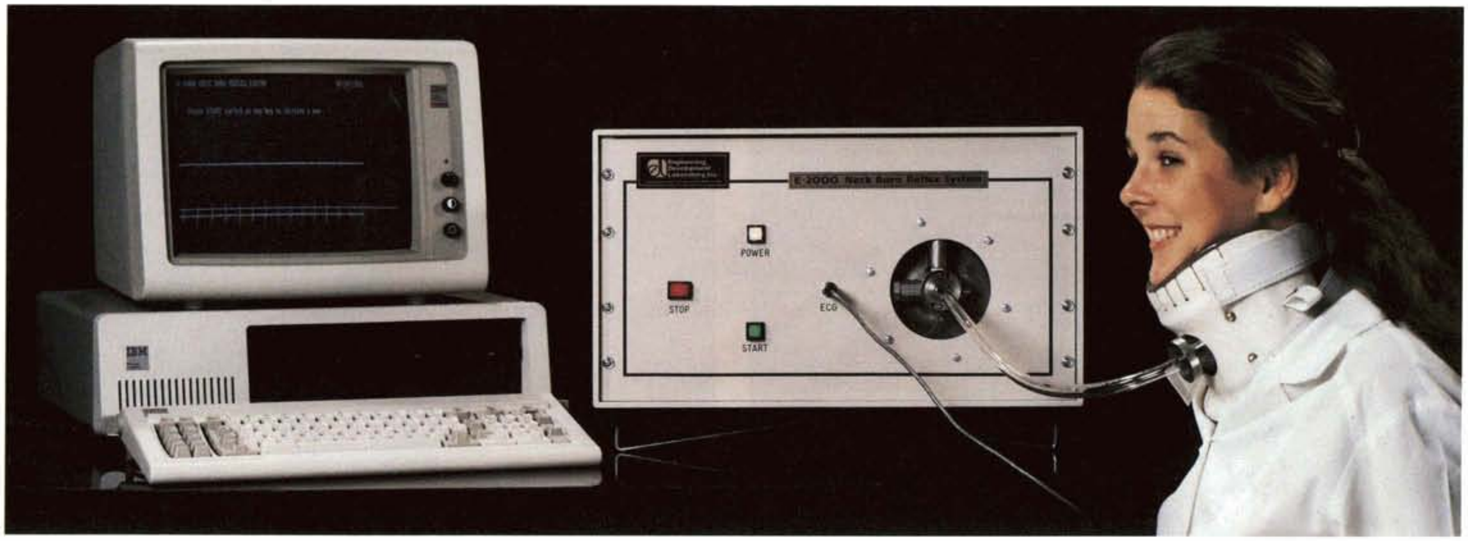




but modified the dosimeter, making it tamper-proof by sealing it, making it more durable and making it smaller for easy wear by infants. At upper right, medical student Bill Brazerol, who assisted the Cincinnati investigators in the study, displays the Medical Center's version of the dosimeter. Right below, an adult wearer of the dosimeter is given a dosage of ultraviolet in a light chamber, part of an additional Medical Center study relating vitamin D synthesis to skin pigmentation.

In the Cincinnati investigation, readings from the solar dosimeter correlated well with the sunshine diary data recorded by participating mothers. The study provided considerable valuable information on the sunshine exposure/vitamin D relationship, including the fact that vitamin D concentrations in the blood of infants correlated directly with the degree of sunshine exposure, and that infants were able to maintain vitamin D concentrations within normal ranges with sunshine exposure of only 30 minutes a week when wearing diapers or two hours a week fully clothed. ▲





In the photo, the model is demonstrating use of the Baro-Cuff, a system typical of that developed for a cardiovascular study of weightless astronauts; it may help people who suffer from congestive heart failure or diabetes. The astronaut experiment was conceived by Veterans Administration Dr. Dwain L. Eckberg; the equipment was developed by Engineering Development Laboratory (EDL), Newport News, Virginia for use on the Spacelab 4 mission as part of a broader Space Shuttle Life Science Experiments program. EDL then conducted an internal research and development program to reduce the complexity of the system and adapt it to Earth-based medical research applications.

During space flight, astronauts experience greater than usual blood pressure and heart rate instability, which sometimes induces postflight lightheadedness or even momentary blackout, temporary symptoms that gradually disappear, suggesting that weightlessness may impair the body's normal blood pressure controls. In the Spacelab 4 investigation, the Baro-Cuff will be used to study "resetting" of blood pressure reflex controls. A silicone rubber chamber strapped to the neck, the Baro-Cuff will stimulate the carotid arteries by electronically-controlled application of pressure or suction.

Patients with congestive heart failure, chronic diabetes mellitus and other conditions also experience abnormal blood pressure reflex controls. As a medical research tool, the Baro-Cuff will be used to study blood pressure controls and the results of stimulation in such patients.

In 1985, EDL delivered its first Model E-2000 Baro-Cuff System to the Veterans Administration Hospital in Gainesville, Florida, where it is being used in kidney function research. The company has also developed and sold specialized configurations for use by U.S. medical colleges in clinical investigations and is marketing the system to international researchers in the field of cardiovascular physiology. ▲

Treatment of cancer with chemotherapeutic drugs (chemotherapy) usually induces hair loss in patients, causing emotional distress and adding an often severe psychological problem to the physiological difficulty. A method of combating alopecia, as hair loss is called in medical parlance, is scalp cooling. It has been found that lowering the scalp temperature reduces the amount of drug absorbed by hair follicles and prevents hair loss in many patients, yet does not weaken the drug's anticancer effect.

A new scalp cooling system based on NASA space suit technology was introduced last year. Known as the CHEMO-COOLER™ Treatment Support System, it is produced by Composite Consultation Concepts, Inc. (CCC), Houston, Texas.

The accompanying photo illustrates the use of the CHEMO-COOLER during intravenous administration of chemotherapy. Under the patient's blue head covering is a network of flexible plastic tubing through which a coolant—usually cold water—is pump-circulated from the reservoir (white cylinder). A thermistor, placed directly on the scalp, senses the surface temperature of the scalp and reports to the controller (black box in right foreground). The controller regulates the cooling temperature within preset limits and provides a digital readout of scalp temperature and elapsed treatment time. The scalp is cooled before, during and after drug administration, the cooling time determined by the type of drug, dosage and other factors.

A study of cancer patients given drugs known to cause alopecia anticipated that none would retain as much as 25 percent of his hair; with the CHEMO-COOLER, 63 percent lost virtually no hair and nine percent suffered only moderate hair loss.

The basic technology involved in the CHEMO-COOLER stems from Johnson Space Center (JSC) development of a liquid cooling undergarment, worn beneath a space suit, through which coolant is circulated to remove the excess body heat of astronauts. In a 1970s community service project, JSC used that technology to develop an experimental scalp cooling system for a cancer patient. The system worked well on the single patient, but the technology lay dormant for several years thereafter—until Virginia Hughes, a JSC employee, contracted lymphoma, a form of cancer for which chemotherapy was prescribed. Her husband—H. Merv Hughes II, a senior management analyst with JSC—requested permission to use the scalp-cooling prototype in an attempt to spare his wife the emotional anguish associated with hair loss. For the second time the prototype worked well; Mrs. Hughes still has a full head of hair.

While going through the daily chemotherapy treatments, Merv and Virginia Hughes decided to make the technology available to others by commercializing the system. After retiring from NASA, Hughes formed CCC to refine and improve the scalp-cooling system and to develop other spinoff products for commercialization. CCC's CHEMO-COOLER bears little resemblance to the JSC prototype; the company spent 3-4 years in development and test before bringing it to the commercial market in 1985. ▲

™ CHEMO-COOLER is a trademark of Composite Consultation Concepts, Inc.

A system for assessing passenger ride comfort highlights spinoffs in the field of transportation

In designing any kind of transportation vehicle, a major consideration is assuring that passengers get a smooth, comfortable ride. Until recently, that was difficult, due to the lack of a reliable and accurate method of measuring the "ride quality" of the vehicle being developed. Ride quality evaluations were based on the subjective judgments of individuals involved in system testing; this imprecise method often caused costly and time-consuming adjustments, sometimes requiring redesign and retooling, to get the desired level of ride comfort.

Last year, Wyle Laboratories, Hampton, Virginia, introduced to the commercial market an instrument that eases the job of the ride quality engineer, a portable Ride Quality Meter designed to measure the discomfort level of a vehicle passenger subjected to complex vibrations and noise. Produced under NASA license, the system is based on a prototype meter and computer model developed by Langley Research Center. Offering the first verifiable way of measuring ride quality, it is a design and diagnostic tool applicable to development of passenger cars, trucks, buses, trains, aircraft, spacecraft and a wide range of special purpose transportation systems.

The Langley ride comfort research program was an offspring of NASA studies, conducted more than a decade ago, of how new types of controls might contribute to smoother rides in passenger aircraft and surface vehicles. In the course of that research, it became apparent that there was a need for a mathematical model for estimating noise and vibration effects on passenger comfort and for the ultimate development of ride quality criteria.

To develop such a model, Langley sought to determine human comfort responses to vehicle vibrations—in different frequencies and in different axes—and noise in various octave bands. Over a period of 10 years, more than 3,000 people served as test subjects in a Langley ride quality simulator. During exposure to controlled combinations of noise and vibration, each subject was asked to make evaluations detailing the level of discomfort experienced. These responses provided the basis for development of the computer model, which transforms individual noise/vibration elements into subjective units, then translates the subjective units into a single discomfort index that typifies passenger sensation of the total environment.

In order to acquire data in actual vehicle operations, Langley developed a prototype portable ride quality meter, which was designed by Wyle Laboratories under NASA contract. That development provided the technology for the Wyle Ride Quality Meter, which the company describes as "the most important advance in ride quality engineering to date."

Mounted on the vehicle to be evaluated, the Ride Quality Meter gets its vibration input from an external package of sensors and its noise input from a commercial sound level meter. About the size of a breadbox, the meter includes a computer and its Langley-

developed software, conditioning elements, a liquid crystal display and a printer. The conditioning elements filter, amplify and average the sensor-generated noise and vibration signals, which are computer processed to determine, display and print a set of discomfort indices representative of the subjective discomfort level produced by the noise and vibration. Among the printer outputs are: the total discomfort index; the vibration component of the total; the noise component; discomfort due to each of five axes of vibration; and discomfort due to individual noise bands. Thus, the meter serves as a "passenger jury" delivering a reliable and accurate verdict as to the ride quality of the vehicle being evaluated.

The system underwent extensive pre-production testing—by Langley/Wyle independently and in cooperation with vehicle manufacturers—and it performed well under a variety of ride conditions aboard helicopters, passenger cars, trucks, trains and surface effect ships. Since it represents the first known capability for summing the effects of noise and vibration into a single ride quality index, it has attracted considerable attention among government and industrial transportation interests; some of the nation's major manufacturers of transportation equipment—including Ford Motor Company, Firestone Tire and Rubber Company and International Harvester—were among the initial customers. ▲

In the upper photos, a technician is using a Wyle Laboratories Ride Quality Meter to assess the level of comfort experienced by passengers in vehicles of the Baltimore Metro system. Shown in closeup above, the Ride Quality Meter includes noise and vibration sensors and a computerized meter that processes the sensor-generated data, then displays and prints a ride quality reading.

For Chrysler Corporation, computer technology is an integral part of all automobile manufacturing operations; the corporation's operations are supported by one of the world's largest computer systems—16 mainframe computers, processing 464 million instructions per second, connected to 700 terminals.

One phase of Chrysler's work is illustrated in the above photo, which shows a computer-aided design system used to create vehicle body designs, including panels, steering geometry, suspension and other systems. The imagery pictured was part of a seating study for the Chrysler LeBaron GTS, which is shown in final configuration at upper left.

One of the computer design tools employed by Chrysler engineers is a computer program developed by NASA's Lewis Research Center. Called SPAR (Structural Performance and Design), it is used to optimize the design of the outer body panels of Chrysler cars and trucks. SPAR's advantages are that it is interactive, easy to use and fast. It is used to solve relatively small problems when quick response is important; other programs provide the necessary structural analysis for large problems.

SPAR was supplied to Chrysler by NASA's Computer Software Management and Information Center (COSMIC)®, which routinely provides 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. COSMIC maintains a library of some 1,300 programs applicable to a broad spectrum of business and industry operations. ▲

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The airplane pictured is the new Air Shark I, a four-place amphibian that makes extensive use of composite materials and cruises at close to 200 miles per hour under power from a 200-horsepower engine. Air Shark I is a "homebuilt" airplane, assembled from a kit of parts and components furnished by Freedom Master Corporation, Satellite Beach, Florida. The airplane incorporates considerable NASA technology and its construction benefited from research assistance provided by Kennedy Space Center (KSC).

In designing the Shark, company president Arthur M. Lueck was able to draw on NASA's aeronautical technology bank through KSC's computerized "recon" library. As a result of his work at KSC, the wing of the Air Shark I is a new airfoil developed by Langley Research Center for light aircraft. In addition, Lueck opted for NASA-developed "winglets," vertical extensions of the wing that reduce drag by smoothing air turbulence at the wingtips. The NASA technology bank also contributed to the hull design. Lueck is considering application of NASA laminar flow technology—means of smoothing the airflow over wing and fuselage—to later models for further improvement of the Shark's aerodynamic efficiency.

A materials engineer, Lueck employed his own expertise in designing and selecting the materials for the composite segments, which include all structural members, exposed surfaces and many control components. The materials are fiber reinforced plastics, or FRP. They offer a high strength-to-weight ratio, with a nominal strength rating about one and a half times that of structural steel. They provide other advantages: the materials can be easily molded into finished shapes without expensive tooling or machining, and they are highly corrosion resistant. The first homebuilt to be offered by Freedom Master, Air Shark I completed air and water testing in mid-1985 and the company launched production of kits. ▲

Flexible circuitry is an arrangement of printed wiring that offers certain advantages over other means of interconnecting the components of an electronic system. First applied on military aircraft and missiles, where size, weight and reliability are of primary importance, the circuitry's flexibility allows it to be molded to the shape of a chassis for marked reduction in bulk. Although flex circuits generally cost more than conventional connectors, they nonetheless offer savings in some applications because they are less costly to install. The flexible circuit is also attractive in dynamic applications, those that involve continuous or periodic movement of the circuitry; in such applications, where reliability must be maintained over millions of flexing cycles, flexible circuits have demonstrated excellent performance.

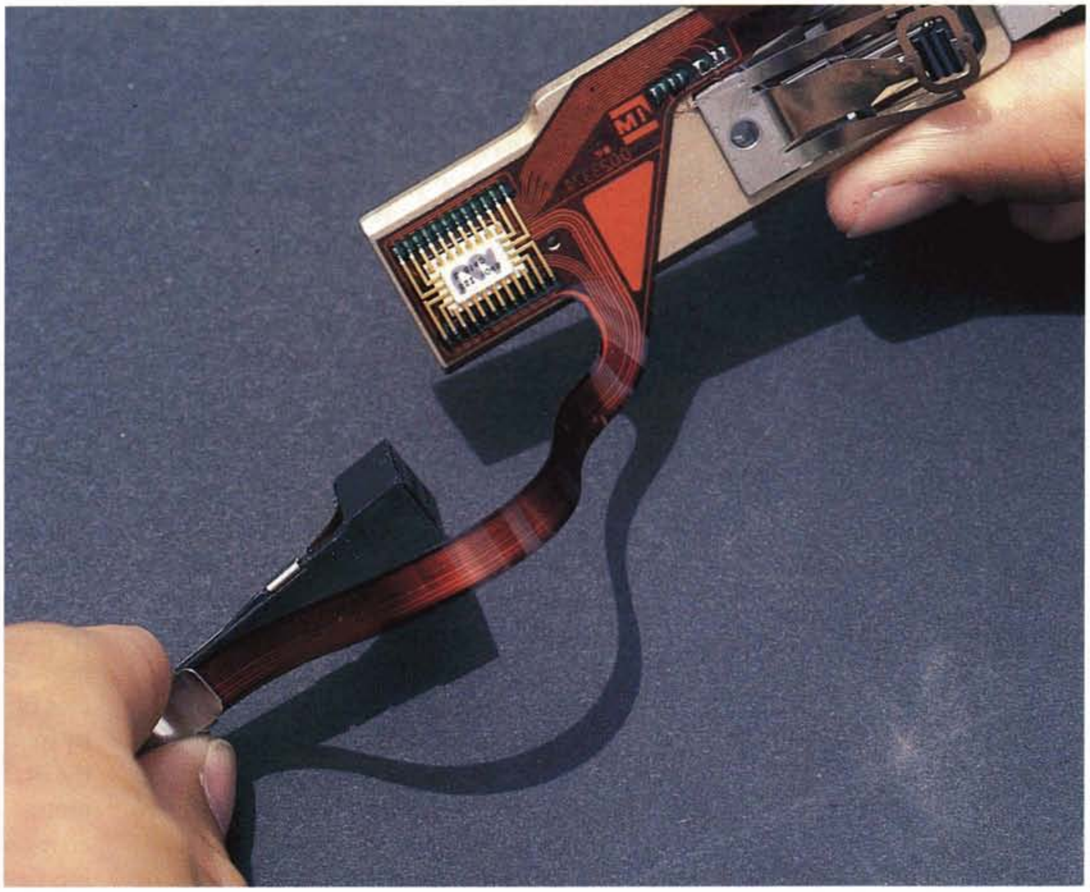
Now being used in a broad range of civil applications as well as in military and space systems, flexible circuits are produced by combining three materials: an insulating plastic film; a metallic conductor, usually copper foil; and an adhesive, one of several types of polymers, to bind the insulator and the conductor into a laminated circuit. The adhesive is important to the overall performance of the circuit and it is selected with care, taking into consideration such factors as bond strength; resistance to temperature during processing and in the operation of the end product; resistance to moisture, which can create "voids" or defects in the bond; insulation resistance; and the flexible lifetime of the printed circuit.

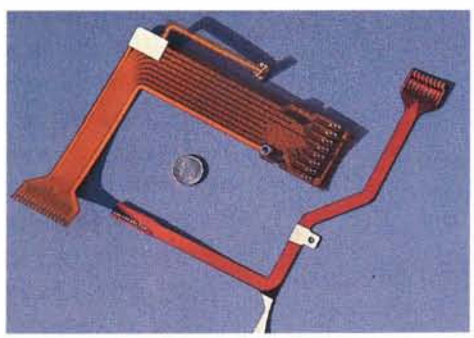
A new type of laminating adhesive has made its appearance in commercial manufacture of flexible electronic circuits. Developed by Langley Research Center, it is a thermoplastic polyimide resin known as LARC-TPI; it is being used to produce laminates, under an exclusive NASA license, by Rogers Corporation's Circuit Materials Division, Chandler, Arizona, one of the nation's largest manufacturers of flexible circuits. NASA has granted a license to Japan's Mitsui Toatsu Chemicals to produce the resin and Mitsui has built a plant for commercial production of the adhesive; NASA is in the process of licensing Rogers Corporation and three other companies to make the resin.

The family of linear polyimides of which LARC-TPI is a member are generally tough, flexible and have excellent mechanical and electrical characteristics over a wide temperature range. Hence, they have been used—and are being considered for broader future use—as structural adhesives for bonding together parts of aircraft, missiles and spacecraft subjected to high temperatures, for example, engine nacelles and cowls, or the friction-heated leading edge of a high speed airplane. The problem with linear polyimides is that they have been difficult to process.

