Spinoff

1988

NASA

Spinoff

1988

National Aeronautics and
Space Administration
Office of Commercial Programs
Technology Utilization Division
by James J. Haggerty
August 1988

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

Foreword

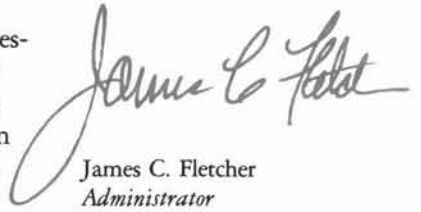
The year 1988, the 30th anniversary of the National Aeronautics and Space Administration, marks the start of a new era of space development and exploration. In the flight hiatus since the *Challenger* accident, the Nation has undeniably lost ground in global space competition. However, we have never lost sight of the goal of space leadership, nor have we lost the capability to attain that goal.

NASA's employees and contractors retain the imagination that opens up new horizons, the management expertise to organize and guide challenging programs, and the technical skills to translate vision into reality. Thirty years of working to advance technology have given us a great bank of know-how to draw upon. NASA also has the tools, facilities and human assets required to seek and demonstrate excellence in space.

We have established a broad and progressive space program that will expand space infrastructure and thus enable pursuit of a wider range of opportunities. Our program also will improve our space transportation system, bring about far-reaching advancements in space science, pursue the many practical benefits space offers, and build a technological foundation for the new NASA goal of extending the human presence beyond Earth orbit.

We have a renewed mandate from the President, whose National Space Policy, issued in 1988, reaffirmed the basic goal of United States leadership in space. What NASA and the Nation need now is a new national commitment of will and resources to attain that goal. That commitment must be based on the realization that our economic growth and prosperity, our industrial innovation and productivity, our national security, and our prestige and national pride are all closely linked to our future in space.

Given the full support of the American people and resources we need to complete the task, I am confident that the U.S. can and will lead spacefaring nations into a new era of progress and prosperity in the 21st century.



James C. Fletcher
Administrator

National Aeronautics and Space Administration

Introduction

U.S. competitiveness is a subject that is getting a great deal of attention from our national leadership. America's ability to compete effectively in the international marketplace is central to our current and future national economy. The key to competitiveness is technology, which—by one definition—is "that body of knowledge and capability required to bring a product to the marketplace."

The U.S. long dominated world technology but in recent years we have been strongly challenged by foreign nations, who have invested in years of intense research and development to upgrade their own technological capabilities. Our response, if we are to maintain competitiveness, must be to continue development and application of advanced technology to create superior products and services for the world market.

NASA research programs, therefore, are doubly important.

First, they represent a leading source of new technology, because aerospace programs are, by their challenging nature, extraordinarily demanding of technological input and the innovations they generate are exceptionally diverse. Because it is readily transferable, the technology being developed today provides a wellspring of know-how for new applications tomorrow.

Secondly, NASA programs of the past three decades have created a vast storehouse of already-developed technology that is available *now* for use by industry in creating new products and processes. It is a natural resource that can be put to work to enhance national productivity and competitiveness. Its importance is underlined by the fact that more than 30,000 secondary applications of this technology—spinoffs—have emerged to the benefit of the nation's lifestyle and economy.

The Congress has charged NASA with the task of stimulating the widest possible use of this valuable resource in the national interest. NASA seeks to meet that responsibility through its Technology Utilization Program, whose aim is to broaden and accelerate the technology transfer process and to gain thereby a substantial dividend on the national investment in aerospace research in the form of new products, new businesses and new jobs. The program is designed to serve as a channel linking NASA technology with those who might be able to apply it productively.

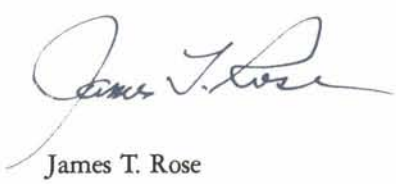
This publication is intended to heighten awareness among potential users of the technology available for transfer and the economic and social benefit that might be realized by secondary applications.

Spinoff 1988 is organized in three sections:

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

Section 2, the main feature of this volume, contains a representative sampling of spinoff products that resulted from secondary application of technology originally developed to meet mainline goals.