Special requirements for bonding components of a proposed space system led Langley Research Center to undertake development of an advanced structural adhesive by chemically altering the structure of the linear polyimide to improve its overall characteristics and eliminate processing problems. The resulting LARC-TPI has substantially improved processability; it can be processed at lower temperature and it has good moisture resistance, both of which contribute to preventing formation of voids; and it has excellent adherence to a large number of plastics and metals. Although originally developed as a structural adhesive, LARC-TPI was found to have special utility in laminating flex circuits and it has other applications, such as a matrix for fiber reinforced composite materials; for high temperature resistant films, foams and fibers; and as a molding powder for void-free molded parts.

In its initial commercial application by Rogers Corporation's Circuit Materials Division it is being used as the adhesive that binds the insulating film Kapton® to copper foil conductor material in the manufacture of flexible circuits; the photo at left shows a spool of copper foil and a spool of Kapton. In the other photos are representative Rogers Corporation flexible circuits; the coins indicate size. The product line of the Circuit Materials Division spans a broad spectrum that includes flexible circuits for such consumer products as electronic watches, cameras, TV games, calculators and burglar alarms; industrial applications such as display panels, medical instruments, test instrumentation, optical controls and electrostatic copiers; computer jumpers, memories, terminals and printers; aerospace systems such as missiles, transponders, telemetry and avionics; such automotive applications as dashboard clusters, fuel controls, engine controls and pollution controls; and, in communications, CB radios, telephone receivers, telephone switching equipment, pagers and antennas. ▲





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Technology for Television

An energy saving device for television transmission highlights technology transfers in energy supply and conservation

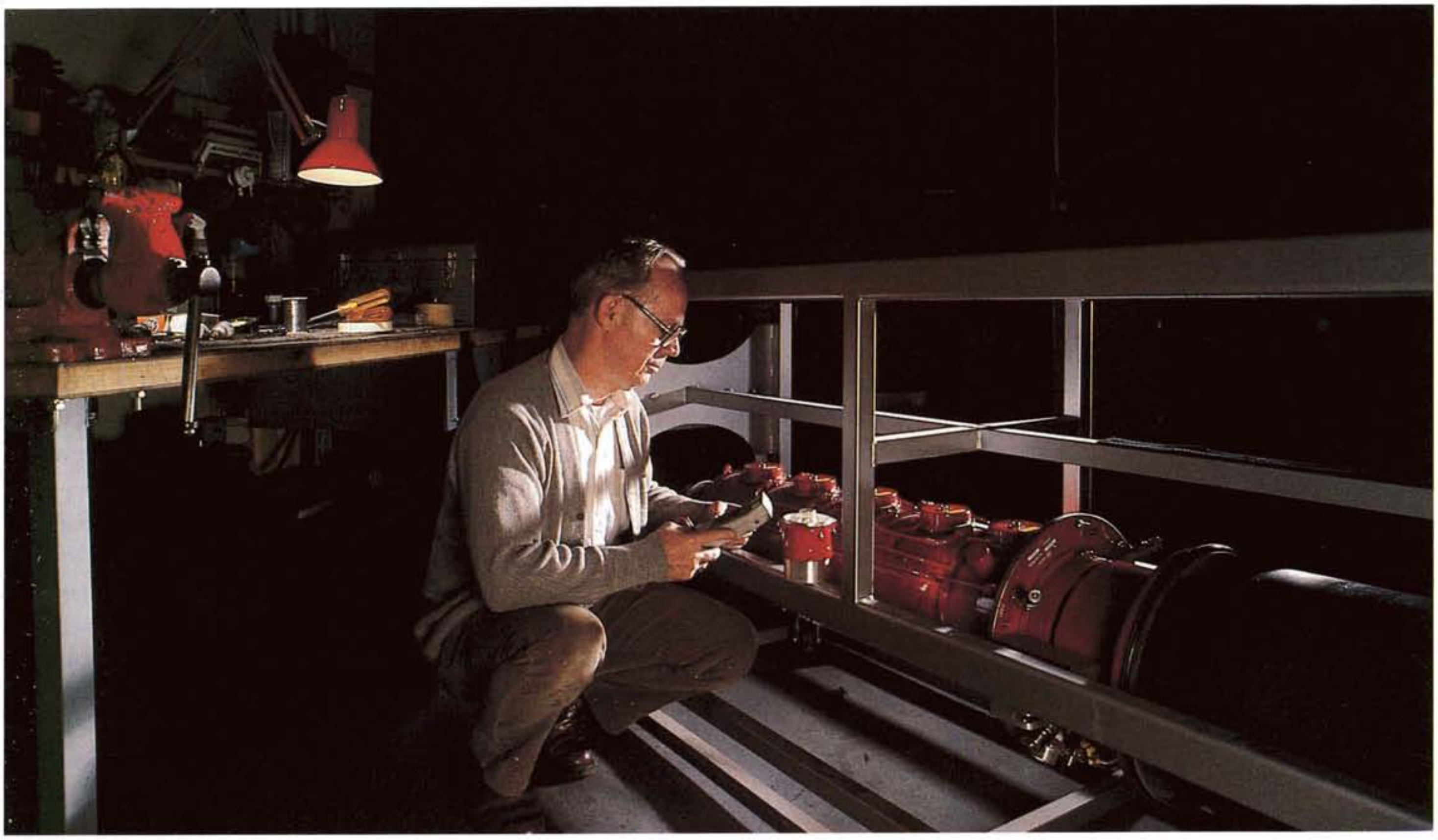
In 1952, the Federal Trade Commission adopted the dual-band system for television broadcasting, opening up the ultra high frequency (UHF) range in addition to the earlier established very high frequency (VHF) system. The number of UHF-TV stations on the air has grown steadily, from only six in 1953 to more than 400. But UHF-TV was born with a handicap that has never been corrected: UHF stations need greater transmitter power for adequate reception than is required for equivalent VHF reception and, additionally, the efficiency of UHF transmitters is inherently much lower than their VHF counterparts. As a result, UHF station operators must pay, on the average, about four times as much in electric utility costs as VHF stations, a substantial competitive disadvantage.

UHF electricity costs could be sharply reduced if there were available power amplifying devices with efficiencies comparable to those of VHF. Such a development is the aim of a NASA technology utilization program involving adaptation of space technology to UHF transmissions; the program is being conducted by Lewis Research Center (LeRC) in cooperation with the UHF-TV broadcast industry.

The project is based on work in the early 1970s by LeRC's Dr. Henry Kosmahl, who developed a radio wave amplifier to improve efficiencies of communications satellite transmissions. Called a Multistage Depressed Collector, or MDC, the amplifier allowed satellites to transmit more powerful signals, thus making possible the use of smaller, less costly Earth terminals for signal reception. Dr. Kosmahl later conducted preliminary research on adapting the MDC to boost the efficiency of UHF-TV klystron transmitters.

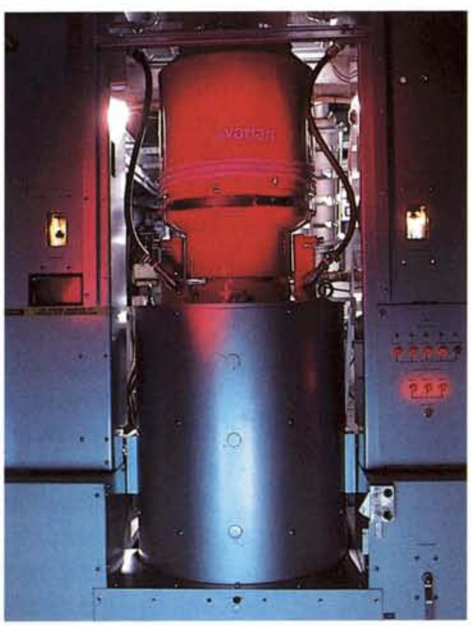
The klystron is a vacuum electronic tube used to generate and amplify ultrahigh frequencies for broadcasting TV signals. The kylstron abstracts radio frequency energy from a high voltage electron beam when amplifying UHF-TV signals, but it does so at a low level of efficiency; on the average, only 10-15 percent of the beam energy is converted to radio frequency energy. The rest is dissipated as heat, mostly dumped into cool water. The concept behind the LeRC development program is that the MDC could recover much of the energy being wasted by recycling a large part of the electron beam energy. LeRC feels that efficiencies up to 30 percent can be attained by modifying klystrons to incorporate the MDC and another Lewis development—a spent beam refocuser—that changes the magnetic field shapes of electron beams in a manner designed to aid the energy recovery function of the MDC. Efficiency gains of the order contemplated would result in energy savings of 50 percent for UHF-TV stations.

The MDC klystron development project is being conducted, under LeRC contract, by Varian Associates, Inc., Palo Alto, California, the largest manufacturer of UHF-TV klystron tubes in the United States and Canada. Jointly funded by NASA, the National Association of Broadcasters and Public Broad-



casting Systems, the program is in the second year of a planned three-year effort. The initial design and materials selection phases have been completed and 10 experimental MDC klystrons are being built and tested to demonstrate their performance capabilities.

If the development effort proves successful, it would offer benefits of significant order to the UHF-TV industry. A typical 200,000-watt UHF-TV station in a medium-to-large metropolitan area spends some $300,000 a year on electricity; thus the target efficiency of 30 percent for MDC klystrons would allow a saving of $150,000 for the typical station, an estimated $45 million a year nationwide. ▲



Above, an engineer of station WETA-TV, Bethesda, Maryland, is checking an experimental advanced klystron prior to installation; the installed klystron is shown at left. Klystrons generate and amplify UHF-TV broadcast signals; a NASA/industry development program seeks to improve klystron efficiencies for large-scale savings in energy costs.

The search for alternative fuels sparked by the oil crises of the 1970s prompted extensive research and development investments, by both government agencies and private firms, toward new forms of coal. Progress in that area, coupled with increased emphasis on reducing energy costs, has brought coal more prominently into the U.S. fuel picture in recent years. Among a number of techniques aimed at developing practical, environmentally acceptable coal forms as fuel for large energy users are ways of producing "clean" coal or coal slurries—pulverized coal mixed with oil or water. Coal slurries offer several advantages, in particular a significantly lower cost than oil.

One company involved in developing improved coal-cleaning and slurry fuel processes is Advanced Fuels Technology (AFT), Cleveland, Ohio. AFT has developed an economical process for cleaning coal that removes up to 85 percent of the mineral sulphur and an average 75 percent of the ash. Coal thus cleaned provides more energy with less variability in burning characteristics; it also provides better boiler performance and reliability while reducing air-pollutant emissions. At left is the control room of AFT's pilot plant at Bridgeport, New Jersey where coal development work is conducted; in the lower photo is a ball mill that grinds the coal in preparation for cleaning and slurrying.

In the course of their coal-cleaning technology development, engineers at AFT-Bridgeport tested unclean slurry against clean slurry to determine the amount of sulphur and ash that would be allowable. To evaluate the products left after combustion—solid, liquid and gaseous materials—AFT employed a computer program developed by Lewis Research Center that provides specific capabilities for determining products of combustion. The program was supplied to AFT by NASA's Computer Software Management and Information Center (COSMIC)®, located at the University of Georgia. COSMIC maintains a large library of programs originally developed by NASA and other technology-generating agencies of the government and routinely supplies them to government and industry customers at a fraction of their original cost. 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. AFT reported a saving of four man-months that would have been required to develop similar software had the Lewis program not been available. ▲

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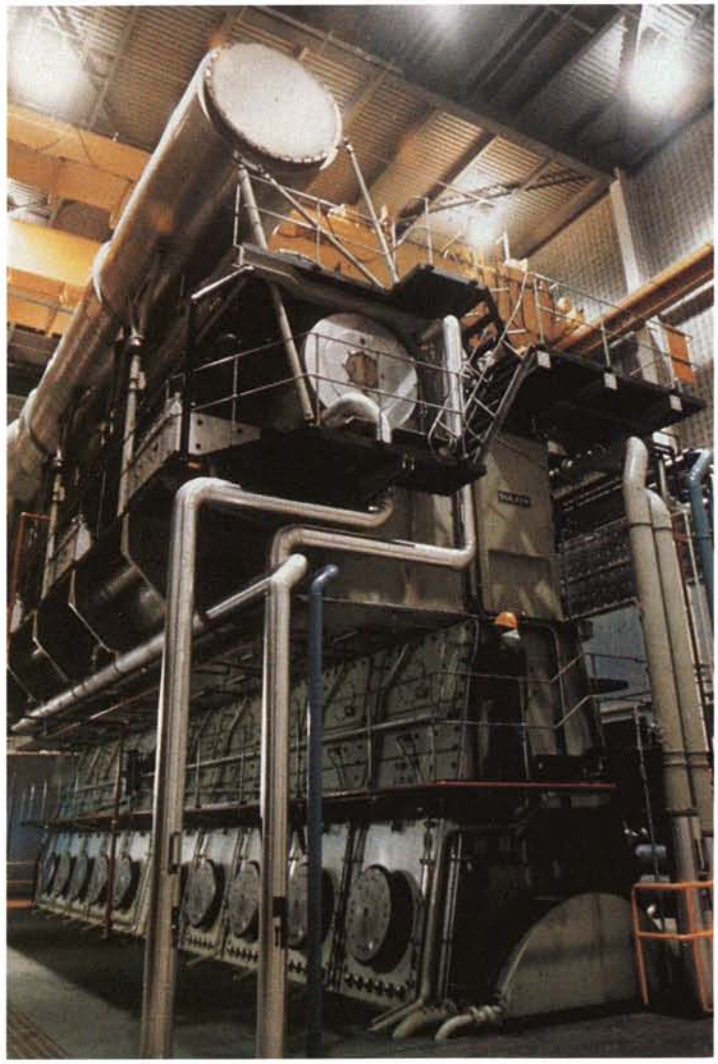
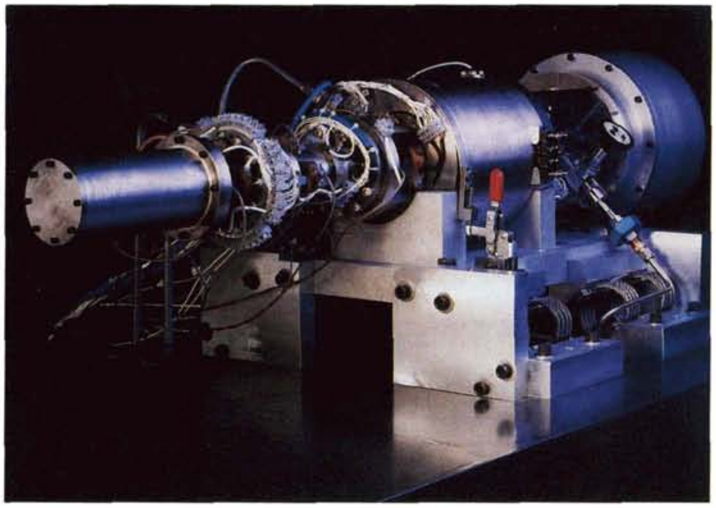
Cogeneration is the use of one energy source—usually coal, oil or gas—to produce both process energy and electricity. For example, a school that burns coal to heat its buildings can often fit a small generator into the system to tap the excess steam energy and generate a portion of the electricity it needs. Or a mine using diesel engines to run ore processing equipment can use excess engine heat to drive a small generator. Cogeneration turns waste heat into power, conserving natural resources and reducing operating expenses.

The Energy Systems Division of Thermo Electron Corporation, Waltham, Massachusetts specializes in custom design of cogeneration systems. Many companies manufacture the components of the cogeneration system—boilers, turbines, valves, generators, piping, pressure regulators, etc. Two such components are pictured: in the upper photo is a 22,300 kilowatt diesel prime mover and in the lower photo is a steam turbine rotor. Thermo Electron engineers analyze the needs of the customer and the parameters of the components to design a system of maximum efficiency, using a computer modeling system to predict the fuel efficiency that would be achieved with different brands, sizes and models of boilers or turbines or piping.

One element of Thermo Electron's computer system is a software package called PRESTO (Performance of Regenerative Superheated Steam Turbine Cycles), supplied by NASA's Computer Software Management and Information Center (COSMIC). Developed by Lewis Research Center, PRESTO is flexible enough to handle the specifications for most energy systems and precise enough to give a realistic prediction of design efficiencies. An engineer can enter a manufacturer's specifications for different models of a turbine, for example, and check the effect of each model on system efficiency quickly and accurately. PRESTO is not the only program that can perform such calculations, but alternative software was much more expensive. Thermo Electron estimates savings on the order of $13,500 a year through use of PRESTO. ▲





Satellite-based scientific instruments that observe in certain non-visible portions of the electromagnetic spectrum—such as infrared, x-ray and gamma ray detectors—must be kept at supercold temperatures to pick up the faint levels of energy emanating from distant bodies in space. This has been accomplished so far by use of cryogenic gases that cool the instruments to temperatures 300 degrees or more below zero Fahrenheit. But there is a problem with this approach—the cryogenic gases boil off gradually, thus limiting the satellite's data gathering lifetime to about a year. An alternative approach investigated by NASA is the closed-loop cooling system, in which the same gases are used over and over. This technique could lengthen satellite life, but it poses new problems: wear of the system's mechanical components due to friction and possible contamination of the coolant by organic materials and lubricants. For planned orbital observatories that will be operating in the 1990s and beyond, NASA is looking for a superior refrigeration system that will cool instruments for five years or more without generating adverse effects on other components of the observatory.

Goddard Space Flight Center (GSFC) believes it has the solution: a novel refrigeration system whose components work without seals, lubricants or conventional bearings and do not wear down from friction. Developed with GSFC guidance by Philips Laboratories, Briarcliff Manor, New York, a division of North American Philips Corporation, the system offers an extraordinary range of potential spinoffs—in industrial applications, medical research, computers, food processing and robotic machinery—because of its long-life, friction-free, non-contaminating characteristics.

Called the Stirling Cycle Cryogenic Cooler, the NASA/Philips closed-loop system is designed to produce five watts of supercooling to 65 degrees Kelvin, which corresponds to minus 343 degrees Fahrenheit. Friction is eliminated by use of electronically controlled linear magnetic bearings—rather than conventional sliding or ball bearings—so that the refrigerator's components remain levitated while working, centered in magnetic fields and moving without touching the sides of their housing. The design minimizes the chance of mechanical failure through employment of a direct linear drive motor that drives a piston and displacer, eliminating the mechanical linkages and shaft required by rotary motors. Contamination of the system's helium working fluid is eliminated by metal and ceramic construction and by the fact that no lubricants are needed.

The initial model, called the Proof of Principle Model, has successfully completed more than two years of operation without degradation of performance and it has demonstrated its ability to cool to 65 degrees Kelvin. Philips Laboratories is fabricating a second generation cooler, known as the Technology Demonstration Model, that has design refinements for survival of Shuttle launch and operations in space; it is scheduled for completion in the late spring of 1987.

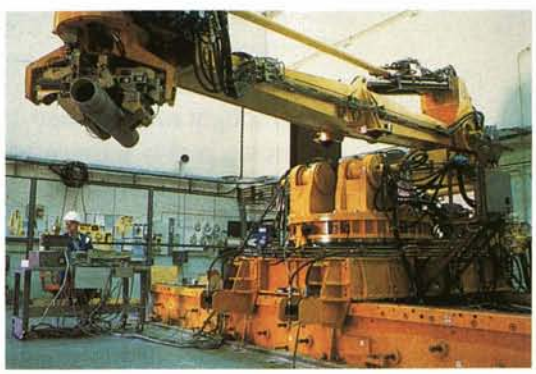
Philips Laboratories, which seeks to identify and develop technologies that will be important to the parent company's business five to 10 years in the future, sees a variety of Earth-use possibilities for the cooler technology. It could, for example, be adapted to development of pumps, motors, compressors and other mechanical devices featuring longer, wearproof lives. ▲

Shown at right, the "Canadarm," or Remote Manipulator System as it is known to NASA, is a Space Shuttle-based crane that performs a variety of functions, operating as a 50-foot extension of an astronaut's arm either automatically or under astronaut control. Weighing less than 1,000 pounds, the arm is capable of lifting 65,000 pounds (the equivalent of a fully-loaded bus) in the weightlessness of space. Usually employed to deposit payloads in orbit or to retrieve malfunctioning satellites for repair, the versatile Canadarm has also been used as an astronaut work platform, as a huge tool to knock an ice plug from a frozen Shuttle drain line, and as a robotic hand flicking a flyswatter in an attempt to start an errant satellite. Redesigned versions of the Canadarm are now finding Earth-use utility in energy and mining uses.

Designed and built by Spar Aerospace Limited, Toronto, Ontario, under contract to the National Research Council of Canada, the Remote Manipulator System was Canada's contribution to the Space Shuttle program, funded by the Canadian government in the conviction that the technology would generate Earth spinoffs. The first spinoff version, its sophisticated software and some of its hardware redeveloped to work in an Earth gravity environment, will go into service late this year with Ontario Hydro, a Canadian provincial electric power company.

The Hydro manipulator (lower right) will be employed in refurbishment of the utility's Candu nuclear reactor. Capable of lifting more than 2,500 pounds, the system has a grasping accuracy to within one-tenth of an inch; it will be able to maneuver the brittle, highly radioactive calandria tubes for more than 25 feet without wavering a fraction of an inch. Additionally, the device will be used to perform about 60 other tasks under the direction of an operator outside the reactor chamber. Its use will enhance safe and timely reactor refurbishment and save the utility money in the process; its economic advantage is evident in the fact that downtime of a reactor costs Ontario Hydro $250,000 a day for alternative energy.

Last year, Spar Aerospace signed a memorandum of



understanding with Inco Limited, Mississauga, Ontario, the world's largest nickel producer, to join in development of remotely controlled underground mining equipment, based on Canadarm technology, for improved safety and productivity in deep-Earth, hard-rock mining. ▲

At left, employees of Intellinet Corporation, Baltimore, Maryland, are fabricating units of the company's Power Phaser® Series MSP-II solid state motor starters; a completed unit is shown at right center.The starters electronically regulate the starting current and running voltage of any alternating current (AC) motor; they are designed to reduce energy consumption, lower maintenance costs and extend motor life. The Power Phaser systems incorporate technology originally developed at Marshall Space Flight Center (MSFC) as part of NASA's energy conservation research in support of the Department of Energy.

In the mid-seventies, MSFC sought to find a way of curbing power wastage caused by the fact that AC motors operate at a fixed voltage. The fixed voltage is what motors need to handle the heaviest loads they are designed to carry. But a motor usually does not operate at full load conditions. Nonetheless, it gets full-load voltage while operating at less than full-load, even while idling, and the cumulative power wastage—considering the millions of electric motors in service—is of enormous order.

MSFC engineer Frank Nola came up with an answer: a device called the Power Factor Controller (PFC) that matches voltage with the motor's actual need. Plugged into a motor, it continuously determines motor load by sensing shifts in the relationship between voltage and current flow. When the PFC senses a light load, it cuts the voltage to the minimum needed; this in turn reduces current flow and heat loss. Laboratory tests showed that the PFC could trim power used by six to eight percent under normal motor load conditions and as much as 65 percent when the motor was idling. With such potential for energy savings, the PFC quickly became one of the most widely adopted technology transfers; more than 150 companies sought and were granted NASA licenses for commercial use of the technology.

Intellinet used the PFC technology as a departure point for its own five-year research and development effort that culminated in the introduction of the Power Phaser MSP-II motor starter, featuring "soft-start" and "load-responsive" control modes. In the soft start mode, the system controls the voltage applied to the motor so that the motor accelerates gradually and smoothly, rather than abruptly; this protects motor, gears and belts from mechanical stresses caused by instantaneous starting. The Load-Responsive™ control tunes voltage to match the motor to its load almost 200 times a second; during periods when motor loads are light or line voltage is high, the Load-Responsive circuit automatically reduces operating voltage without reducing motor speed.

MSP-II starters also have a number of motor protection features, including the basic fact that curbing excess energy lowers motor heat and thus extends the useful lives of electrical insulation and bearing lubricants. Another feature is a proprietary Diagnostic Module, whose indicator lights help in quickly isolating faults in the control system, power line or motor and load.

The photos illustrate some applications of the MSP-II starters. At upper right an engineer is checking gages after a comparison test at an industrial facility.

The gage at his left monitored a motor equipped with an Intellinet starter/controller; it registered power usage some 25 percent less than the right gage, which checked a motor not equipped with the Power Phaser.

At Baltimore's Fort Howard Veterans Administration Hospital, the patient air system supports kidney dialysis and other critical procedures. Because the system must be available at all times, it is supported by the hospital's emergency power system in the event that public utility power fails. In emergency tests, starting surges from the system's three compressor motors, cycling off and on in response to air pressure demand, overloaded and cut off part of the hospital's backup system. Intellinet provided a motor control center (right) equipped with three Power Phasers and now, because of the soft-start feature, emergency power tests work without a hitch, no matter what the cycle rate.

At a United States Gypsum factory, starting the final segment of a 750-foot-long conveyor (right) sometimes broke drive chains and interrupted production for several hours. Intellinet field engineers studied the problem and supplied a motor starter that operates with a variable-speed drive and provides smooth starts; it solved the problem. ▲

TM Power Phaser and Load-Responsive are trademarks of Intellinet Corporation.

SPINOFF FROM A MOON BOOT

A new line of athletic shoes typifies aerospace technology derivatives for consumer, home and recreational use

The Apollo lunar suit worn by a dozen moonwalking astronauts was a masterpiece of design and engineering, a complex space system that included a built-in artificial atmosphere for breathing and pressurization, protection against temperature extremes, micrometeoroid shielding, eye protection against blinding glare and a score of other features intended to assure lunar mobility with safety and comfort. One little-known feature was use of a special three-dimensional "spacer" material in the lunar suit's boots for cushioning and ventilation. That material has turned up, in modified form, as the key element of a new family of athletic shoes designed for improved shock absorption, energy return and reduced foot fatigue.

Manufactured by KangaROOS USA, Inc., St. Louis, Missouri, the new line of shoes resulted from a two-year research and development program. The company sought to reduce athletic impact forces, which are transferred by the muscular-skeletal system through the foot and lower leg, and at the same time provide "medio lateral control" or lateral stability. The problem was that the two functions were inversely related—if conventional design techniques were employed, improving one would work to the disadvantage of the other.

The development effort involved KangaROOS High Performance Development Division, aided by consultants, and used as an informational base a study performed by NASA's Aerospace Research Applications Center, Indianapolis, Indiana. From this effort emerged the Dynacoil™ athletic shoe cushioning system, featuring a departure from conventional design that, says the company, not only reduces impact shock and provides the requisite lateral stability, but also contributes to increased athletic efficiency.

The mechanical core of the cushioning system is "Tri-Lock" three-dimensional space fabric; an advancement of the original lunar boot material, the woven fiber fabric includes a series of fiber coils as the third dimension. In the KangaROOS Dynacoil midsole design, the space fabric is encapsulated within a polyurethane foam carrier, which in turn is surrounded by a stable "motion control rim."

This design, says KangaROOS, produces a cushioning system that loses virtually none of its shock-absorbing capabilities throughout the life of the shoe. The Dynacoil midsole attenuates the pounding that accompanies running and court sports by virtue of the fact that the waves of interlocking fibers engineered into the space fabric spread the impact of foot strike over a longer time interval, greatly reducing impact forces. In addition, KangaROOS states, the midsole's exceptional resiliency helps cycle energy back into the athlete. The company explains:

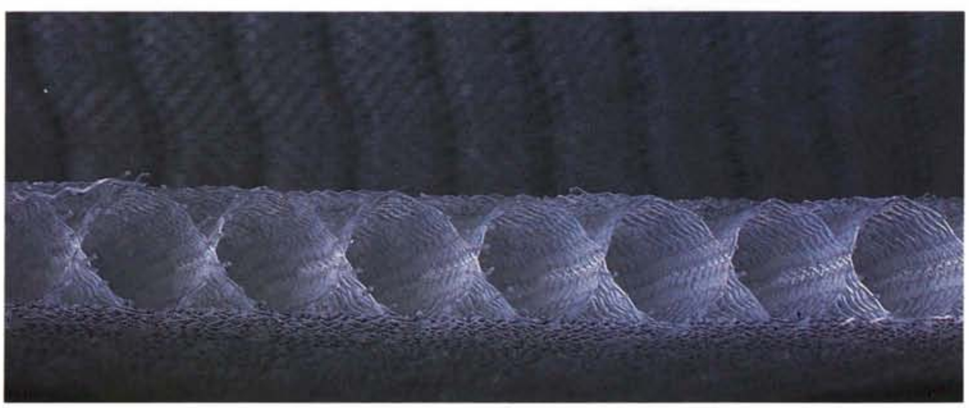
"As the foot makes contact with the ground, the encapsulated space fabric is compressed. As the foot begins to reach the end of its stride, the heel-to-toe waves of fibers provide a rebound effect, producing upward force much

Team KangaROOS runners and Olympic milers John Walker and Ray Flynn are wearing a new type of athletic shoe that incorporates technology from lunar astronauts' boots.

like that of a resilient spring. The 'coiled energy' effect actually absorbs and redistributes energy back into the athlete with every step in a Dynacoil midsole. This energy saving adds to athletic efficiency and reduces foot fatigue."

Subjective wear tests by athletes and additional testing by independent biomechanic and exercise physiology laboratories support the company's claim that KangaROOS Dynacoil offers superior shock absorption, stability and motion control. KangaROOS plans a complete program of Dynacoil-based footwear to include running, tennis, basketball, aerobics, walking and cleated shoes, each product design-tuned—by scaling the shape and size of the fabric coils—to a specific sport and individual athlete. ▲

M Dynacoil is a trademark of KangaROOS USA, Inc.



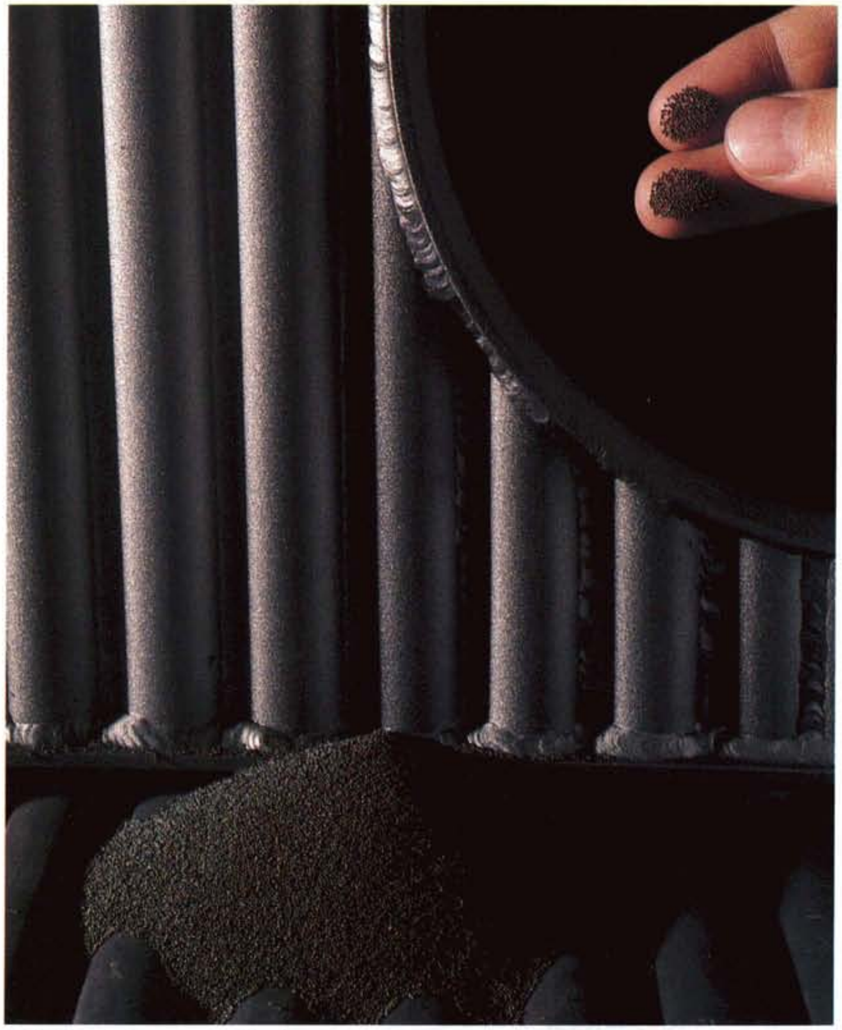
In the top photo are samples of KangaROOS shoes with Dynacoil midsoles designed to reduce user fatigue through improved shock absorption. The core of the cushioning system is a space-derived three-dimensional woven coil fabric shown in cross-section in the lower photo.

Chatham Manufacturing Company, Elkin, North Carolina is a large manufacturer of fabrics for furniture, auto interiors, wearing apparel, rugs, carpets and other products. Shown above is a display of Chatham blankets, produced by a patented Fiberwoven process on looms such as the one shown at left, where a company employee is inspecting a finished blanket for flaws. The looms were designed and built by Chatham Research and Development, a division of Chatham Manufacturing also located in Elkin.

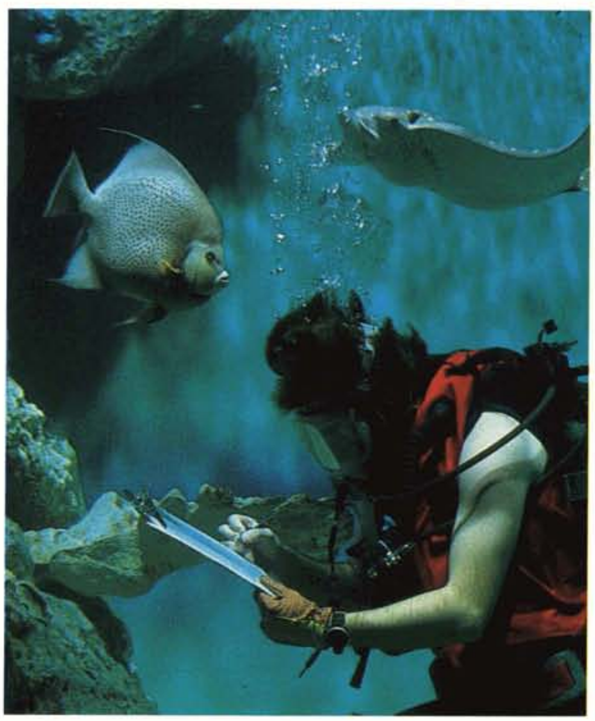
A key element in the machines' operation is the rocker arm assembly, a welded steel structure (right foreground in the lower right photo) that oscillates at very high speed, driving an array of barbed needles through the batt of fibers, thus entangling them to form the fabric. When the machines were first put into service, engineers discovered that the rapid oscillation created a problem for Chatham and other manufacturers to whom Chatham leases looms: it accelerated metal fatigue and caused fractures in the metal, a significant matter due to the high cost of replacing parts.

Chatham R&D tried to select materials and fabrication techniques to minimize the problem. They succeeded in reducing the incidence of failure, but the failure rate was still far too high. At that point, Chatham R&D sought problem solving assistance from the North Carolina Science and Technology Research Center (NC/STRC), Research Triangle Park, North Carolina, one of nine NASA-sponsored dissemination centers that provide information and technical help to industrial and government clinics. NC/STRC conducted a computer search of the NASA data bank and provided a number of reports on metal fatigue and crack propagation, several of which proved particularly pertinent and helpful in finding a solution.

Chatham R&D determined that metal fatigue was caused by tensile stress, that such stresses varied widely within a given piece of metal and that cracks generally develop on the surface; their goal, therefore, was to find a way of reducing surface tensile stresses. The NASA-provided literature suggested a method of doing that: build in a residual compressive stress; any tensile load applied to the part would have to overcome the compressive stress before the surface was put into tension, thus the resultant tensile load on the surface would be lessened.



The only practical method for creating compressive stress on large irregular surfaces, such as those of the loom machines, was by "shot peening," a technique in wide use in the manufacture of aircraft engine components and other aerospace parts. Shot peening consists of bombarding a part with a high velocity stream of very small shot, which act like thousands of tiny ball peen hammers pounding and compressing the surface of the part. Chatham R&D purchased a standard shot peening machine, modified it to handle the company's bulky machine parts and it proved to be the solution. Since then, Chatham has shot peened all moving parts of its machines, such as the rocker arm shown at right above; the black metal in foreground is unpeened, the silvery metal is a peened rocker arm and the tiny shot employed is shown on the fingers and in the mount at left. In eight years of using the technology, Chatham has not had a single failure of a part that had been shot peened and the savings are estimated to approach a quarter million dollars annually. ▲



At left is a Fisher Space Pen, one of a score of space pen models manufactured by Fisher Pen Company, Forest Park, Illinois. Originally developed for NASA astronaut record-keeping on Apollo missions, the pens were also purchased by the Soviet Union for cosmonaut use and the resultant publicity helped build a multimillion dollar a year civil market for the pens.

Developed personally by company president and founder Paul C. Fisher, the Fisher Space Pen was created to allow writing in orbit where ordinary pens that rely on gravity and atmospheric pressure for ink flows are inadequate. Fisher's answer was a cartridge pressurized with nitrogen. The cartridge seals out air, preventing evaporation and oxidization of the ink; interior pressure forces ink outward toward the ball point regardless of gravity condition or the position in which the pen is held. A companion Fisher development was a special "thixotropic" visco-elastic (rubberlike liquid) ink, needed because standard ink would ooze out of the ball point under pressure. The thixotropic ink is almost solid; only when the ball point revolves does friction liquefy just enough ink for smooth writing. These features combine to provide advantages in everyday Earth use of the pens, for example, uniform ink flow without skipping, long pen life, and the ability to write on many types of surfaces, even under water (lower left).

To meet NASA specifications, the Fisher Space Pen had to demonstrate failproof operation at temperatures from minus 50 to plus 45 degrees Fahrenheit and to withstand atmospheric extremes from pure oxygen to hard vacuum. The antigravity pen passed those tests and also demonstrated continuous-writing endurance several times better than the NASA requirement.

The pens were introduced to space service on the Apollo 7 mission and have been in regular NASA use since then. ▲

The sunglasses shown at right are Serengeti® Drivers, produced by Corning Optics, a division of Corning Glass Works, Corning, New York. They are unique in that their copper Spectral Control™ lenses self-adjust and selectively filter the light to sharpen the image while suppressing glare or blue light. The lenses act much like the haze filter of a camera, the company says, improving visibility and reducing eye fatigue by cutting through the scattered blue light in haze. The photochromic lenses adapt quickly to changing light conditions, darkening or lightening to optimize the level of light reaching the eye; they also eliminate more than 99 percent of the ultraviolet rays in sunlight.