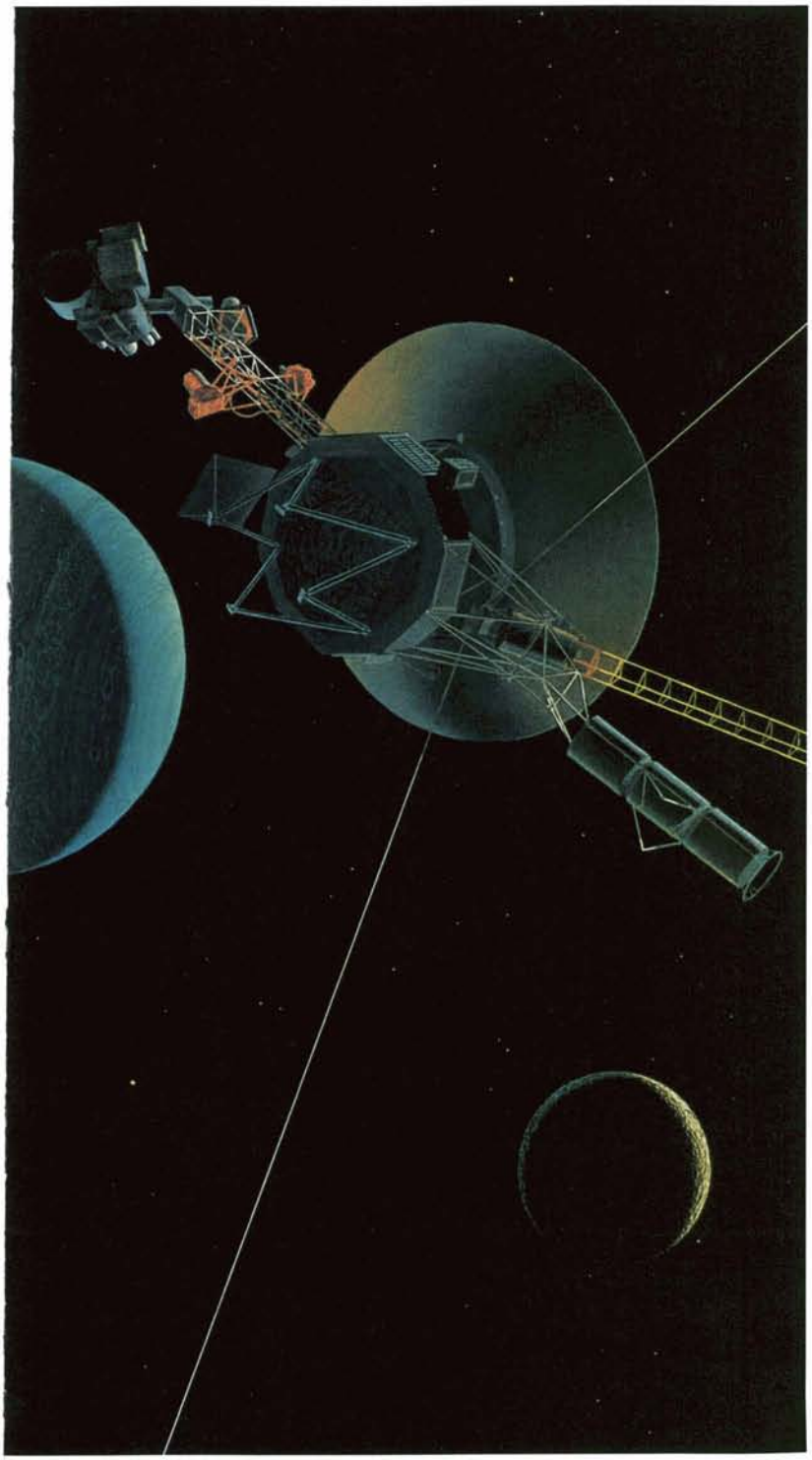
Section 3 describes the various mechanisms NASA employs to stimulate technology transfer and lists, in an appendix, contact sources for further information about the Technology Utilization Program.



James T. Rose

Assistant Administrator for Commercial Programs

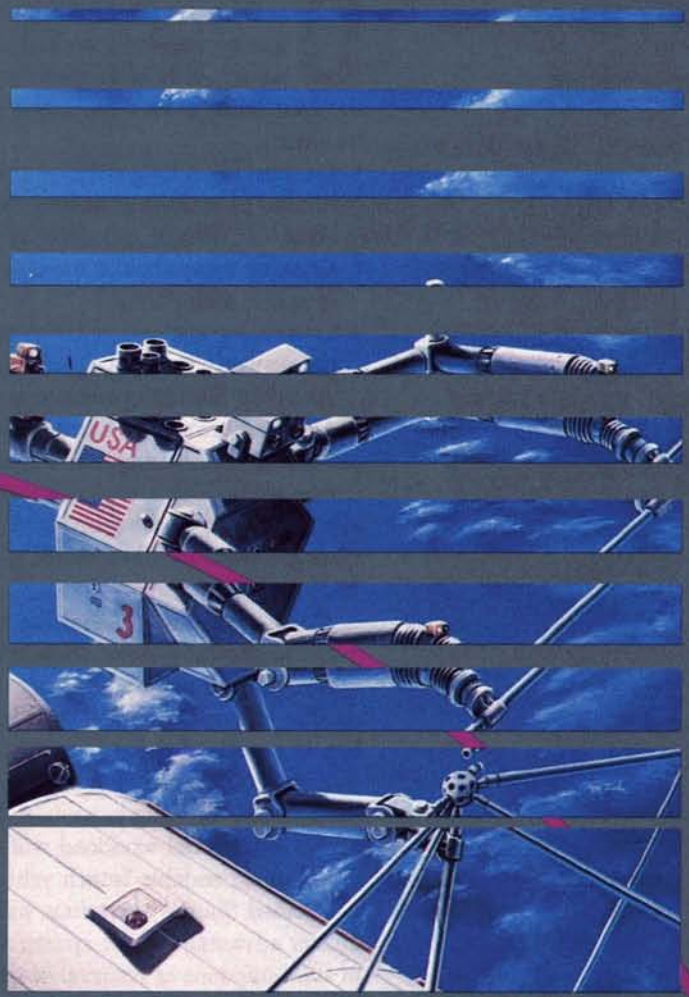
National Aeronautics and Space Administration



Contents

Aerospace Aims

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


USA
3

Space Operations: The Next Decade

NASA's "new beginning" agenda features development of the Space Station Freedom in international partnership and steps toward expanding human presence beyond Earth orbital space

On February 11, 1988, President Reagan announced a revised national policy to guide U.S. space activities into the 21st century. Its three major components include:

- Establishing a long range goal to expand human presence and activity beyond Earth orbit;
- Creating opportunities for U.S. commerce in space; and
- Continuing the national commitment to a permanently manned Space Station.

As Space Shuttle operations resume and NASA commences its fourth decade of space research and technology development, these aims—along with a vigorous space science effort—constitute the framework of NASA's space program for the remaining years of the 20th century.

The Space Shuttle begins life anew a much improved system whose role in space operations will undergo a change of emphasis. For its first 24 flights, the Shuttle was largely a payload delivery system. It will continue to deliver free-flying payloads and the Spacelab orbiting workshop, but much of the commercial workload will be transferred to expendable launch vehicles.

Planned Shuttle operations will take greater advantage of the system's versatility in such missions as retrieval of orbiting spacecraft for repair, refurbishment and reuse; on-orbit servicing of long duration satellites and observatories such as the Hubble Space Telescope; serving as an orbital platform for investigations where human direction of the research is essential or beneficial; and conducting tests and evaluations of Space Station-related technologies. In the mid-1990's, it will become a combined delivery vehicle and construction base for assembly of the U.S./international Space Station Freedom and the station's link with Earth for resupply and crew rotation.