The frames were also the subject of extensive research and their design benefited from use of technology contained in a NASA Anthropometric Source Book. Anthropometry is the study of the size, shape and motion characteristics of the human body; the three-volume NASA source book is probably the world's most comprehensive compendium of anthropometric data. Its compilation was intended primarily for use in designing clothing, equipment and workplaces in flight vehicles, but its information is also useful in a wide range of non-aerospace applications. Corning drew upon the NASA data in "bio-engineering" the Serengeti frames (right) for optimum fit and comfort. Featuring self-adjusting nose pads and hinges with self-locking screws, the frames are available in metal or tortoise-shell styles. ▲

® Serengeti is a registered trademark of Corning Glass Works.

™ Spectral Control is a trademark of Corning Glass Works.

Working under NASA contract in cooperation with the Florida Solar Energy Center (FSEC), Dinh Company, Alachua, Florida has developed a prototype heat pipe dehumidification system that can double the moisture removal capacity of any air conditioner and save substantial amounts of energy. This marks a major step in a NASA application engineering program intended to apply space-developed technology to control of humidity in building environments. Moisture removal remains a persistent problem in warm, humid climates, not only with respect to personal comfort but also in providing adequate dehumidification for proper storage and functioning of costly equipment. Heat pipe technology developed for temperature control of space electronic systems offers a promising approach to cost-effective dehumidification.

The idea of a heat pipe-based dehumidifier originated with Khanh Dinh, who at one time was associated with NASA's Southern Technology Applications Center (STAC), where he conducted research on gravity heat pipes. In 1981, Dinh visited FSEC and learned of a problem that FSEC was then investigating: the high energy losses incurred in extracting excess moisture from superinsulated buildings in very humid climates. In a moderately humid climate, a typical room air conditioner cools air and lowers humidity with normal cooling coil operation. In a highly humid environment, however, the same air conditioner will only partially reduce humidity, leaving uncomfortably humid room air. To lower the humidity to an acceptable level, the air conditioner must operate longer and use more energy. Then, in the process of lowering humidity, it overcools the room air; that necessitates reheating the air to get it back to a comfortable temperature—and that takes additional energy.

On the basis of his NASA/STAC experience, Dinh submitted a proposal to FSEC for an advanced energy saving dehumidifier fitted with three banks of heat pipes. FSEC accepted the proposal and had Dinh build an experimental air conditioner/dehumidifier, which was successfully tested. It attracted the attention of Kennedy Space Center's Technology Utilization Office, which awarded FSEC a contract to study the feasibility of the heat pipe-based dehumidifier. The following year, the newly-formed Dinh Company received a NASA contract for further development of the dehumidification system.

In the Dinh system, the heat pipes are used to precool the air before it reaches the cooling coil of an air conditioner. The cooling coil removes additional heat and humidity, then the heat pipes restore the overcooled air to a comfortable temperature. In other words, the cooling coil operates for a normal period of time regardless of humidity conditions and leaves the job of reheating to the passive heat pipes, which use no energy. With dryer air, the same comfort level can be attained with higher thermostat settings. Thus, the Dinh system offers typical energy savings of 15 to 20 percent.

The heat pipe is undergoing test at several sites in Florida, one of them the home pictured at left; the Dinh unit is the blue box nearest the garage door adjacent to the hot water tank (white cylinder); visible on the roof are the solar panels that provide electric-

ity for the heat pipe system. In another Florida home, Dinh Company has installed a retrofit cooling coil, known as the "Z" coil, on an existing standard heater/ air conditioner (above); the Z coil, which replaces the regular A coil evaporator, increases moisture removal by almost 100 percent. Khanh Dinh (at right in photo) is explaining the bonus benefit of a heat recovery unit, included in this installation, that takes heat removed by the Z coil during the dehumidification process and uses it to provide free hot water. The upper right photo shows the various components of the heat pipe dehumidifier. At lower right are a number of production units in various stages of completion; in the foreground, a company employee is performing a quality control check on the Z coil.

In 1985, Kennedy Space Center and the NASA Application Team instituted a three-year extension of the heat pipe technology program that involves further development and commercialization of the Dinh dehumidifier, optimization of dehumidifiers and heat pipes by FSEC, and support from Carrier Corporation for large-scale implementation of the heat pipe-based dehumidifier and comparison of its effectiveness with conventional approaches. NASA is sharing the funding and serving as technical monitor for the program.

Formed in October 1983, the Dinh Company is engaged in several areas of development related to heat transfer and solar power. In addition to the dehumidifier, the company has developed a photovoltaic (solar cell-powered) air conditioner and a highly efficient

solar-powered water pump. It is also planning development of a solar dish concentrator that combines photovoltaic and heat pipe technology in an attempt to make a dramatic reduction in the cost of solar electricity. ▲

A device that increases efficiency in smoke-cleaning precipitators leads a sampling of environment related spinoffs

Started in 1980, Project Recoup was a program for applying advanced technology to solution of a problem shared by a growing number of U.S. communities: how to dispose of refuse in areas where acceptable landfill sites are scarce. Jointly sponsored by Langley Research Center, Langley Air Force Base and the adjoining City of Hampton, Virginia, the program involved development of a Refuse-fired Steam Generating Facility that incinerates trash, reduces it to a readily-disposable ash, and employs the heat of trash-burning to create steam for practical use at Langley Research Center.

Shown above is the Refuse-fired Steam Generating Facility at Hampton, Virginia, a highly efficient trash-burning, energy-producing plant jointly developed by NASA, the Air Force and the City of Hampton. Effective air pollution control required development of an advanced electronic control system for the facility's precipitators, which remove pollutant particles from smoke.

A design base for modeling similar projects elsewhere, the facility has proved eminently successful. It disposes of all solid waste from the NASA center, the Air Force Base and other government installations in the area, and it also accommodates about 70 percent of Hampton's municipal waste. Hampton, principal financier for the project, realizes revenue from trash disposal fees and from the sale of steam to Langley Research Center. And there is an energy conservation bonus in that the steam generated by burning waste cuts the amount of fuel normally used at Langley by some two million gallons a year.

The project produced another bonus that has largely escaped notice: an air pollution equipment control device, developed of necessity in the course of the program, that is now commercially available. The device is an advanced electronic control for electrostatic precipitators, widely used in pollution control applications throughout industry. It is built by Kinetic Controls, Inc., Newport News, Virginia, a company formed by two NASA/Langley employees—T. K. Lusby, Jr. and David F. Johnston—who developed the control as their contribution to Project Recoup, working for the most part on personal time and with private funds.

The function of an electrostatic precipitator is to remove particulate matter from the combustion gas created by the burning of a fuel before the gas is expelled through a smokestack. The gas is passed through a precipitator chamber and exposed to an electrostatic field; dust particles in the gas become electrically charged and migrate to collecting surfaces under the influence of the field, thus cleaning the smoke. To maximize the capture of particles, a precipitator must be operated at the highest practical voltage; the limiting factors are phenomena known as "sparking" and "arcing," essentially electrical breakdowns of the gas that, uncontrolled, would decrease the precipitator's efficiency.

In developing the Hampton Refuse-fired Steam Generating Facility, researchers encountered a problem. When standard fuels are burned, the smoke is of relatively constant composition and the highest practical voltage is fairly constant; once the voltage is set, as long as the same type of fuel is used, only small changes in precipitator voltage are needed. But when refuse is used as a fuel, the composition of the smoke changes continually —and that requires corresponding changes in precipitator voltage over a very wide range. If a constant voltage were applied in a refuse-burning facility, it would have to be set very low to prevent sparking and the precipitator would, therefore, be less efficient.

So, to insure minimal pollution of the atmosphere, the two NASA-Langley employees undertook to develop an innovative, microprocessor-based control that automatically senses and compensates for the changes in smoke composition by adjusting the precipitator's voltage and current to permit maximum particle collection. It proved to be the answer to efficient precipitator operation at the Refuse-fired Steam Generating Facility, but it has much broader applicability. Because its developers included a number of advanced features—such as constant monitoring and control of sparking and built-in diagnostic capability—and because the control is adaptable to any electrostatic precipitator, it offers a reliable, high technology means of upgrading existing precipitators, regardless of whether they burn coal, oil or refuse.

Since late 1983, when they formed Kinetic Controls, developers Lusby and Johnston have been busy readying their product for the commercial market and building the first units. The controls are marketed through PrecipTech, A BHA Group Company, Kansas City, Missouri. In addition, Western Precipitation Division of Joy Manufacturing Company, Los Angeles, California, a manufacturer of electrostatic precipitators, also uses the technology in its systems. Both companies design customized units for their customers and Kinetic Controls manufactures the controls to the companies' specifications. Each of the companies has made its first installations and the future of the spinoff device appears promising. ▲

The spinoff electronic control system is in use at General Motors' Flint, Michigan plant (top). Above, a company technician is inspecting one of the installation's four control panels. The microprocessor-based control automatically senses changes in smoke composition and adjusts precipitator voltage and current to assure maximal removal of pollutant particles.

In mineral exploration, clues to the presence of precious metal deposits are obtained by analyzing rocks and soil to identify and quantify the specific minerals in the sample. There are a number of ways of effectively conducting such analyses, but they take time, are often costly and require use of a well-equipped laboratory. Barringer Research Limited, Rexdale, Ontario, Canada has designed, tested and is preparing to introduce to the commercial market a cost-effective, portable system—called Claypak—for rapid on-site analysis of clay minerals.

Claypak is an adaptation of Barringer's Hand Held Ratioing Radiometer (HHRR), which the company manufactures under NASA license. The HHRR was originally developed by Jet Propulsion Laboratory for "ground truthing," making on-the-spot examinations of ground targets as a means of verifying remotely-sensed data reported by NASA's Landsat satellites.

A radiometer is an instrument for measuring the intensity of reflected radiation as a means of discriminating among classes of visually-similar objects or, in mineral study, discriminating among different minerals present in a sample. The term "ratioing" describes an added capability of the Barringer HHRR: the system simultaneously analyzes radiation intensities in two separate bands of the spectrum and calculates the ratio of one to the other. This affords more positive identification of the material being analyzed. Computer-processed and displayed in digital form, the "reflectance ratio" enables analysts to determine the particular characteristics of the target. Ratioing radiometers have application in such areas as agriculture, water quality studies and determining pollution effect on forest cover.

The Claypak is a special version of the HHRR for use as an aid to precious metal exploration: it offers on-site identification and quantification of such clay minerals as kaolinite, illite, illite/smectite, chlorite, muscovite and biotite. In tests of more than 50 rock and soil samples from Alberta, Saskatchewan, Ontario and Nevada, the Claypak system correctly determined the mineral grouping in 94 percent of the cases wherein a mineral was present in a quantity greater than 10 percent. At upper left, the Claypak HHRR is shown in a simulation of a sample analysis; at left is the data processor, at right (blue box) the HHRR. The unit atop the HHRR is a portable artificial light source, needed in clay analysis because the system uses a region of the spectrum just outside of natural light wavelengths. At lower left, the black, masklike object is an accessory called the Core Viewing Attachment (CVA), used in analysis of small, drilled core subsurface samples such as the one pictured at left. The CVA clips over the radiometer's "eyes," causing it to "squint": this allows closeup measurements at a distance of 30 centimeters rather than the usual distance of more than 100 centimeters. ▲

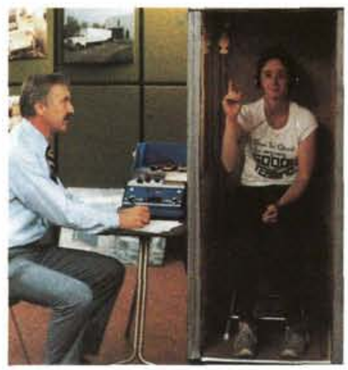
During development of the Apollo spacecraft, researchers found a severe vibration problem in an early version of the spacecraft's guidance system. The problem was traced to a plastic compound encapsulating the system's electronics; it did not absorb sufficient energy to dampen vibrations. Arthur C. Metzger, then NASA's resident manager at Massachusetts Institute of Technology, discovered 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 a company to develop and market the compound and associated products, a line of noise-deadening adhesives, sheets, panels and enclosures.

These materials are known as SMART® products (for Sound Modification and Regulated Temperature) and Metzger's firm is SMART Products Company, Inc., Framingham, Massachusetts. The company is finding scores of applications for its acoustic materials at a time when environment laws and labor union insistence are making it necessary for many firms to institute noise abatement measures. SMART products, 75 to 80 percent lighter than traditional soundproofing materials, have demonstrated high degrees of effectiveness. For example, an independent laboratory test that compared a comparable product with a SMART acoustical vibration damping pad for the American Motors Alliance auto showed that the SMART pad produced 15 percent better performance at 75 percent lower weight. Last year, American Motors introduced SMART pad on production Alliances and SMART Products licensed the Sanbree/Renault Corporations as worldwide sales agents for transportaion applications.

The photos illustrate two recent applications in other areas. Varian/Extrion Division of Varian Associates, Danvers, Massachusetts fabricates enclosures for high voltage terminals and other electronic system components. The work demanded considerable sanding and grinding in an open "snagging" area where employees were exposed to extremely high noise levels. Richard

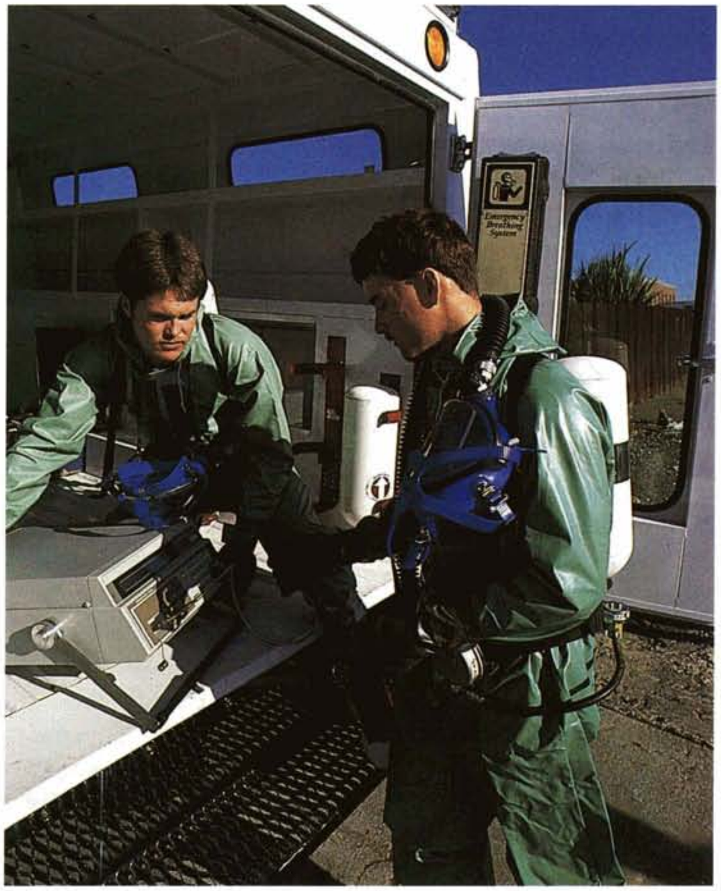
Sheppard, Varian's safety administrator, sought help from SMART Products in creating individual, less noisy work cells for the snaggers. Above, Sheppard displays the result: a work cell enclosed by a series of panels that incorporate SMART compound; the panels not only sharply reduce noise, they offer flexibility in that they are mounted on overhead tracks and can be shifted to vary the number and size of the cells as workload dictates.

SMART Products also manufactures audiometric test booths for industrial firms that must comply with a federal regulation requiring periodic hearing tests for employees who are consistently subjected to high noise levels. Easter Seal Center, Waterbury, Connect-



icut wanted a lightweight, portable booth that could be taken on the road to conduct the tests in factories. In the above photo, audiologist Thomas J. Kisatsky is conducting a hearing test using the SMART Micro One Minni Booth, which can be quickly disassembled and reassembled and is easily transportable. ▲

® SMART is a registered trademark of SMART Products Company, Inc.



At upper left is the Michromonitor™ M500 Universal Gas Analyzer, a portable system intended for field and laboratory use, operable by unskilled operators with little or no technical training. Heart of the system is a series of miniature modules, each of which is a complete gas chromatograph, an instrument that separates a gaseous mixture into its components, then measures the concentrations of each gas in the mixture.

Manufactured by Microsensor Technology Inc. (MTI), Fremont, California the system has a broad range of applications, such as environmental analysis, monitoring work areas for gas leaks or volatile chemical spills, industrial safety and hygiene, stack gas monitoring for compliance with pollution laws, analyzing industrial process gases, food processing, and identifying gases produced during energy exploration. The photos illustrate a special application by the U.S. Coast Guard, working in cooperation with the National Oceanic and Atmospheric Administration, for identification of unknown substances in public areas that might be hazardous. At left, two emergency team members of the Alameda (California) Coast Guard Station unload the Michromonitor from their response truck. At right, wearing safety gear, they are using the system to investigate a barrel that has washed up on the shoreline of San Francisco Bay. The Michromonitor identifies components of compounds in the barrel—or escaping from the barrel—and determines whether it is safe to handle and dispose of the barrel.

The miniaturized gas chromatograph technology on which the system is based originated in a NASA planetary research program. In the early 1970s, NASA was developing instrumentation for two automated Viking Landers destined to land on Mars and conduct extensive photographic and soil sampling research, including an effort to detect life on the Red Planet. One of the instruments planned was a gas chromatograph. Such systems were then in wide industrial and laboratory use, but they were generally very bulky units. NASA wanted an extremely sophisticated system capable of detecting respiratory gases given off by Martian microbes—if they existed—but the system also had to be very small and lightweight to fit in a spacecraft packed with other instrumentation for life detection, soil analysis and atmospheric sampling.

Ames Research Center designed such a miniature chromatograph and Stanford University built flight units for the Viking Landers. As things turned out, however, the system never went to Mars; the device had not been developed in time. But the technology interested the National Institute for Occupational Safety and Health (NIOSH), which was looking for a portable means of detecting toxic gas leaks in industrial environments. NIOSH funded further development of the Ames/Stanford gas chromatograph system. Subsequently, three Stanford researchers who had worked on the project left the university to form MTI for commercial application of the technology.

Anyone can use the Michromonitor after a few minutes instruction. The operator uses a pushbutton keyboard to select one to 10 gases for analysis, then touches a START button. The microcomputer automates the entire analysis cycle, calculating and displaying the gas concentrations. The system consists of a sensing wand connected to a computerized analyzer that measures gas concentrations as small as one part per million. The Michromonitor is programmed to identify as many as 100 different gases and it runs through a 10-gas cycle in 45 seconds. Then the operator pushes the DISPLAY button and the results of each analysis—identity of gas, its concentration in parts per million or percentage, the time of analysis—appear in the system's display window. ▲

™ Michromonitor is a trademark of Microsensor Technology Inc.

The black cylinder at left is an Aquaspace industrial filter used by a pharmaceutical manufacturing company to insure the purity of the water it uses in pharmaceutical processing. It is one of a line of filtration products, manufactured by American Water Corporation (AWC), Hollywood, Florida, that provide clear, safe, good-tasting water by removing all toxic contaminants, microbiological agents, chlorine and other water-processing substances used by utilities, unpleasant taste, color and odor. AWC produces a wide range of filter systems to meet a variety of needs ranging from camping filters to high capacity units for communities in developing nations where the water is highly contaminated.

For example, there is the Gemini Minisoftener-Purifier, the white tank unit (above), which not only filters the water but also removes the minerals that make the water hard; the Apollo Pocket Filter, the pen-like object at left in the same photo, which is used like a drinking straw; the Lunar, for camping (above right), the Carafe, for restaurants (near right) and, at far right, a new model for sinktop installation in home or office. There are also models such as Skylab, for undersink installation in the home, Spacecraft, a large capacity unit for restaurants and hotels, and a complete line of very large capacity commercial and industrial filters.

As the space-related names for many of the AWC products suggest, Aquaspace filters incorporate technology originally developed for manned space operations.

The key to the AWC filters is Aquaspace Compound, a proprietary AWC formula which, through a complex manufacturing process that the company keeps secret, scientifically blends various types of granular activated charcoal with other active and inert ingredients; a sample of the compound is shown in the large photo on the opposite page, the black substance in the small dish below the Gemini module. The systems remove some substances—chlorine, for example—by catalytic reaction, remove certain types of particulate matter by mechanical filtration, and still other substances—such as a suspension of organic vapor—by a combination of filtration and adsorption.

AWC's Dr. Ivo Pera began work in 1980 to find a more effective method of purifying potable water that was highly contaminated. His search of technical literature uncovered research accomplished by NASA concerning methods of on-board water purification in long duration manned spacecraft. Dr. Pera obtained a number of NASA reports on these efforts; NASA information that proved especially useful, he says, was technology related to use of silver ions in water sterilization and methods dealing with the absorption and adsorption of organic compounds. The NASA technology contributed importantly to Dr. Pera's development of Aquaspace Compound, which is finding wide acceptance in industrial, commercial and recreational applications in the U.S. and many foreign countries.

With Aquaspace Compound a success, Dr. Pera turned his attention to a related environmental problem: odor control. Using the technology arising out of the original research, AWC developed a new line of products based on a deodorizing compound called Biofresh™. One Biofresh product, called Frigipure—for preserving food and removing odors in refrigerators—is shown in the upper left photo next to the dish of Aquaspace Compound. Biofresh compound is composed of millions of tiny sponge-like granules containing hundreds of small

holes that trap gas and moisture inside the unit. Biofresh has a lengthy list of applications; to mention just a few cited by AWC: animal rooms, bathrooms, chemical plants, physicians' offices, exhaust hoods, greenhouses, kitchens, soap factories, tanneries and any unventilated space. ▲

™ Biofresh is a trademark of American Water Corporation.

All rights to Aquaspace were sold to Western Water International Incorporated, which is currently manufacturing Aquaspace water filter products in their Forestville, Maryland facility.

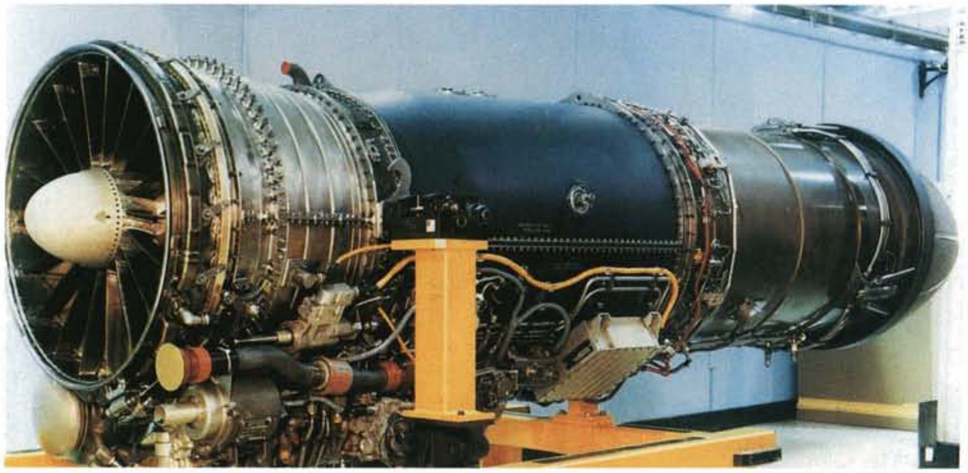
A new type of composite material heads spinoff advances in manufacturing technology and industrial productivity

In the never-ending quest for reduced weight in all types of aerospace vehicles, designers are more and more turning their attention toward composite fiber-reinforced materials, fibers bound together in a matrix. The resultant composite is generally lighter yet stronger than the metal it supplants. Extensive research and development over the past two decades resulted in expanding use of composite components, initially in military aircraft and missiles, later in commercial jetliners, more recently in private airplanes. Polymer matrix composites are also used in a broad range of non-aerospace applications where lower weight is advantageous, such as automobiles, boats, rapid transit vehicles and a variety of sports equipment from golf clubs to racing cars.

Until now composites have been limited to uses wherein they encounter only low or moderate temperatures. This year, composite materials development takes a giant step forward with the first use of a high temperature polymer matrix composite component as a primary structural member in a production-type jet engine—General Electric Company's F404, power plant for the Navy's F/A-18 strike fighter. The composite segment is the engine's outer duct, a passageway for "bypass" air, cool air that bypasses the compressor section and is ducted toward the rear of the engine to mix with the hot exhaust gas. The mix increases engine thrust and the cooler bypass air serves as a coolant for afterburner parts that operate at very high temperatures.

The composite material replaces titanium that had to be machined to shape, then chemically milled. Its use in the outer duct trims engine weight, thus contributing to lower fuel consumption, and reduces engine cost by more than $9,000 per unit. Since the F/A-18 is scheduled for high volume production over several years, savings on that single program may run as high as $30 million—and General Electric is extending the technology to several other engine programs.

The material used in the duct is a fabric woven of Union Carbide's Thornel™ graphite fiber impregnated with a high temperature polyimide resin. Known as PMR-15, the resin was developed by Dr. Tito T. Serafini and other investigators at Lewis Research Center in response to a need for a resin capable of withstanding higher temperatures to enable a significant expansion of composite applications. Epoxy resins, the resins most widely used as composite matrix materials, have excellent mechanical properties and can be processed easily, but they are limited to applications where temperatures do not exceed 350 degrees Fahrenheit. Polymers with theoretically double the temperature resistance posed extraordinary processing difficulties. More than a decade ago the Lewis team started research toward a high temperature polyimide resin that could be readily processed. After lengthy experimentation involving alteration of the chemical nature of the resin and methods of processing it, they successfully developed PMR-15, which offers good pro-



cessing characteristics and remains stable at high temperatures, thus allowing fabrication of defect-free fiber reinforced composites that can operate in an environment of 600 degrees Fahrenheit or more.

But laboratory development of the polyimide was only a milestone; it then had to be converted to a manufacturing material for cost-effective production line use. In 1979, when the Lewis work was in an advanced stage and PMR-15 began to look highly promising, General Electric's Aircraft Engine Business Group, looking for a lightweight, low cost substitute for titanium plate in the F404 engine duct, became interested. There ensued a four-year processing technology effort, jointly funded by NASA and the Navy, followed by a Navy-sponsored manufacturing technology program which resulted in a manufacturing process for use of the graphite polyimide composite. Initially clothlike in appearance, the material is cut, layered and shaped to a desired configuration, then cured in an autoclave, where the fibers and resin are molded under pressure into a component that looks metallic but weighs about 15 percent less than the predecessor titanium duct. Fabricated by General Electric's Albuquerque, New Mexico facility, the F404 composite duct was extensively ground and flight tested in 1984-85 and qualified for production line use beginning in 1986.

The PMR formulation was made available to commercial suppliers of composite materials and General Electric selected Ferro Corporation, Culver City, California to provide the "prepreg," or resin-impregnated fiber material, for the F404 duct. Other manufacturers are producing composite fabrics and tapes based on PMR-15 for a range of applications that is growing rapidly. ▲

TM Thornel is a trademark of Union Carbide.

The engine duct at left is the first composite primary structural component qualified for use on a production jet engine. Key to its high temperature resistance is a polyimide resin formulation developed by Lewis Research Center. In the photo above, the duct is shown in place (center section) on the General Electric F404 jet engine.

These are samples of composite fabrics produced by Ferro Corporation, which supplied the clothlike raw material for the General Electric engine duct. The material is tailored to shape and pressure molded to become a composite duct lighter but stronger than the metal duct it replaces.

The upper photo shows a series of Worthington centrifugal pumps used to recirculate wood molasses at Superwood Company, Duluth, Minnesota. Wood molasses is a highly viscous substance and it would pose intake problems for conventional pumps. But the Type 316 stainless steel pumps pictured—manufactured by Worthington Pump Division, Dresser Industries, Inc., Mountain Side, New Jersey—feature an added device for increasing pump intake capability that Worthington calls a flow inducer. At left, a Worthington technician is inspecting inducers of several sizes.

The inducer is essentially a small booster pump that lifts the suction pressure sufficiently for the rotating main impeller of the centrifugal pump to operate efficiently at higher fluid intake levels. In the Worthington design, the boosting inducer and the main pump are incorporated into one casing and mounted on a single shaft. The concept derives from NASA technology of the early 1960s, when space payloads were becoming heavier and rocket thrust demands were rising, requiring faster fuel flow in liquid fuel rocket systems. NASA developed the inducer as an auxiliary impeller to boost the flow rate capability of rocket fuel pumps.

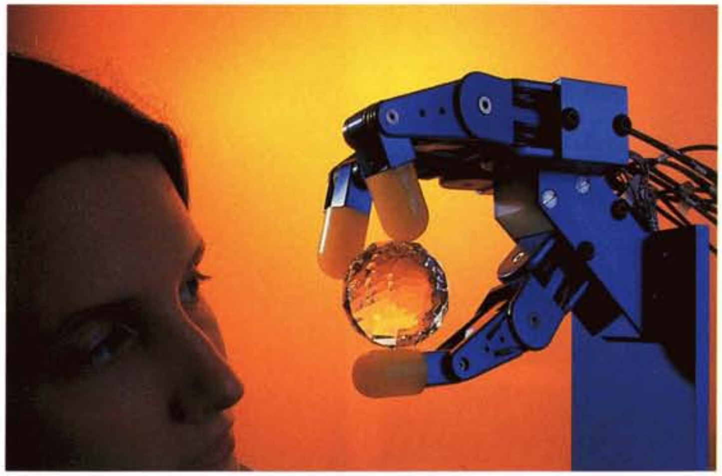
Worthington picked up the NASA technology and further advanced it to meet a need, in the 1970s, for higher industrial pump operating speeds, occasioned by rising production costs and industry's drive to offset them by getting maximum performance out of plant equipment. There are several ways to increase pump operating speeds but, according to Worthington, the inducer offers the most cost-effective way. The company offers inducer-equipped pumps for special applications requiring improved suction performance; they come in a number of sizes, primarily in the small, higher speed range.

An interesting sidebar is that the inducer concept originated with a Worthington employee, one Oscar Dorer, who was granted the first inducer patent about 1926. The concept was too advanced for its time and the idea was forgotten until NASA developed the implementing technology. ▲

Although recent years have seen considerable advances in robotic systems technology, limitations are slowing broader use of robots in industry. A major limitation to the manipulative capability of a robot is the dexterity of the "hand," technically known as the end effector. Current hands have shortcomings in grasping objects; they are limited in the range of configurations the hand may assume and many types of robots must be fitted with special fingers for each object being handled. Robots are also limited in effecting precise position and force control. Attainment of true robot dexterity requires improvement in robot mechanisms coupled with advancements in robot control technology.

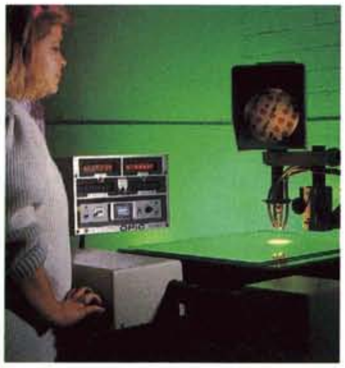
Beginning in 1982, NASA sought to promote such advancements, toward future use of dexterous telemanipulators in space or in industrial applications, by developing a test bed for research on control and utilization of dexterous robot hands. In cooperation with Stanford University and California Institute of Technology (Caltech), Jet Propulsion Laboratory (JPL) initiated development of an articulated hand capable of adapting its grasping posture to a wide variety of object shapes and of performing rapid, small motions required for delicate manipulation without need for moving the more massive arm joints. Initial specifications were drawn up by Carl Ruoff of JPL and Dr. Kenneth Salisbury, then with Stanford and now a research scientist with Massachusetts Institute of Technology's Artificial Intelligence laboratory. Later, Salisbury developed the final, detailed design.

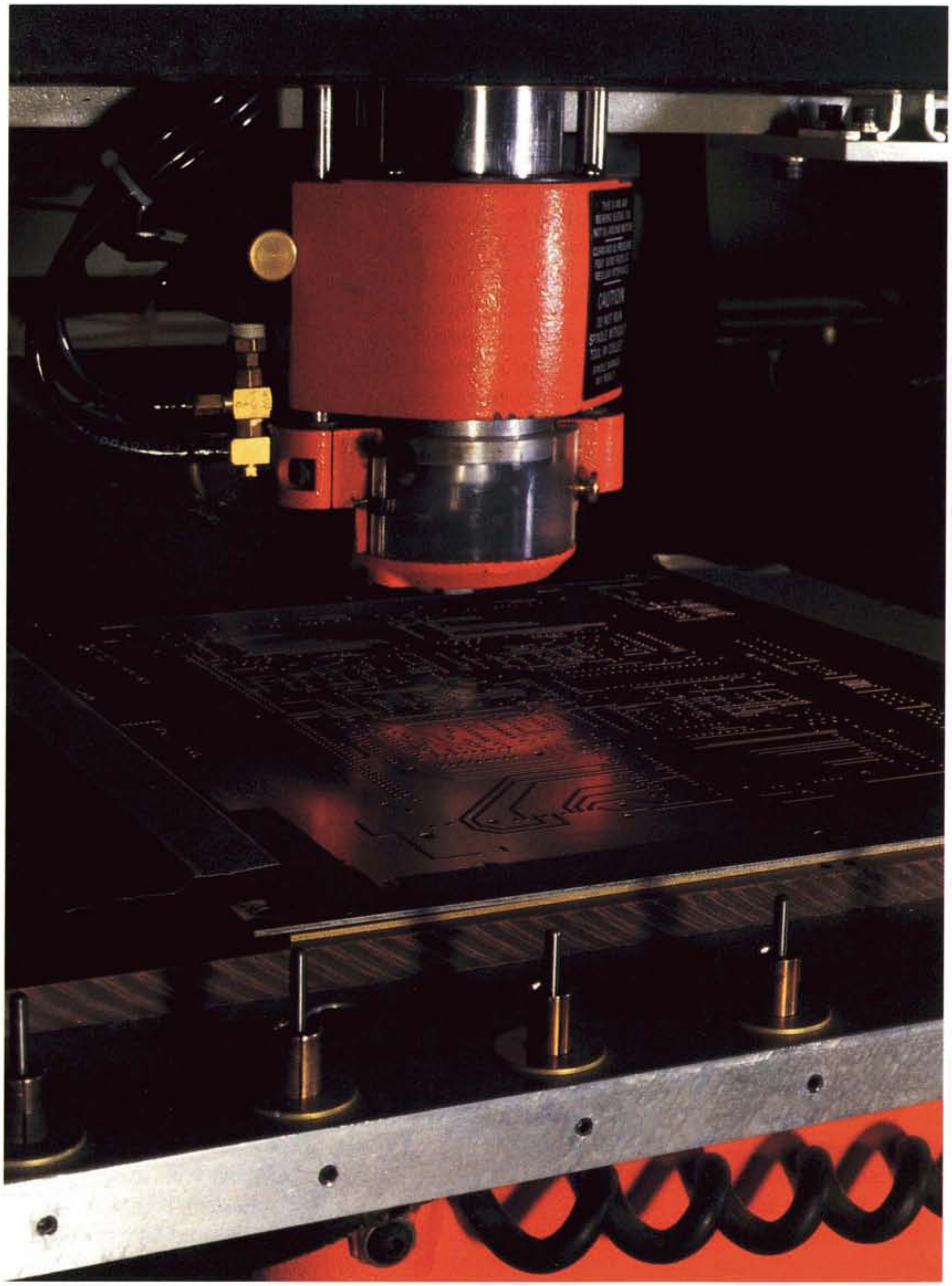
The Stanford/JPL Hand, which has more recently come to be known as the Salisbury Hand, has three human-like fingers, each with three joints. The rounded tips of the fingers are covered with a resilient material that provides high friction for gripping. Like the fingers on a human hand, the robot hand fingers can provide more than three contact areas since more than one segment of each finger can contact an object. Thus, the robot hand can move objects about, twist them and otherwise manipulate them by finger motion alone. The hand can be adapted to different arms.



At MIT's Artificial Intelligence Laboratory, Salisbury has continued his work on the robot hand, concentrating on advanced software for commanding finger motion and interpreting information from fingertip sensors. The accompanying photo shows a National Bureau of Standards demonstration wherein the robot was commanded to explore the faceted crystal ball and construct a map of the object's shape, using input from finger-sensed contacts. It has successfully demonstrated that it can produce accurate representations of complex surfaces explored. Although real industrial application of such advanced robot hands is still some distance in the future, Salisbury feels that the JPL/Stanford/MIT work has provided a solid base for further exploration of the potential of dexterous robot hands.

In response to requests from other research groups for copies of the hand, Salisbury formed Salisbury Robotics, Inc., Palo Alto, California, to reproduce the device. In addition to the prototype, still in use in Stanford's Robotic Project, and another unit at MIT, copies have been delivered to General Motors Research Laboratory, the National Bureau of Standards, Sandia National Laboratories and the University of Massachusetts at Amherst. ▲





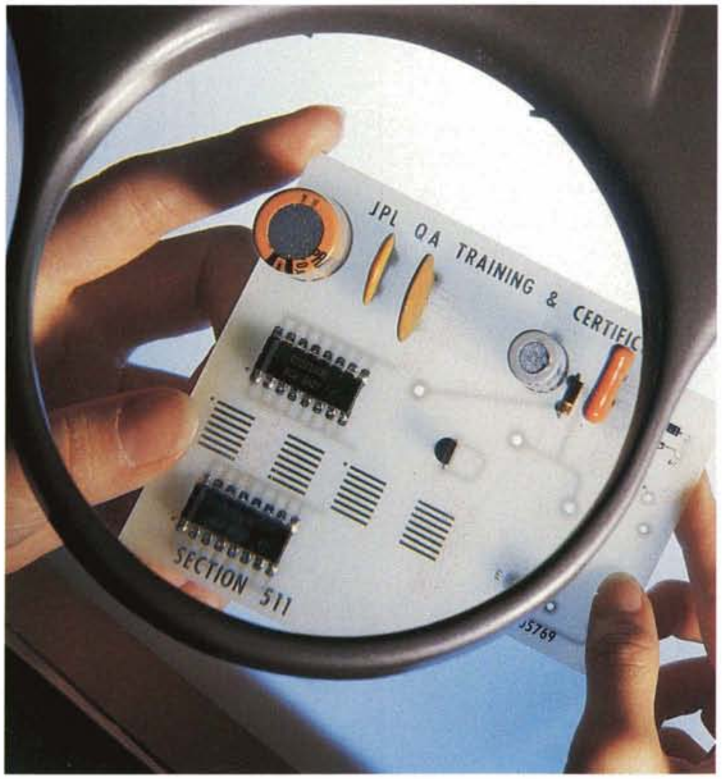
Young Electronics Company, Inc., North Hollywood, California is literally a young company, not yet three years old, but it is already a thriving business producing printed circuit boards. The product line ranges from one- and two-sided boards for computers and television sets to complex 21-layer boards for the on board computers of Air Force fighter aircraft. A new Young Electronics product is a training circuit board developed by NASA as a quality assurance aid.