The Shuttle reenters service a changed system. In addition to the redesigned Solid Rocket Boosters, Shuttle Orbiters *Discovery, Atlantis,* and *Columbia* have undergone, or are undergoing, some 30 modifications—for example, changes in the Orbiter's main engines, attitude control engines, landing gear, brakes, ancillary power units and the critical thermal protection system, plus the addition of a crew escape system. Shuttle flight rate will build up gradually, from 7-8 missions in 1989, to 10 in 1990, to better than one a month when the as yet unnamed fourth Orbiter joins the fleet in 1992.

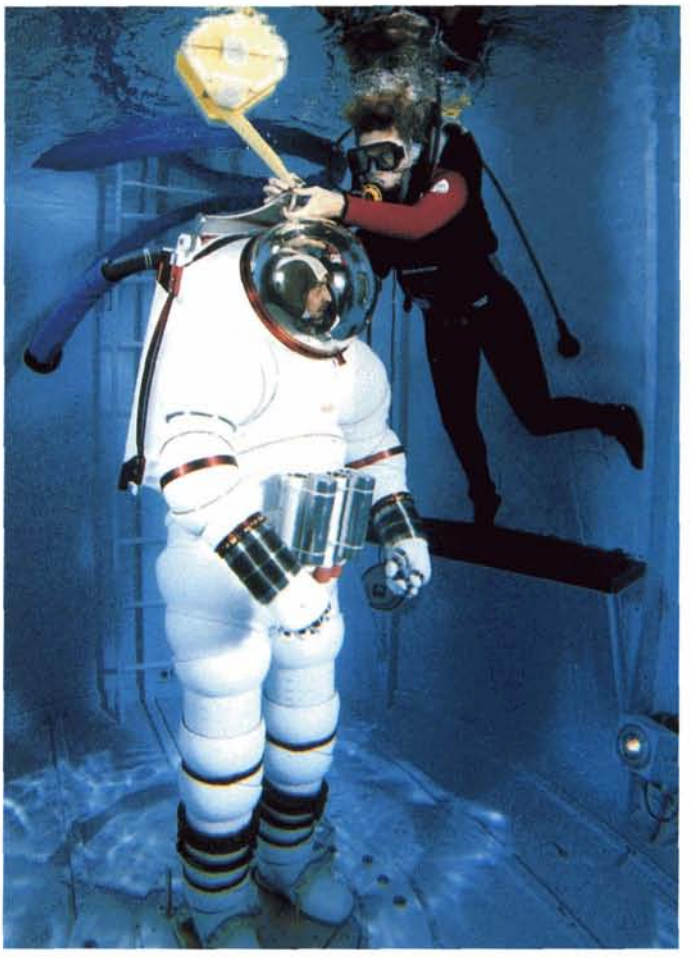
The new directive to plan for human space activities beyond Earth orbit will involve earlier consideration of design factors related to use of the Space Station as a staging base for exploration of the solar system. It does not change the immediate focus of the program: to establish a permanently manned research complex in low Earth orbit, a facility for scientific observation of Earth and the cosmos; for development of new technologies; and for research in life sciences and materials processing under conditions of near-zero gravity; and for realization of the commercial potential of space.

A new and important activity beginning in Fiscal Year 1989 is Project Pathfinder, established by a Presidential directive that accompanied the space policy declaration. Amplified in later pages of this chapter, Pathfinder is a research and technology development effort intended to "provide a base for wise decisions on long term goals and missions," such as the widely discussed lunar outpost and manned expedition to Mars. ▲

Symbol of a new beginning: The Orbiter *Discovery* being rolled to the launch pad for Space Shuttle flight STS-26.

The crew of STS-26: mission commander Frederick H. (Rick) Hauck (right front); pilot Richard O. Covey (left front); standing, left to right, mission specialists David C. Hilmers, George D. (Pinky) Nelson and John M. (Mike) Lounge.

Space Suit



When the Space Station *Freedom* becomes operational, extravehicular activity (EVA) is expected to become almost routine and on each EVA astronauts will work outside the station for long periods. To provide astronaut protection from radiation, micrometeoroids and space debris yet allow adequate mobility and range of motion for the wide variety of EVA tasks anticipated, NASA is developing an advanced space suit intended for EVA periods up to eight hours.