The testboard was developed by Jet Propulsion Laboratory (JPL) as a tool for training and qualifying personnel in board assembly and in the art of soldering components—such as transistors, integrated circuits, resistors, capacitors and surface mount devices—without damaging boards or components. Looking for a company to manufacture the training boards in quantity, JPL selected Young Electronics. Working to NASA specifications, Young built and delivered 200 units to JPL.

Within a few weeks, Young was getting calls from electronics companies interested in purchasing training boards for their own operations. Young sought—and was granted—permission to use the NASA blueprints and tooling for commercial production and sale of training boards.

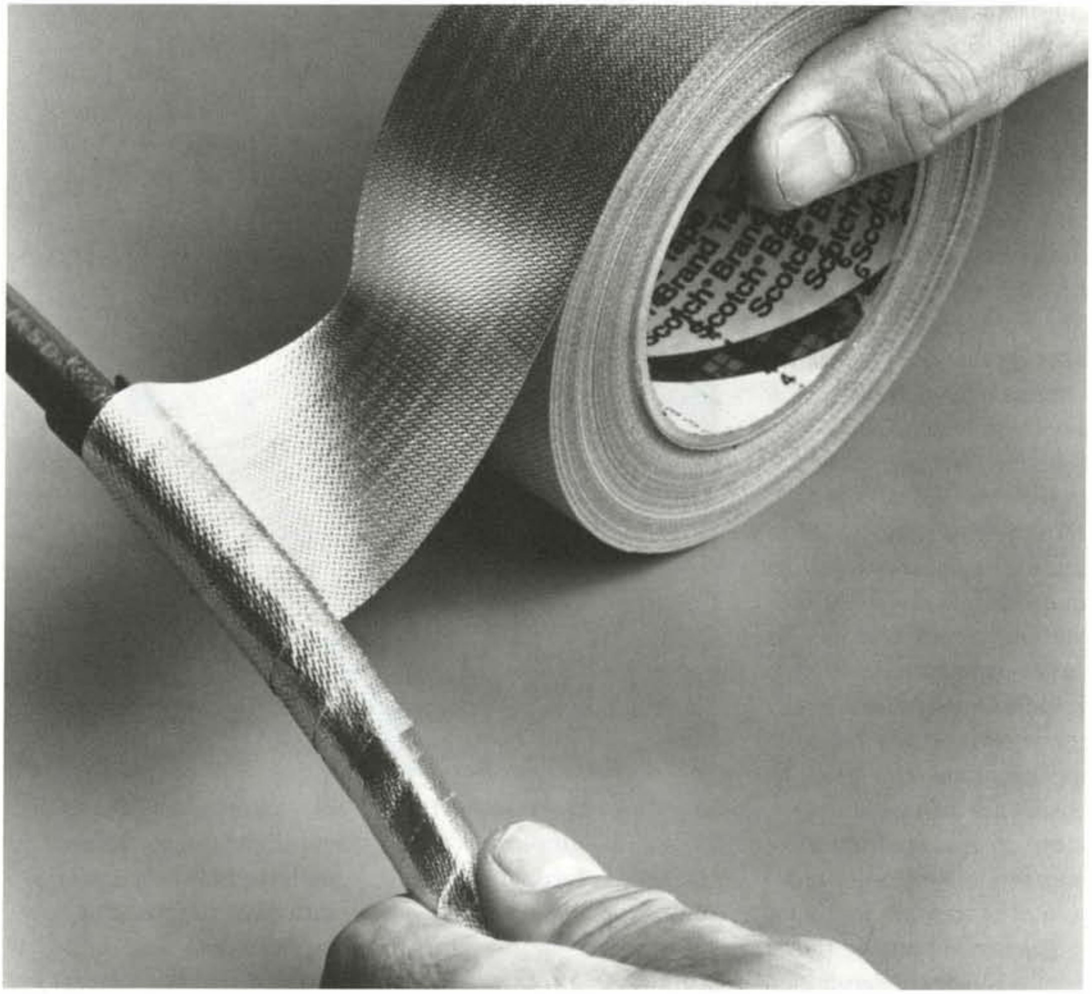
Young modified the original JPL design and went into production. The company has built a broad customer base for the training boards among principal electronic systems manufacturers, who buy them in substantial quantities and use them primarily as a means of pre-employment testing. Candidates are required to set up an electronic assembly and solder the components under stringent quality guidelines established by company or government specifications. The training boards are also used by some companies for periodic requalification of personnel as they are upgraded.

The accompanying photographs illustrate Young Electronics' manufacturing operations. At far left on the opposite page, an employee is using a target sight to program holes to be drilled in the circuit board; she aligns the holes on a template and assigns them coordinates on a computer tape that will later guide the drilling



machines. In the lower left photo, two employees are image-transferring from film onto copper inner layers prior to drilling; they are working in a yellow fluorescent light environment as a "safelight" condition for exposing the film. In the large photo at left center, a high speed air bearing drill is working on a copper circuit board.

Young Electronics manufactures the boards without the components. The basic boards are designed to provide various levels of difficulty in assembling and soldering the components. Employment candidates or requalification personnel are tested for how fast and with what degree of quality they can complete the board. Upon completion, an inspector checks the soldering for quality (above); the testboard then becomes part of the individual's permanent record. ▲



A high temperature tape originally developed for NASA use by 3M Company is now being produced as a commercial product by 3M's Industrial Tape Division, St. Paul, Minnesota.

Known as Scotch® Brand Tape 364 (upper photo), it is an aluminized glass-cloth tape used, in aerospace applications, to protect electrical and instrumentation cables and fluid lines from rocket launch blast conditions (lower photo). The tape can withstand prolonged exposure to temperatures up to 500 degrees Fahrenheit and it is capable of functioning in temperatures as low as minus 65 degrees.

No. 364 is a second generation cable wrapping that combines the best characteristics of aluminum foil and glass-cloth tapes. Coated with a silicone adhesive, it spiral-wraps smoothly without cracking and is easily applied to compound surfaces. It has excellent solar energy reflectance, tested at more than 85 percent, and tests also indicate an extremely low propensity for developing static charge, so it does not present an electrostatic hazard.

As a product for non-aerospace use, 3M Industrial Tape Division sees uses in the automotive and general transportation industries and for heat reflection applications in high temperature building construction. ▲

® Scotch is a registered trademark of 3M Company.

Two areas of the Texas utility pictured were test-coated with SuperSpan® RM 8000, an anti-corrosion coating specifically designed to meet a problem widely experienced by the power industry: damage to emissions control systems, or scrubbers, due to corrosion caused by the use of high sulfur content coal. The utility company had previously found it necessary to repair or replace ducting and other parts of the facility every few months. Nine months after SuperSpan RM 8000 was applied, the two test areas were inspected; neither showed any signs of acid degradation, abrasive wear or cracking. At the end of 1985, the coating had been in service for more than three years at the utility without component failures.

SuperSpan RM 8000 was developed by RM Engineered Products, Inc., North Charleston, South Carolina with an assist by the NASA-sponsored New England Research Applications Center (NERAC), one of nine dissemination centers providing search and retrieval services to industry clients.

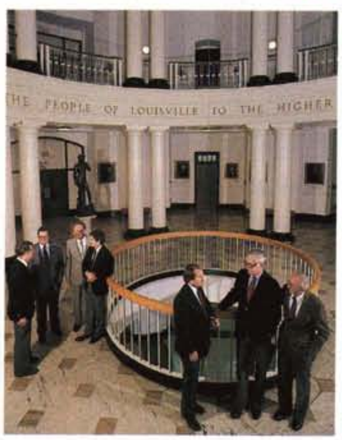
RM's decision to develop an anti-corrosion coating stemmed from the company's experience as a producer of nonmetallic expansion joints for utilities and industrial processes. "We were well aware," said RM vice president John Halberda, "of a major problem in the power generating industry: the necessity to shut down plants temporarily to repair or replace carbon steel duct work that had become corroded by the acid gases produced as part of the process of burning coal. What we needed was state-of-the-art information to ensure that the company's research and development did not duplicate existing research and that our efforts would result in a product superior to those already on the market."

RM requested help from NERAC, which conducted customized searches of several data banks, including NASA's, and provided a great many abstracts outlining research pertinent to RM's development; where the basic information proved of particular interest, NERAC followed up with full-scale reports. Of special utility was NASA-developed space technology in areas related to the thermoconductivity of carbon steel and the bonding characteristics

of polymers. NERAC's information confirmed the need for a new compound that would outlast other coatings and reassured RM that its research effort was headed in the right direction. NERAC's searches also identified other groups in the same field and helped RM project a completion date for an early entry into the market.

RM's successful development program resulted in a terpolymer coating—SuperSpan RM 8000—that, the company says, will provide protection to steel ducts six times longer than epoxy coatings and 38 times longer than polyester/flaked glass coatings. The product has found good market acceptance; sales are already in the multimillions and RM is projecting a \$10-\$15 million increase over the next five years. The success of the initial collaboration with NERAC prompted RM to seek NERAC's assistance on a second coating development, still in R&D status. ▲

® SuperSpan is a registered trademark of RM Engineered Products, Inc.



Advanced Process Systems, Inc. (APS), Louisville, Kentucky, is a small but growing business engaged in application of advanced technology to the design and production of equipment used principally in manufacturing processes, generally self-contained components of larger manufacturing systems. APS has designed and fabricated such diverse equipment as solvent, resin and oil recovery systems, juice and wine concentrating plants, carbon dioxide scrubbers and other environmental control systems. APS is also establishing research and development ties with universities, an area of effort that stemmed from company awareness of new technological opportunities resulting from a contractual association with NASA. In the photo, company and university officials confer in the University of Louisville's robotics laboratory.

Founded in 1982, APS won a NASA contract in October, 1983 for design and construction of a self-contained environmental control system for ground use on the Space Shuttle Orbiter. Mounted on a flat-bed truck, the Portable Purge Unit is designed to protect flight and ground crews from toxic fumes and, additionally, to provide a post-landing controlled environment for the Orbiter's sensitive electronic equipment when the spacecraft's environmental control system is turned off.

APS feels that its NASA work has future spinoff potential but company officials say that the real benefit of APS' association with NASA came from awareness of a NASA goal that prompted the company to refocus its research and development strategy. One facet of NASA's Microgravity Science and Applications program involves establishment of "centers of excellence"—similar to an existing materials processing center at Massachusetts Institute of Technology—to stimulate government/industry/academia collaboration in specific areas of research. APS awareness of the NASA program sparked initiatives that led to development of a joint research and development effort which will involve APS and several universities in the company's vicinity. Thus, says the company, its association with NASA has had the two-pronged effect of contributing to an expanded APS market and broadening the company's research and development horizons. ▲

Raymond Engineering Inc., Middletown, Connecticut designs, develops, engineers and manufactures precision electromechanical and electronic systems and devices primarily for the military market. Among the company's principal products are magnetic tape memory systems and peripheral equipment for digital computers; sophisticated safing, arming and fuzing devices for weapon systems; and specialized bolting and torquing equipment for both military and commercial applications.

During the past few years, Raymond's Power-Dyne® Division, also located in Middletown, has expanded the company's scientific bolting capability through development of a line of sophisticated tools and instruments for producing and controlling high torques affecting bolted joints in military, petrochemical, nuclear power, automotive and other applications. Two examples are pictured: at upper right is an ultrasonic bolt gage for monitoring bolt tension and at lower right a worker is using a wrench attachment known as a blind flange adapter, used where there is no adjacent structure to provide a torque reaction point.

Raymond Engineering credits a NASA industry assistance center—New England Research Applications Center (NERAC), Storrs, Connecticut—with a supporting role in development of the bolting tools and in expanding the company's general technology base. Raymond is building a library of knowledge through in-house experimentation and accumulated field experience, complemented by a computerized data bank of information on bolted joints. NERAC has conducted a series of worldwide literature searches of the latest bolting technology, adding to the Raymond library and also contributing to product development.

Technology located through NERAC's search and retrieval service aided company development of the bolting tools by identifying unfilled technical needs and by providing information that helped define better specifications for Raymond Engineering products. The company has also used NERAC's information in designing and presenting a series of Raymond Bolting Seminars, which have been well received in the United

States, Canada and the United Kingdom.

"Bolted joints are very complex things," said Raymond Engineering vice president John Bickford. "Their behavior is imperfectly understood. NERAC has been able to educate us in the state-of-the-art of bolted joints . . . The information received from the NASA data base has proven to be very beneficial to the overall program." He added that the new bolting tools have contributed to a sizable sales increase and to the creation of new jobs, within Power-Dyne and in other companies supplying materials to Power-Dyne.

Based at the University of Connecticut, NERAC is one of nine NASA user assistance centers, affiliated with universities across the coun-

try, that provide information retrieval services and technical help to industrial and government clients. ▲

® Power-Dyne is a registered trademark of Raymond Engineering, Inc.

A private company founded on NASA data processing technology leads a selection of technology transfers in agriculture and natural resources management

Remote sensing is the process of acquiring physical information from a distance, for example, obtaining data on Earth features from a satellite or an airplane. The best known and most widely used remote sensing systems are the NASA-developed Landsat resources survey satellites, which offer a means of monitoring changing Earth conditions through spaceborne sensors that detect various types of radiation emitted or reflected from objects on Earth's surface. This information can be put to practical use in such applications as agricultural crop forecasting, land use management, mineral and petroleum exploration, mapping, rangeland and forest management, water quality evaluation, disaster assessment and scores of others.

Raw data from Landsat or other remote sensing systems is computer-processed at ground facilities and translated into tapes or images. The data can then be interpreted to tell the difference, for example, between one type of vegetation and another, between densely populated urban areas and lightly populated farmland, or between clear and polluted water. The basic imagery can also be computer-enhanced to correct sensor errors, to make the image compatible with standard maps, or to emphasize certain features. This technology has given rise to a small but growing industry that supports users of remotely sensed data by providing computer-processing, data analysis and interpretation services.

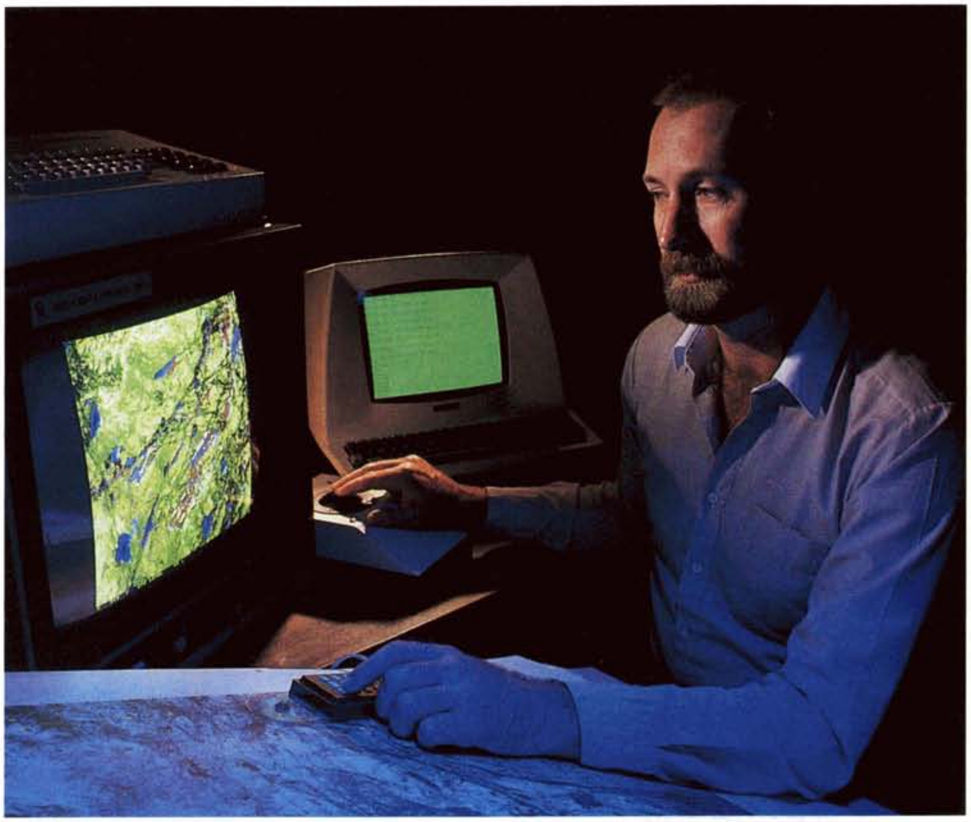
One such company is Delta Data Systems, Inc. (DDS), Picayune, Mississippi, which might be considered a "double-barreled spinoff." It is, on the one hand, an example of the personnel type of technology transfer, in which aerospace scientists and engineers move to other industries or form new companies, transferring their aerospace-acquired skills and know-how to new applications. In addition, a major DDS development—the ATLAS software system—is an adaptation of a NASA-developed computer program.

DDS was formed by a group of former NASA/industry engineers with extensive experience at NASA centers in designing hardware and software for digital image processing systems. Says DDS president Ferron Risinger: "This company is an outgrowth of our previous work for NASA; its purpose is to carry on beyond NASA's role in transferring remote sensing technology." Risinger was formerly a systems engineer with Lockheed Electronics, later a computer systems analyst for the NASA Earth Resources Laboratory at the National Space Technology Laboratories.

In the latter connection, Risinger was project leader for installations—at Ames Research Center and other facilities—of the NASA-developed computer program for processing remotely sensed data called ELAS (Earth Resources Laboratory Applications Software). After founding DDS, he and his associates used ELAS as a "shell" for developing the company's ATLAS geographic information system, used to process satellite and aircraft data, to digitize soil and topographic maps and to generate land use maps. The ATLAS system has been used by a number of DDS clients for producing land cover classification maps. Although ATLAS was developed for geographic use, DDS also plans some medical applications that involve processing of digital image data. An unusual application is computer-directed tuna processing; the computer assigns values to different parts of the fish (cat food, white meat, dark meat, etc.), then directs the movements of a robotic cutting waterjet to slice the tuna with maximum efficiency.

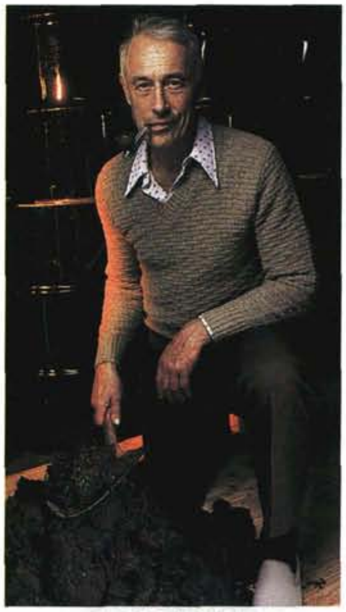
The company estimates that use of ELAS as a basis for ATLAS development saved an additional four man-years that would have been required to develop the 100 applications modules in the ATLAS system. ELAS was supplied to DDS by NASA's Computer Software Management and Information Center (COSMIC)®, an extension of NASA's Technology Utilization Program which provides NASA computer programs to other agencies of the government and to the private sector (see page 127).

Among DDS hardware designs are a microprocessor-based system for production control and energy management systems, turnkey remote sensing systems and high speed interfaces between several types of computers and associated equipment, such as image displays. DDS also provides a number of specialized services for the remote sensing community, including consultation, training personnel in use of the ATLAS system, in-house data processing and on-site data processing support. The company's customers include private firms, educational institutions, state and federal agencies, among them the National Park Service, Vandenberg Air Force Base, the Florida Department of Transportation and several universities. ▲



In the upper photo, a Delta Data Systems technician is computer-enhancing a Landsat image to include geographic coordinates. At right, company president Ferron Risinger is adjusting a wire wrap board, one of a number of hardware systems developed by Delta Data Systems for processing remotely sensed data.