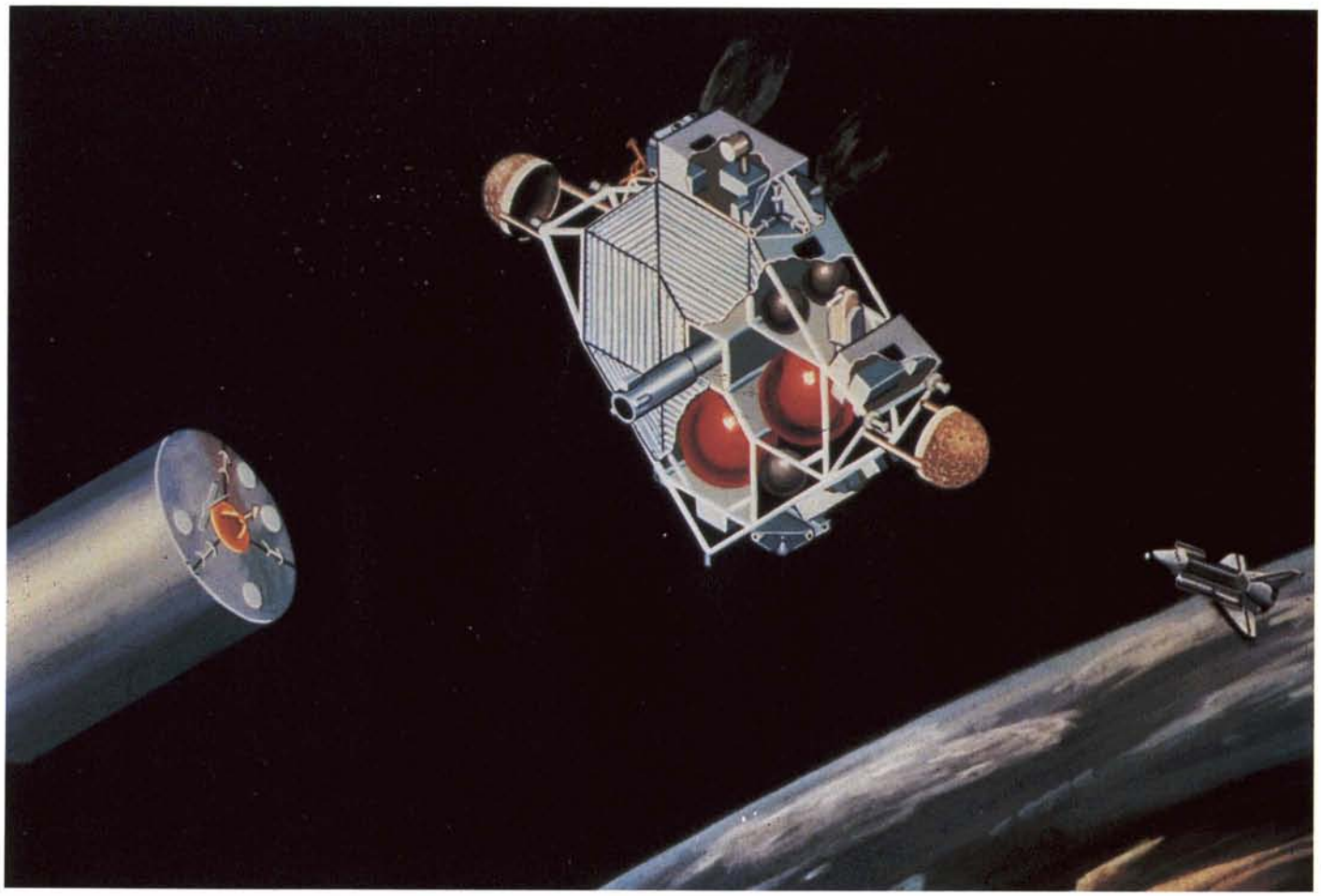
In January 1988, NASA began evaluating two experimental prototypes of EVA suits being developed by Ames Research Center and Johnson Space Center, each employing a different design approach.

Shown undergoing test in a water tank is Ames' X-5, worn by space suit designer Herbert C. "Vic" Vykukal of the center's Aerospace Human Factors Research Division. The AX-5 is an "all-hard" suit, made of aluminum and stainless steel with no "soft" (fabric) parts. Micro Craft, Inc. is Ames' principal contractor.

Johnson Space Center (JSC) is taking a design approach based on the philosophy that soft parts enhance wearer comfort and should be employed to the extent possible. Its ZPS Mark 3 suit has both hard and soft elements.

The "ZPS" stands for "zero prebreathing suit." Both suits are designed to eliminate the existing requirement, for Shuttle-based EVA, that astronauts prebreathe pure oxygen to eliminate nitrogen from body tissues before beginning EVA. Both suits, therefore, are designed to operate at substantially higher pressures than the Shuttle suit, which necessitates use of some hard parts. Both suits are intended to provide greater mobility than the Shuttle suit offers with more comfort, despite the design constraints imposed by the higher pressure. NASA will select one suit or the other, or possibly a new hybrid design that combines features of both, as the standard suit for Space Station or Space Shuttle EVA in the 1990s. ▲

Orbital Maneuvering Vehicle



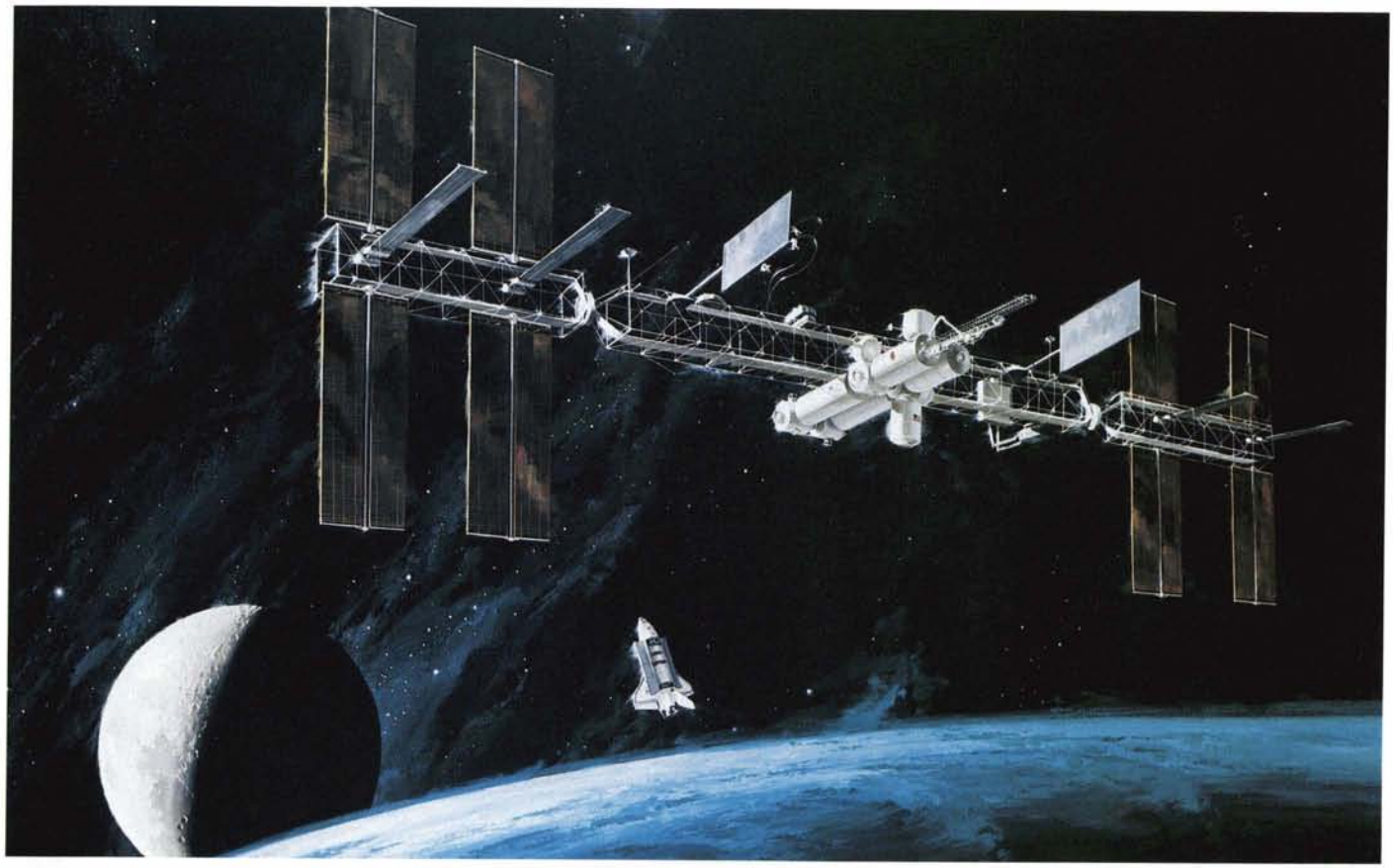
The artist's concept shows a Shuttle deployed Orbital Maneuvering Vehicle (OMV) retrieving an orbiting payload for return to the Shuttle Orbiter. The next planned addition to the space Transportation System, the OMV is being developed by TRW Inc.; Marshall Space Flight Center is project manager.

The reusable OMV is a space tug intended to extend the reach of the Shuttle Orbiter by moving satellites and other objects to and from altitudes beyond the Orbiter's normal operating area of 150-300 miles above Earth's surface. It can, for example, propel a payload as far as 1,200 miles after deployment from the Orbiter—or it can retrieve a payload, deliver it to the Orbiter for repair, then return it to its operational orbit.

Remotely-controlled by ground-based astronauts employing television and other sensors to guide its movements, the OMV can handle routine on-orbit servicing, maintenance or payload changeout, and can be useful as a "Shuttle associate" in construction of large space structures. By use of modification kits, the versatile system can be configured to perform a wide variety of space tasks.

No provision has been made for basing an OMV at the initial baseline Space Station, but the OMV could evolve later into a station adjunct, performing such tasks as deployment of station-assembled satellites or positioning Shuttle-delivered resupply modules. The system is targeted for service in 1993. ▲

Space Station



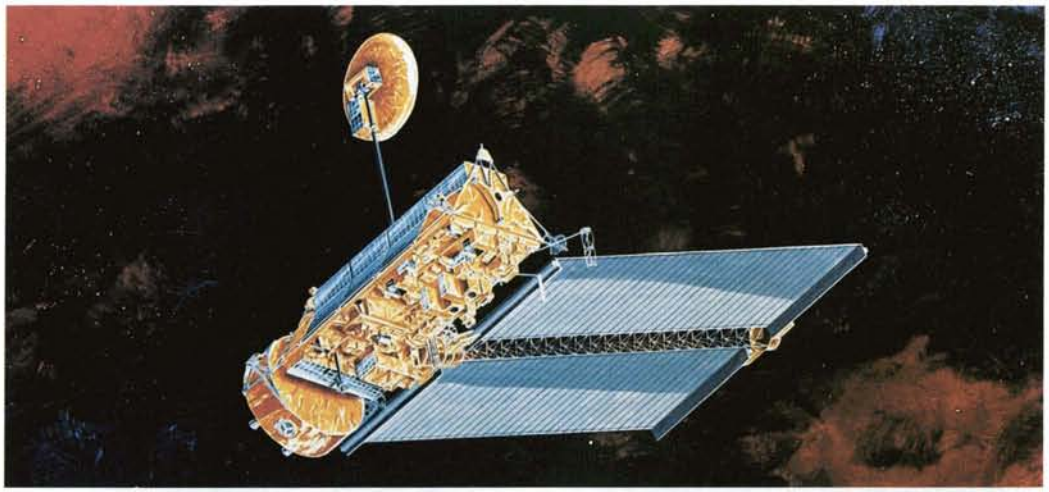
The Space Station program moved ahead in the summer of 1988 as NASA completed negotiations with its international partners—Canada, the European Space Agency (ESA) and Japan—and cleared the way for formal signing of agreements in the fall.

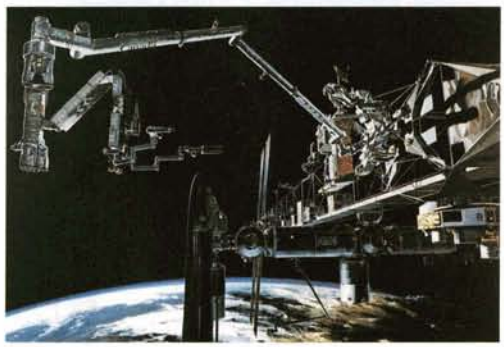
Shown above is the baseline Space Station with its four solar power modules at the ends of a 445-foot-long truss. In the center of the truss are the pressurized living and working areas, a U.S.-built habitation module and three laboratory modules to be provided by the U.S., ESA and Japan.

Linking the modules are pressurized "resource nodes," which contain equipment to expand the available working/living space. With the modules and nodes, the baseline Space Station will have 31,000 cubic feet of pressurized volume. The station design also includes provisions for mounting major experiments externally on the horizontal truss.