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



Humics, Inc., Camden, New Jersey is a new small business manufacturing purified humic acid and humic acid salts, primarily for agricultural applications. A partnership of Hal Hartung, a chemical engineer, and E.F. Moran, who has background in textiles and industrial chemicals, the company was created expressly to explore and exploit the commercial potential of products derived from peat, an organic soil widely used in Europe as a fuel. Humics, Inc. credits a NASA user assistance center with a major assist in identifying potential applications of humic acid and helping to focus the company's research and development activities.

Hartung and Moran started work in 1981 on the premise that peat was "too valuable to burn," that there were probably many important applications other than fuel. Hartung's early study and experimentation convinced him that the humic substances in peat offered the greatest potential value. However, extraction of humic acid and salts by conventional means was not economically feasible. The partners directed their work toward developing an economical method for extracting humics; their efforts proved successful and in July 1984 they were granted a U.S. patent for a method of separating wet peat into component fractions and processing it to produce a variety of useful materials. The upper photo shows Hal Hartung with a batch of raw peat material; in the lower photo, a company employee is inspecting a separator used in peat processing.

In the meantime, the partners had formed Humics, Inc. to commercialize their technology. Looking for the widest possible range of applications, they learned of a NASA service provided by a network of industrial applications centers that offer information retrieval and technical help. They asked the New England Research Applications Center (NERAC), Storrs, Connecticut to conduct a computerized literature search for applications of humic acid as a supplement to their own research.

"What came back over the next year or so astounded us," Hartung says. NERAC's searches provided some 5,000 references and revealed that humic acid had worldwide interest for scores of uses; what was needed was a reliable, pure and economic source. "We were forced to rethink the scope and nature of our project," Hartung adds.

Humics, Inc. directed its initial effort at agriculture, where a market existed. Humic acid and soluble humates have been shown to improve germination of seeds, stimulate root development, increase plant vigor, improve crop yields and help plants withstand stresses, such as temperature extremes. Humic, Inc.'s extraction process allowed the company to develop two initial purified humic acid products for which demand required doubling plant capacity in a matter of months. The company is exploring the potential of humic acid as a sewage disposal agent; test marketing a kind of horticultural peat, a byproduct of humic acid production; and conducting field and laboratory experiments toward introduction of a number of industrial applications. And, although the original idea was to explore non-fuel uses of peat, the company now feels that its technology makes possible economical production of peat fuels. Humics, Inc. estimates that gross sales of peat-derived products will reach $8-10 million within the next two to three years. ▲

The accompanying photos illustrate research by the University of Georgia's Agricultural Engineering Department on new designs for poultry houses. Improved housing offers great potential benefit for Georgia's poultry farmers, whose industry is a billion-dollar-a-year business. One investigation involved winter use of passive solar heating for the poultry houses, using a southern exposure with concrete walls; the design process could be most efficiently handled by computer thermal models based on the thermal analysis capabilities of the NASA Structural Analysis System (NASTRAN)®.

The NASTRAN program, originally developed for aerospace design applications by Langley Research Center and supplied by NASA's Computer Software Management and Information Center (COSMIC), is a general purpose program that mathematically analyzes a design and predicts how it will stand up under the various stresses and strains it will encounter in operational service. This permits engineers to study the structural behavior of many different designs before settling on a final design.

At the University of Georgia—and other universities—students are being trained to use the NASTRAN system for a variety of new and different applications, including thermal analysis of agribusiness-related structures, nursery containers and postharvest handling of vegetables. In the latter application, NASTRAN is used to develop a model for monitoring the transient cooling of vegetables that have been harvested and stored in bins. The produce can deteriorate in quality because of the high temperatures often experienced. The University of Georgia's Agricultural Engineering Department is investigating the use of convective and evaporative cooling to reduce temperatures, thereby reducing quality loss.

Another study at the University of Georgia involved thermal analysis of black and green nursery containers commonly used by commercial nurseries to grow plants. The growth media in the containers can be subjected to temperatures of 110 degrees Fahrenheit or more due to solar radiation. Plant root growth is generally retarded above 85 degrees and ceases above 100 degrees. Attempts have been made to reduce heat-induced stress on plant roots through use of perforated containers, white plastic containers and evaporative cooling. Using NASTRAN, a thermal analysis was conducted to quantify the thermal environment of a nursery container exposed to summer solar radiation; researchers explored the potential for reducing media temperatures of such parameters as different media composition and different container surface colors, geometry and dimensions.

The Agricultural Engineering Department faculty reports that use of NASTRAN and exposure to finite element analysis has encouraged student appreciation of numerical problem solving techniques. The department plans additional applications of NASTRAN in its continuing program for teaching and applying sophisticated computer analysis. ▲

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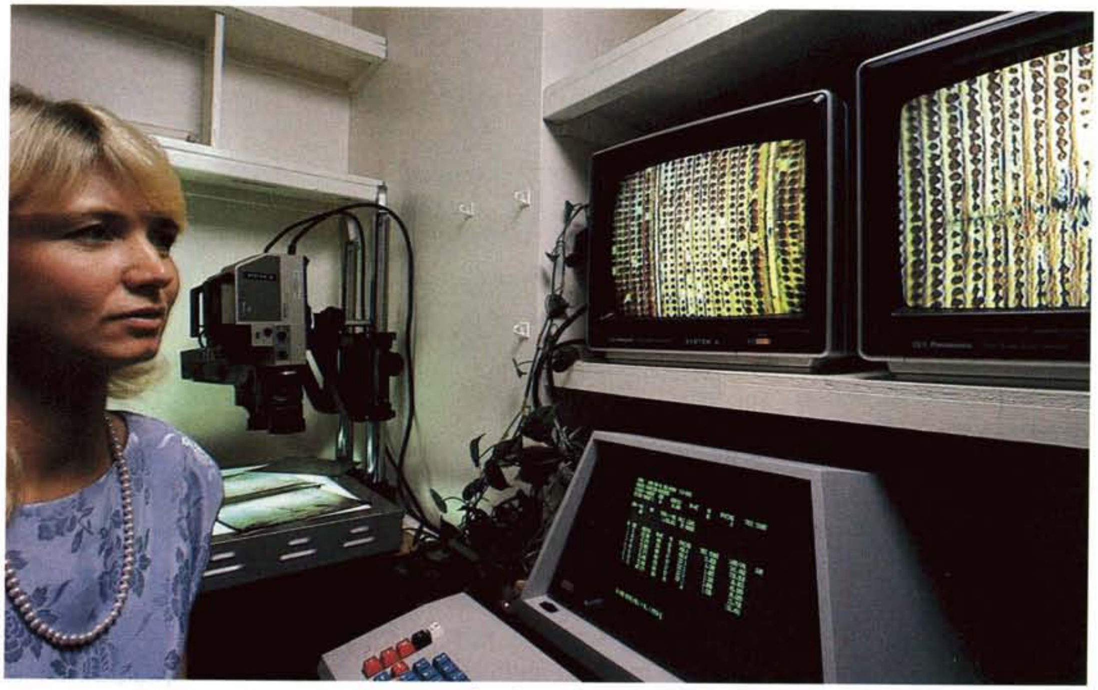


An aerial color infrared (ACIR) mapping system developed by Kennedy Space Center (KSC) has been adapted by Oliver Lowe, Property Appraiser for Florida's Charlotte County, for inventorying citrus trees as a basis for assessing citrus grove valuations. With ACIR, Lowe has been able to obtain more accurate property valuations while reducing the county's appraisal costs. As recently as 1981, it took two appraisers six to nine months to appraise the county's 8,500 acres of citrus; today, survey of the county's 10,000 acres takes one appraiser about 75 days with the help of the dual video system (above and left) for interpreting ACIR photographs. The video system was jointly developed by KSC and the Citrus Research and Education Center of the University of Florida.

Aerial photographic flights were made annually each June during 1983-1985 and the resultant photos interpreted by the video system, composed of paired color video cameras connected to two monitors; this system makes it possible to view two different annual images and detect changes that may have occurred from one year to the next. Differences found are verified by field visits, which additionally serve to determine the probable cause of tree losses, damage or decline. Appraiser Lowe invites citrus growers to view photographs of their properties (individual property boundaries are outlined in the ACIR transparencies) and see for themselves areas where problems may exist, thus eliminating many potential tree failures and enabling growers to plant citrus in areas where better chances of successful growth are indicated.

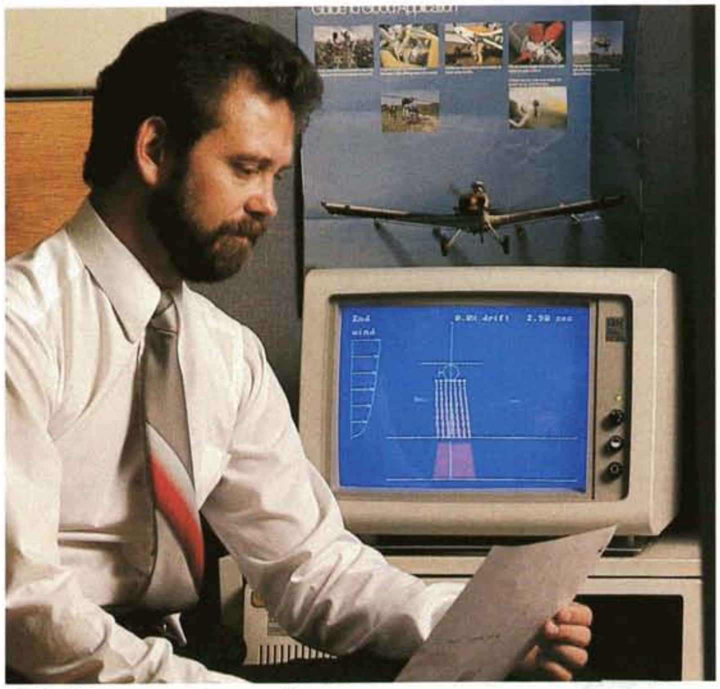
The Florida State Department of Revenue would like to see development of an image analysis system that would automatically survey and photointerpret grove images; such a system would make inventory and appraisal feasible and economical in counties with very large citrus acreages, where visual interpretation and data input would be too slow a process. KSC's Technology Utilization Office has awarded a contract to Dr. C.H. Blazquez of the Citrus Research and Education Center to adapt a prototype system that would automatically count trees and report a total of trees per block or grove. ▲

A decade-long program of research on agricultural aviation, conducted by Langley Research Center, focused on investigations designed to help the aerial crop dusting and spraying industry solve a major problem: wasteful drift of chemical beyond target areas, a matter that was heightening environmental concerns and was becoming ever more expensive as chemical costs increased.

Langley's investigations involved studies of aircraft wake and how the wake affects chemical dispersal patterns; the aim was to identify modifications to airplanes or to dispersal equipment to allow more accurate, more uniform spray patterns. From this research came an important aid to aerial applicators and equipment designers, a computer code called AGDISP (for Agricultural Dispersal) that allows accurate spray and drift predictions. Jointly funded by NASA and the Forest Service of the Department of Agriculture, AGDISP was written for Langley by Continuum Dynamics, Inc., Princeton, New Jersey.

Continuum Dynamics has since advanced the technology another step by developing, with company funds, a commercially available version of the code for use on a personal computer by an operator who need not have any prior computer experience. Called SWA+H (Spray Width for Airplanes Plus Helicopters), the software models the turbulent flow behind an agricultural aircraft and predicts the motion of materials released from spray nozzles, taking into consideration airplane, atmospheric, material and nozzle characteristics. The printer output (right) provides detailed information on the concentrations and motions of the spray cloud, including an estimate of drift. The user may then change certain factors—such as spray height or nozzle position—to achieve the desired swath width and application concentration while minimizing drift.

SWA+H users include the Forest Service, the Federal Aviation Administration and a number of agricultural chemical manufacturers, one of which is The DuPont Company's Agricultural Products Division, Wilmington, Delaware. It is difficult and expensive to field test different equipment and chemicals in actual flight, because the environment is so variable, so DuPont uses



SWA+H to save time and money by narrowing the parameters; computer data is then checked out by "field testing for truth." Essential input to the computer code is data on the characteristics of the chemicals and dispersion systems. One of the ways DuPont accomplishes this is by using the laser system at right to measure the particle characteristics of various spray compounds. Particles released from a dispersal system (top of photo) are measured by the laser unit (gold); then the laser beam is moved from side to side (red) and the particles are measured along the radius of their trajectory. ▲

TECHNOLOGY UTILIZATION

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

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 in the course of NASA programs is an important national asset in that it offers potential for secondary applications—new products and processes that collectively represent a valuable contribution to the U.S. economy. But such technology transfers do not materialize automatically; translation of the potential into reality requires an organized effort to put the technology to work in new applications and reap thereby a dividend on the national investment in aerospace research.

NASA's instrument for accomplishing that objective is the Technology Utilization Program, which employs a number of mechanisms intended to broaden and accelerate the transfer of aerospace technology to other sectors of the economy. An important mechanism is the job of "getting the word out"—letting potential users know what NASA-developed technologies are available for transfer. This is accomplished primarily through *Tech Briefs*, a bi-monthly publication that describes for a wide government/industry audience newly developed processes, research advances and other innovations stemming from NASA technology development (see page 127).

An example of how *Tech Briefs* benefits industrial firms is the case of the Zimmatic agricultural irrigation system built by Lindsay Manufacturing Company, Lindsay, Nebraska. The system is a network of water pipes and spray nozzles supported by a series of wheeled towers. The whole system rotates around a center pivot, watering hundreds of acres in a single revolution. Each of the three-ton towers has its own electric motor, which transmits power to the wheels through gear boxes, one on each wheel. These gear boxes incorporate NASA lubrication technology that protects them from stress and wear.

The technology originated in a Lubrication Handbook compiled by Midwest Research Center under contract with Marshall Space Flight Center. Intended as a reference source for designers and manufacturers of aerospace hardware and those responsible for maintenance of such equipment, it has much wider applicability because it details the chemical and physical properties, applications, specifications and test procedures for more than 500 types of lubricants. Engineers of Lindsay Manufacturing Company learned of the handbook through *Tech Briefs* and used it in redesigning gear boxes for the center pivot system. In the new design, gears are immersed in NASA-developed lubricants that provide wearing surfaces and bearings with low-friction protective coatings. The information in the handbook helped reduce the amount of lubricant required and allowed selection of comparable but less expensive lubricants.

Tech Briefs more often than not simply provides a lead for follow-up contact that may generate a spinoff product or process, but in some cases the information in *Tech Briefs* is by itself sufficient to inspire a new development. An example is the work of Carlos F.

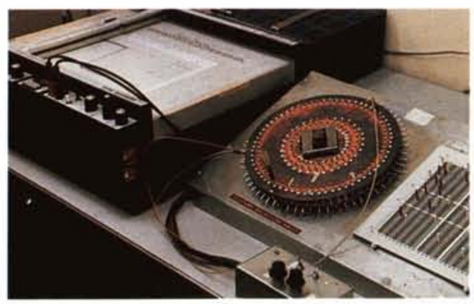
Horvath, senior engineer of Burroughs Corporation, Paoli, Pennsylvania, which manufactures large computer systems.

Looking for a better way of testing ECL (Emitter Coupled Logic) chips, integrated circuits used in Burroughs' computer systems, Horvath developed his own unit, an AC/DC tester with an associated ramp voltage generator that checks out ECL devices and their functionality within the computer. Horvath's invention allows rapid manual checking without extensive programming, as is required by other test methods; thus the ECL tester makes it easier to find out what component is malfunctioning and it does the job faster. With minimal training, anyone can use the equipment, where prior testers require skilled technicians.

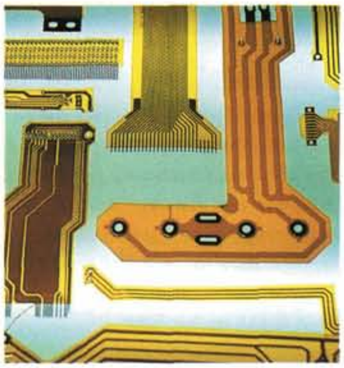
Horvath reported that a single article in Tech Briefs provided the information that led to his development of the ramp voltage generator, an essential accessory to the basic tester. The tester itself did not evolve from any specific article but from an accumulation of information on new electronic circuit and component technology published in a number of issues of *Tech Briefs*.

NASA's Technology Utilization Program is managed by the Technology Utilization Division, an element of the Office of Commercial Programs. Headquartered in Washington, D.C., the division coordinates the activities of technology transfer specialists located throughout the United States. In addition to *Tech Briefs* and related publications, other mechanisms employed by the division include Technology Utilization Officers, located at each of NASA's nine field centers, who serve as regional Technology Utilization Program managers; a network of user assistance centers that provide information retrieval services and technical help to government and industry clients; applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology; and a software center that provides, to industry and government clients, computer programs adaptable to secondary use. The mechanisms are amplified on the following pages. ▲

The Zimmatic irrigation system (above) consists of a series of wheeled spray towers rotating around a center pivot and watering hundreds of acres on a single swing. Electric motors drive the system through gear boxes on each wheel (left). The manufacturer improved the efficiency of the gear boxes through a redesign that incorporated NASA technology.



A Burroughs Corporation engineer developed this computer component tester using information from a number of issues of the NASA publication Tech Briefs.



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 nine Industrial Application Centers (IACs) 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 application centers, clients have access to nearly 100 million documents contained in the NASA data bank and over 250 other computerized data bases. The NASA data bank includes reports covering every field of aerospace-related activity plus the continually updated, selected contents of some 15,000 scientific and technical journals.

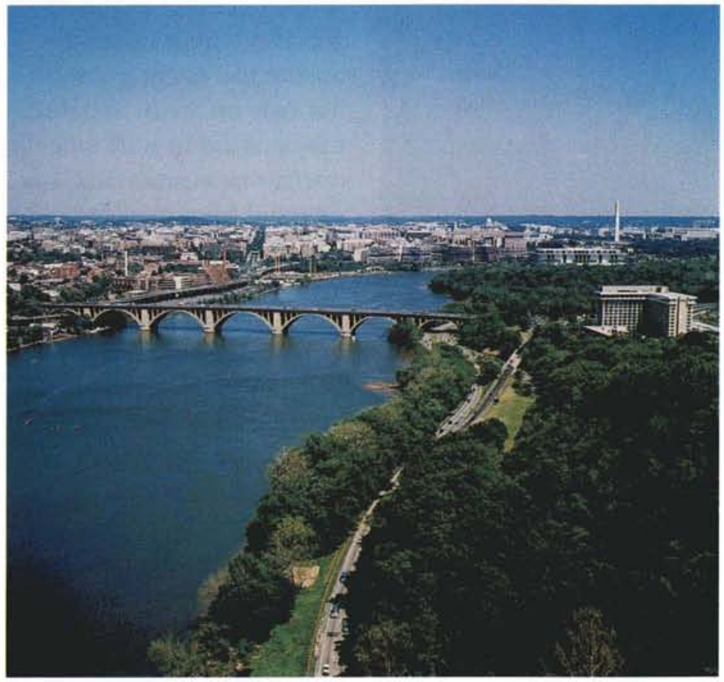
How this technology is put to work is exemplified by the work of one of the centers—the New England Research Applications Center (NERAC), Storrs, Connecticut—in providing flexible etched circuits for electronic systems. The company is Advanced Circuit Technology (ACT), Nashua, New Hampshire. At top left, sculptured circuits are being assembled in ACT's manufacturing room; at lower left is a selection of the types of circuits produced.