Additional experiments will be accommodated by unmanned platforms operating separately from the manned base in polar orbit, one to be built by the U.S., the other by ESA. The U.S. platform is shown at top right; an important element of NASA's earth observation program, it will carry a variety of instruments for Earth biological, geological and oceanographic observations, atmosphere monitoring, observation of the Sun and plasma physics measurements.

Designed to be serviced in orbit, it is being developed, under Goddard Space Flight Center management, by GE





Astro-Space Division with assistance from team member TRW Inc. The GE/TRW team is also responsible for integration into the Space Station of the Flight Telerobotic Servicer, a multi-armed robot that will help astronauts assemble the Space Station (above), later help maintain attached payloads and assist in servicing spacecraft.

Another major component of the Space Station is the Mobile Servicing System (MSS) being developed by the Canadian government. Shown above, the robotic MSS operates from the horizontal truss, positioned by a U.S.-provided mobile transporter, performing assembly, maintenance and servicing tasks. In the concept shown, the MSS manipulator arm is adding an experiment module to a truss-attached payload.

In addition to the GE/TRW contracts described, which are part of Work Package Three, NASA awarded letter contracts in December 1987 to three other major contractors, each of which is supported by a number of team subcontractors.

Under Work Package One, managed by Marshall Space Flight Center, Boeing Aerospace Company will provide the U.S. laboratory and habitation modules, logistics elements, resource node structures, airlock systems, the environmental control and life support system, audio and video systems, and associated software.

Work Package Two, managed by Johnson Space Center, is being performed by a team headed by McDonnell Douglas Astronautics Company. It embraces the truss structure, the MSS transporter, airlocks, outfitting of the resource nodes, hardware and software for the data management system, the communications and tracking system, the guidance, navigation and control system, EVA systems, the propulsion system, the thermal control system and associated software.

Rocketdyne Division of Rockwell International Corporation is handling Work Package Four under the management of Lewis Research Center. The Rocketdyne team will provide the complete power system and associated software, including power generation, storage, management and distribution of electric power. Rocketdyne will also provide the electric power system for the U.S. polar orbiting platform.

(Continued)

The schedule for development and assembly of the Space Station *Freedom* is dependent upon funding levels, which had not been finally determined at publication time. A tentative schedule, based on the Administration's budget plan, calls for the first launch of the assembly series in March 1995, when the Space Shuttle will deliver to an orbit 250 miles high an initial group of components for assembly in space.

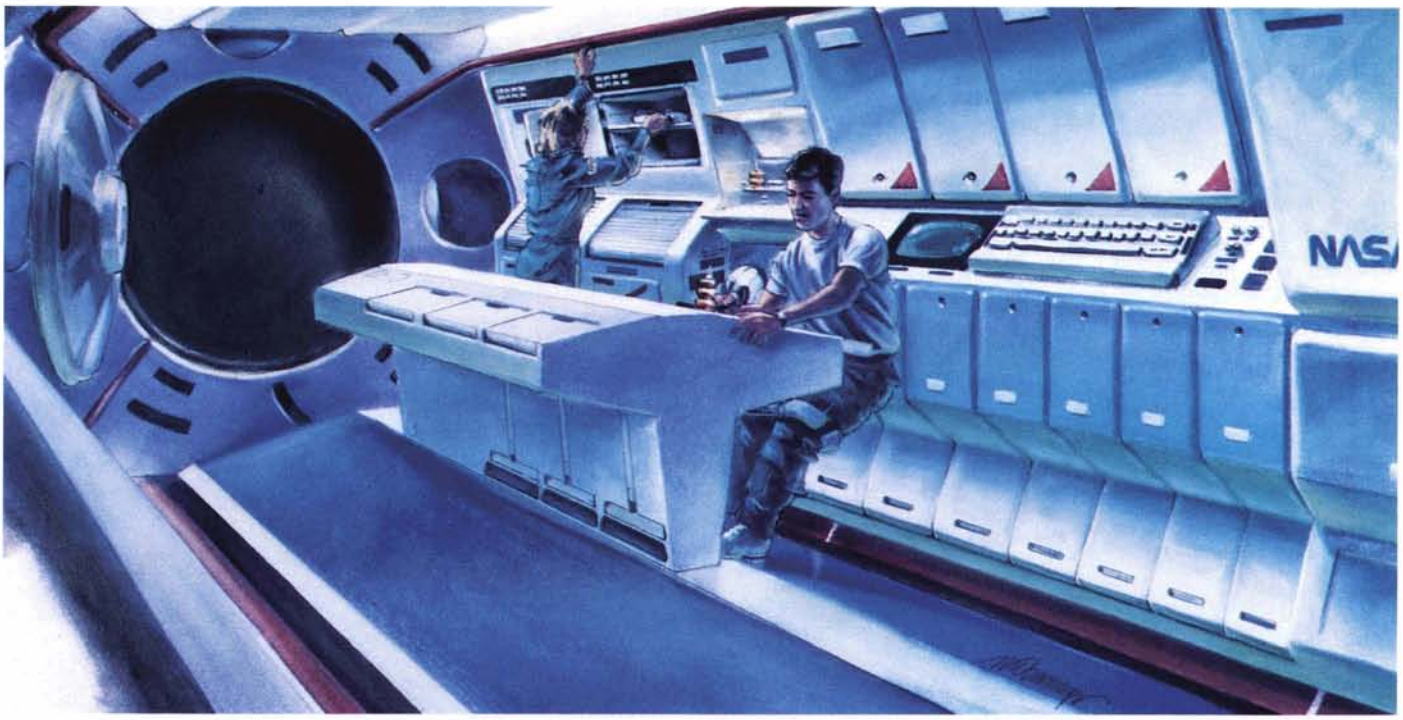
Over the following three years, there will be 19 additional flights, 12 of them for delivery of manned base segments, six for logistics and outfitting. The other flight, planned for late 1995, will deploy the U.S. polar orbiting platform.