NERAC conducts computerized literature searches to find and apply technical information pertinent to its client's needs. ACT's product research and development group regularly employs NERAC's search service to stay abreast of new developments in interconnection technology and, in particular, to find new opportunities for applying its sculptured circuit process. NERAC provides information in such areas of company interest as materials and processes used in printed circuit fabrication, new interconnection products and latest advances in manufacturing technology.

Search efforts divide into two classes: currency—aimed at company awareness of broad trends in electronics development and manufacture—and product intelligence, research of a more specific nature directly applicable to ACT development programs. NERAC furnishes abstract listings to ACT personnel, who periodically follow up with requests for full length reprints of documents that seem to warrant detailed study. ACT has several new products in development and the company reports that each of them has benefited from NERAC's computerized technology search.

Another NERAC example is the assistance the center provided to John Hill, a photographer who operates Tigerhill Studio, Western Springs, Illinois. Hill specializes in high quality oblique aerial photography, supplying three dimensional frontal photos such as the oblique view of the Art Institute/Michigan Avenue area of Chicago shown at right and the segment of Washington, D.C. along the Potomac River (far right).

In preparing his business plan for entering this highly specialized field, Hill—aware of many NASA advances in photography, remote sensing and computerized image enhancement—sought to build an informa-



tion base on space age technology related to his work. He was advised by the Chicago Small Business Administration office to contact NERAC.

NERAC searched the NASA data base and provided extensive information on aerial oblique and architectural photography, electro-optics, image enhancement and processing. Hill followed up the NERAC report through personal contacts with manufacturers of photographic equipment and film, aerial surveyors, processing laboratories and camera retailers. As a result of this cooperative research effort, Hill was able to effect an immediate and substantial reduction in overhead costs. Much of the saving stemmed from his switch from a heavy military aerial camera to a lighter weight, more manageable camera that makes sharper pictures and can be used in a small fixed-wing airplane as well as in more costly helicopters. Additionally, he is using NERAC-provided information on electro-optics, image enhancement, microwave and infrared systems to plan for his introduction of advanced optics.

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

For further information on IAC services, interested organizations should contact the director of the nearest center; addresses are listed in the directory that follows. ▲

In the course of its varied activities, NASA makes extensive use of computers, not only on Space Shuttle missions but in such other operations as analyzing data received from satellites or deep space probes, conducting aeronautical design analyses, operating numerically-controlled machinery and performing routine business or project management functions. NASA and other technology-generating agencies of the government have of necessity developed many types of computer programs, a valuable resource available for reuse. Much of this software is directly applicable to secondary use with little or no modification; most of it can be adapted for special purposes at far less than the cost of developing a new program.

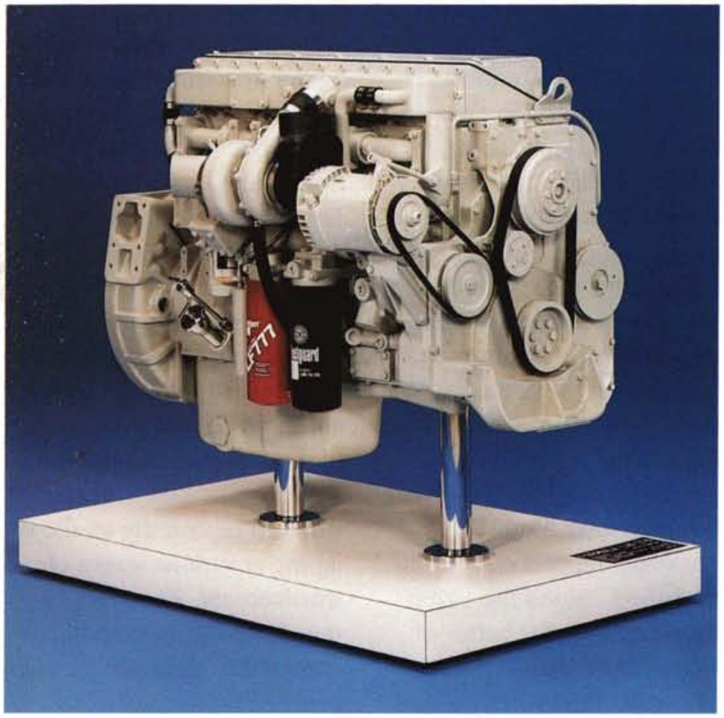
To help industrial firms, government agencies and other organizations reduce automation costs by taking advantage of this resource, NASA operates the Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC collects, screens and stores computer programs developed by NASA and other government agencies. The Center's library currently contains more than 1,400 programs that provide computer instructions for 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.

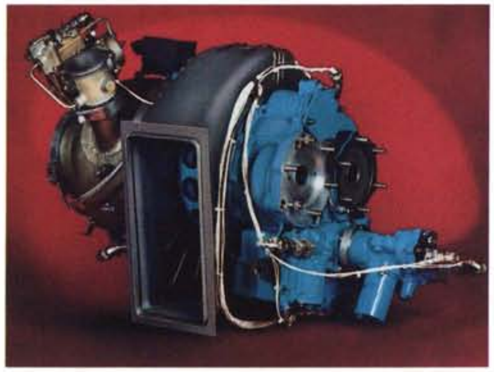
An example of COSMIC's service is found in manufacture of heavy duty trucks such as the one pictured at left. The truck is powered by the L-10 turbocharged engine shown at right center, one model of a diversified line of diesels manufactured by Cummins Engine Company, Columbus, Indiana.

Part of the company's research effort is aimed toward introduction of advanced turbocharged engines that deliver extra power with greater fuel efficiency. In a number of feasibility studies of turbine rotor designs, engineers of Cummins' turbocharger group utilized a COSMIC computer program. Originally developed by Lewis Research Center, the program—Fortran IV Program to Estimate Off Design Performance of Radial Flow Turbines—calculates turbine rotor mass flows and efficiencies to assist in predicting the performance characteristics of a possible turbine design. The company reports that use of the program substantially reduced software development costs.

In a related area, COSMIC also provided assistance to AiResearch Manufacturing Company, Los Angeles and Torrance, California, a division of The Garrett Corporation engaged in manufacturing a broad variety of products for the aerospace, energy, metals, transit and marine industries. Among many activities at its Torrance facility, AiResearch provides design and analysis of ancillary equipment—such as fuel controls and rotating accessories—for gas turbines produced by another Garrett division, Garrett Turbine Engine Company, Phoenix, Arizona.

An example of the Garrett gas turbine line is the GTCP36-100 auxiliary power unit (APU) shown at top right. These APUs provide pneumatic power for starting airplane engines, for cabin air conditioning and





for electric power supply to other aircraft systems while the plane is on the ground. The GTCP36-100 is installed in such business jets as the French-built Dassault-Breguet Falcon 50 (right), the Canadair Challenger and the Grumman Gulfstream; it is also used on the new British Aerospace Model 146 short-haul airline transport.

One step in the design work at AiResearch-Torrance involves analysis of lightweight rubber seals used in accessory equipment on Garrett APUs. Over a period of time, stress and strain cause expansion and contraction of these seals. Computerized analysis is employed to determine how well a proposed seal design will stand up to such stresses. For such analysis, AiResearch used a computer program known as VISCEL, supplied by COSMIC, NASA's software distribution center. AiResearch engineers report that use of the VISCEL program allowed a saving of 400 to 500 hours in software development time; additionally, it contributed to improved efficiency in seal analysis.

To assist prospective customers in locating potentially useful software, COSMIC publishes an annual indexed catalog of all the programs in the center's inventory. Available on microfiche, computer magnetic print tape or in hard copy form, the catalog may be purchased directly from COSMIC. The center also helps customers define their needs and suggests programs that might be applicable. For further informaton 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.

One facet of NASA's Technology Utilization Program is an applications engineering effort involving 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 organizations.

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. NASA 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 through application of aerospace technology.

An example of an applications engineering project is a simulator known as the Emergency Management Computer Aided Training System, or EMCAT, shown above.

Developed by Marshall Space Flight Center (MSFC) in response to a request from the Huntsville (Alabama) Fire Department, EMCAT enables a trainee to assume the role of fireground commander and make quick decisions on best use of his firefighting personnel and equipment.

Watching the fire's progress on the TV screen, the trainee is presented a sequence of decisions on the computer monitor; his response, tapped out on the keyboard, causes the video fire to change for better or worse. If he makes a series of correct decisions, the fire is extinguished; if he errs, he will see the fire go out of control. At the end of the exercise, he is critiqued by an instructor and informed which decisions were right or where he went wrong.

The prototype was shown to firefighting authorities from all over the country in demonstrations at MSFC, in Memphis, Tennessee and in Fresno, California. The highly favorable response as to the system's concept and potential led to initiation of a development program for an advanced EMCAT, a training aid for the firefighting and other emergency management communities. The program is a joint undertaking of NASA and the National Fire Academy, Federal Emergency Management Agency; MSFC is project manager.

In the prototype, the visual portion of the system was created by video taping an actual controlled burn of two condemned buildings. The fire was started and stopped repeatedly to allow taping at various stages of involvement. The tape, transferred to a computer compatible video disc, enabled programmers to choose from a variety of visual outcomes that would result from the trainee's sequence of decisions.

The prototype, however, has only one scenario. A survey showed that potential users would want a variety of fire and other emergency scenarios, each involving somewhat different tactics and management techniques. Since it is impossible to tape actual burnings of such structures as high rise apartments, factories or airport facilities, the development team is using video graphic and animation techniques. Tests indicate that realistic visual scenarios can be created by overlaying pictures of static structures with dynamic flame and smoke imagery.

Another example is an application effort involving aquatic plants—principally water hyacinths—for treatment and recycling of wastewater, a project that originated at National Space Technology Laboratories (NSTL), Bay St. Louis, Mississippi as a solution to a local wastewater problem.

In the early 1970s, NSTL discovered that the glossy green water hyacinths literally thrive on sewage; they absorb and digest nutrients and minerals from wastewater, converting sewage effluents to clean water. Thus, they offer a means of purifying water at a fraction of the cost of a conventional sewage treatment facility. Additionally, they provide bonus value in byproducts. The protein-rich hyacinths must be harvested at intervals; the harvested plants can be used as fertilizer, as high protein animal feed, or as a source of energy.

NSTL first tested the practical application of aquaculture in 1975, when hyacinths were planted in a 40-acre sewage lagoon at Bay St. Louis; the once noxious lagoon soon became a clean water garden. NSTL published a study report that attracted considerable attention and followed up by providing technical guidance to communities interested in applying the technology. Several southern towns, with populations ranging from 2,000 to 15,000, use water hyacinths as their year-round primary method of treating wastewater. Other towns employ aquaculture as a part-time or supplementary process in sewage treatment.

The "aquaculture" technique advanced significantly in the early 1980s with its adoption by a major city—San Diego, California—as part of a multi-step reclamation process designed to recover potable water from sewage. San Diego had developed its own two-phase reclamation system in the late 1970s, but found need for further filtration to remove metals and suspended solids. After consultation with NSTL, the city added a water hyacinth treatment facility and the combined processes began operating as an experimental system in 1981.

The prototype facility operated so successfully over a two-year span that San Diego built a one-million-gallon-per-day plant for service beginning in 1984. The new facility has an aquaculture component that employs—in addition to water hyacinths—a reed-rock filter unit, the latest wastewater treatment developed at NSTL. The hybrid aquatic plant/microbial filter combination, unlike the water hyacinth system, will operate in cold as well as warm climates.

The photos illustrate the aquaculture part of the sewage treatment process at San Diego. At upper right is the first step, in which the sewage passes through a screening device for removal of large solids. The raw sewage is pumped into greenhouse-like aquaculture tanks, such as the one at right. After aquaculture cleansing, the water is further treated by an "ultrafilter," then it passes into the reverse osmosis facility, San Diego's original system, which removes most of the salt and viruses from the sewage. Additional cleanup steps are provided by the NSTL microbial filter process and by a city-developed carbon absorption technique. ▲

TECHNOLOGY UTILIZATION OFFICERS

An important element among the NASA mechanisms for accelerating and broadening aerospace technology transfer is the Technology Utilization Officer, or TUO. TUOs are technology transfer experts at each of NASA's nine field centers who serve as regional managers for the Technology Utilization Program. In the photo are the Langley Research Center TUO (right) and his staff, examining a Langley invention developed as a technology utilization project.

The TUO's basic responsibility is to maintain continuing awareness of research and development programs conducted by his center that have significant potential for generating transferable technology. He assures that the center's professional people identify, document and report new technology developed in the center laboratories and, together with other center personnel, he monitors the center's R&D contracts to see that contractors similarly document and report new technology, as is required by law. This technology, whether developed in-house or by contractors, becomes part of the NASA bank of technical knowledge that is available for secondary use.

The TUO's next job is "getting the word out"—advising potential users of the technology's availability. To do so, he evaluates and processes selected new technology reports for announcement in NASA publications and other dissemination media. Prospective users are informed that more detailed information is available in the form of a Technical Support Package, which the TUO prepares and distributes in response to inquiries.

The TUO also acts as a point of liaison between industry representatives and personnel of his center, and between center personnel and others involved in applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology. On such projects, the TUO prepares and coordinates applications engineering proposals for joint funding and participation by other federal agencies and industrial firms.

NASA conducts—independently or in cooperation with other organizations—a series of conferences, seminars and workshops designed to encourage broader private sector participation in the technology transfer process and to make private companies aware of the NASA technologies that hold promise for commercialization. The TUO plays a prominent part in this aspect of the program. He arranges and coordinates his center's activities relative to the meetings and when—as frequently happens—industry participants seek to follow up with visits to the center, he serves as the contact point.

Support for the TUOs—and for all other groups within the NASA technology utilization network—is provided by the technology utilization office at the NASA Scientific and Technical Information Facility. The facility's Technical Services Group handles centralized maintenance and reproduction of all Technical Support Packages. Additionally, it responds to more than 80,000 annual requests for information. ▲

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 is accomplished primarily through the publication *NASA Tech Briefs*.

The National Aeronautics and Space Act requires that NASA contractors furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. Those reports provide the input for *Tech Briefs*. Issued bi-monthly, the publication is a current awareness medium and a problem solving tool for more than 100,000 government and industry readers.

First published as single sheet briefs in 1962, *Tech Briefs* was converted to a NASA-published magazine format in 1976. In 1985, publishing responsibility—including sale of advertising—was turned over to a commercial firm in a joint venture between NASA and Associated Business Publications, Inc. of New York City. Thus, *Tech Briefs* became the first government publication to accept paid advertisements, an arrangement that relieves the government of publication costs and permits broader circulation.

NASA supplies the editorial content and the basic magazine format used since 1976 remains essentially unchanged. Each issue contains information on a particular product or process described in the publication. Innovations reported in *Tech Briefs* annually generate more than 100,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader use of NASA technology.

Tech Briefs is available to scientists, engineers, business executives and other qualified technology transfer agents in industry or in state and local governments. The publication may be obtained by contacting the Director, Technology Utilization 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, in order to promote competition and bring about wider use of NASA inventions. A summary of all available inventions, updated semiannually, is contained in the NASA Patent Abstracts Bibliography, which can be purchased from the National Technical Information Service, Springfield, Virginia 22161. ▲

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.

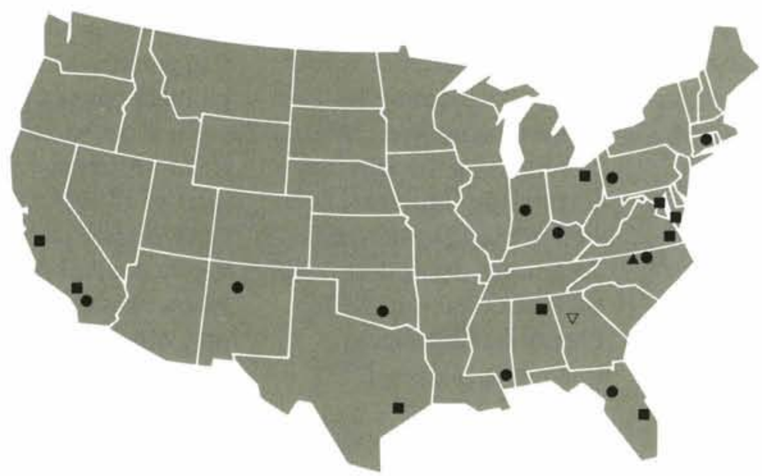
For information of a general nature about the Technology Utilization Program, address inquiries to the Director, Technology Utilization Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240.

■ *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.

▽ *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:
Laurence A. Milov
Phone: (415) 694-5761

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771
Technology Utilization Officer:
Donald S. Friedman
Phone: (301) 286-6242

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas 77058
Technology Utilization Officer:
William Chmylak
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899
Technology Utilization Officer:
Thomas M. Hammond
Phone: (305) 867-3017

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia 23665
Technology Utilization and Applications Officer: *John Samos*
Phone: (804) 865-3281

Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135
Technology Utilization Officer:
Daniel G. Soltis
Phone: (216) 433-5667

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812
Director, Technology Utilization Office:
Ismail Akbay
Phone: (205) 544-2223

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91009
Technology Utilization Officer:
Norman L. Chalfin
Phone: (818) 354-2240

NASA Resident Office—JPL
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Officer:
Gordon S. Chapman
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National Space Technology Laboratories
National Aeronautics and Space Administration
NSTL, Mississippi 39529
Technology Utilization Officer:
Robert M. Barlow
Phone: (601) 688-1929

INDUSTRIAL APPLICATION CENTERS

Aerospace Research Applications Center
611 N. Capitol Avenue
Indianapolis, Indiana 46204
F. T. Janis, Ph.D., director
Phone: (317) 262-5003

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
823 William Pitt Union
Pittsburgh, Pennsylvania 15260
Paul A. McWilliams, Ph.D., executive director
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NASA Industrial Applications Center
Research Annex, Room 200
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New England Research Applications Center
Mansfield Professional Park
Storrs, Connecticut 06268
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Phone: (203) 429-3000

North Carolina Science and Technology Research Center
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Research Triangle Park, North Carolina 27709
James E. Vann, Ph.D., director
Phone: (919) 549-0671

Technology Applications Center
University of New Mexico
Albuquerque, New Mexico 87131
Stanley A. Morain, Ph.D., director
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Southern Technology Applications Center
307 Weil Hall
University of Florida
Gainesville, Florida 32611
J. Ronald Thornton, director
Phone: (904) 392-6760

NASA/UK Technology Applications Program
109 Kinkead Hall
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Lexington, Kentucky 40506
William R. Strong, manager
Phone: (606) 257-6322

COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER

COSMIC
Computer Services Annex
University of Georgia
Athens, Georgia 30602
John A. Gibson, director
Phone: (404) 542-3265

APPLICATION TEAM

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COMMERCIAL SPACE PROGRAMS

Headquarters, National Aeronautics and Space Administration
Office of Commercial Programs
Commercial Programs Division
Washington, D.C. 20546
Gary E. Krier, director
Phone: (202) 453-8430

SCIENTIFIC AND TECHNICAL INFORMATION FACILITY

Centralized Technical Services Group
NASA Scientific and Technical
Information Facility
P.O. Box 8757
BWI Airport, Maryland 21240
Walter Heiland, manager
Technology Utilization Office
Phone: (301) 859-5300, extension 242

National Aeronautics and
Space Administration

Director, Technology Utilization Division
Office of Commercial Programs
P.O. Box 8757
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Maryland 21240