There will also be two flights of the European Ariane launch vehicle, one in 1997 to deploy the ESA polar platform, the other at the tail end of the assembly sequence to deploy the ESA Man Tended Free Flyer, a microgravity experiment facility that will operate in an orbit compatible with that of *Freedom*.

With delivery of the U.S. laboratory module on the fourth flight in late 1995, *Freedom* will have a capability for man-tended operations. Permanent occupancy will begin with the 11th flight late in 1996.

The manned base of the Space Station *Freedom* includes the four pressurized modules, three of them laboratories. The U.S. laboratory module is a cylinder 45 feet long and 14 feet in diameter. It will be pressurized—as will the other human habitable modules—to Earth sea level equivalent pressure.

At top is a Boeing Huntsville concept of the U.S. lab module. The astronaut in left photo is working in a commercial processing area that can be closed off to pro-



tect proprietary work. The astronauts in the center are using a general work station, and at far right an astronaut is entering the module from a tunnel that connects with another module and with the visiting Shuttle Orbiter.

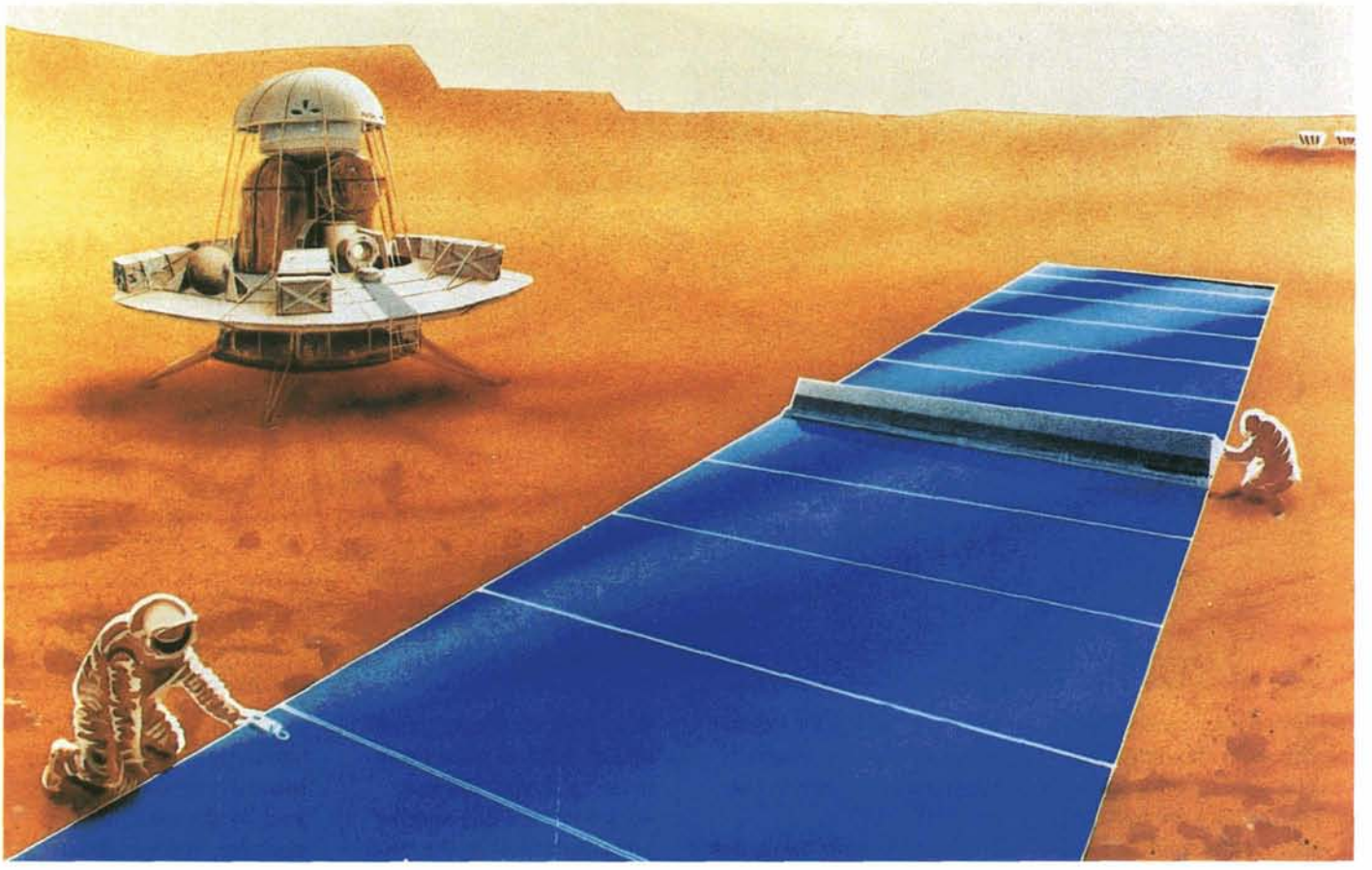
ESA's Columbus laboratory is of similar size, with an airlock for temporary exposure of experiments to the vacuum of space or for transfer of equipment to support external activities.

Japan's JEM (Japanese Experiment Module) includes a short pressurized segment to which a dome-shaped experiment logistics module can be attached, plus an "outdoors" exposed experiment facility for experiments where unpressurized conditions are preferred or essential.

The U.S.-built habitation module, designed for a maximum of eight astronauts, has everything needed for long duration occupancy, including facilities for eating, sleeping, relaxation, medical procedures and work activities. At left is a Johnson Space Center (JSC) full scale mockup used for habitability studies. Above is a contractor concept of the module in which one astronaut (center photo), held in place by restraining straps, sits at a work station while another prepares a meal in the module's galley (far left).

Intended to operate for several decades, the Space Station can be expanded in both size and capability as NASA's overall space program evolves. Among major enhancements envisioned are a servicing bay for maintenance and repair of unmanned satellites; another free-flying platform like the polar orbiters, this one operating in the same orbit as the Space Station; a solar dynamic power system to augment the electricity generated by the solar power modules; and additional truss booms to provide extensive accommodation for attached payloads. ▲

Project Pathfinder



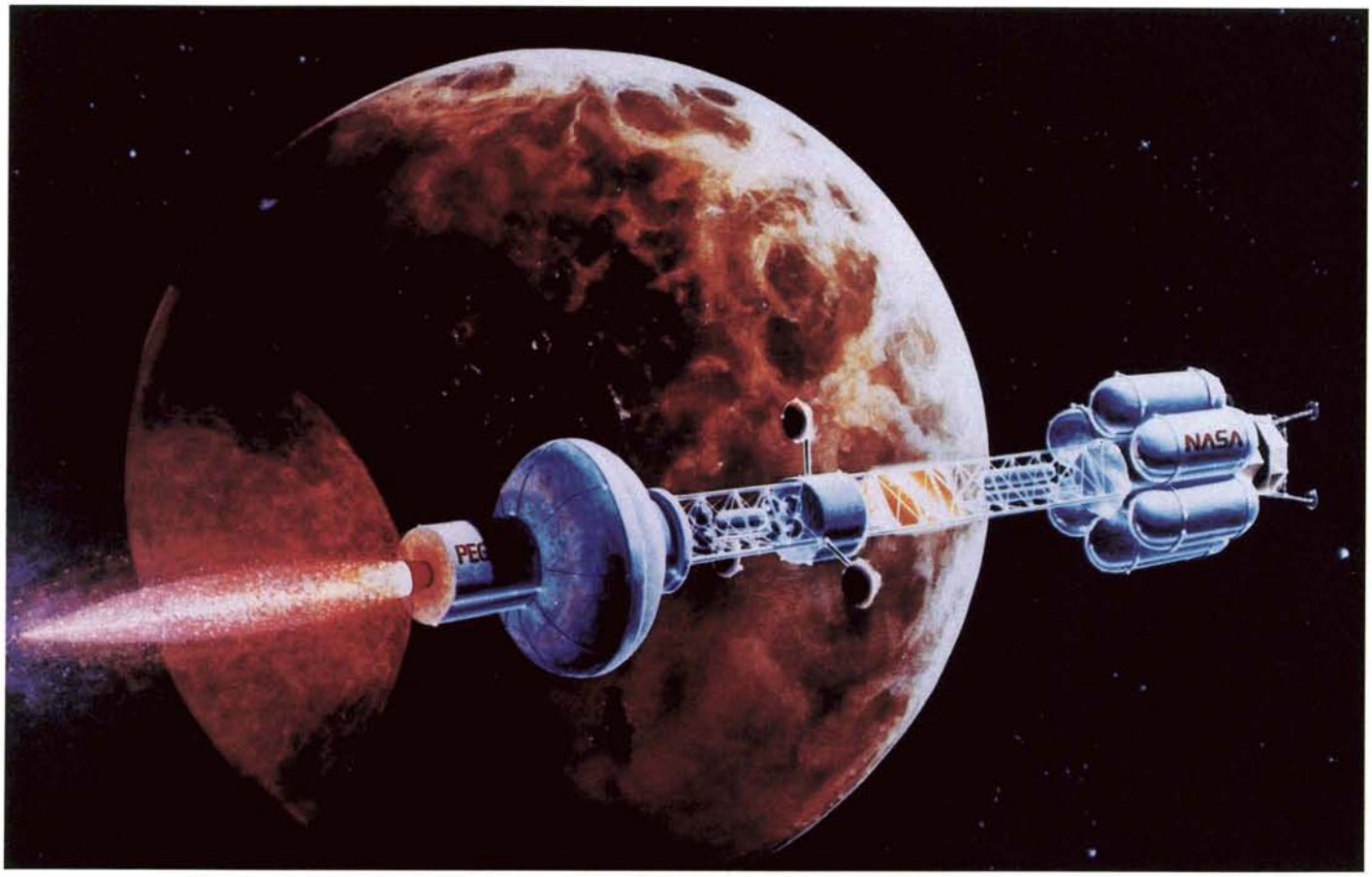
The Presidential space policy announced in February 1988 directed that NASA pursue a long range goal "to establish human presence and activity beyond Earth orbit." The directive recognized, however, that an immediate decision on specific goal, or set of goals, would be premature; intelligent goal selection among the alternatives being considered demands a broader science and technology base.

Therefore, to lay a foundation for deciding advanced goals, the President's directive created Project Pathfinder, a major new program for research and development of "precursor" technologies that will enable a wide range of manned and unmanned missions beyond Earth orbit.

Pathfinder will complement and build upon the ongoing Civil Space Technology Initiative (CSTI). Where CSTI aims to develop technologies related to space operations in low Earth orbit, Pathfinder will concentrate on emerging, innovative technologies that would make possible such lunar/interplanetary missions and advanced robotic exploration of the solar system, a human-staffed outpost on the Moon, or a manned expedition to Mars.

Project Pathfinder is organized around four major thrusts: Exploration, Transfer Vehicles, Humans in Space, and Operations. Each thrust focuses on a set of key technology elements to support critical mission capabilities.

Examples of the Exploration thrust include development of the technologies needed for automated or as-



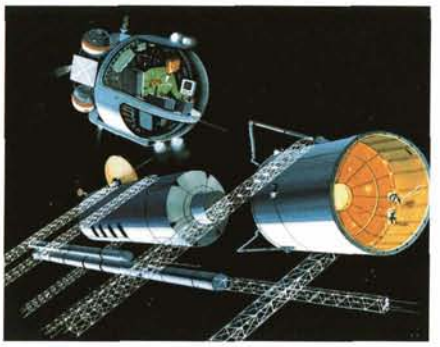
tronaut-driven roving vehicles that could operate on Mars or Earth's Moon; readily assembled surface power systems to support manned exploration of Mars or the Moon (left); and technologies for acquiring, analyzing and preserving surface and subsurface samples from the moon.

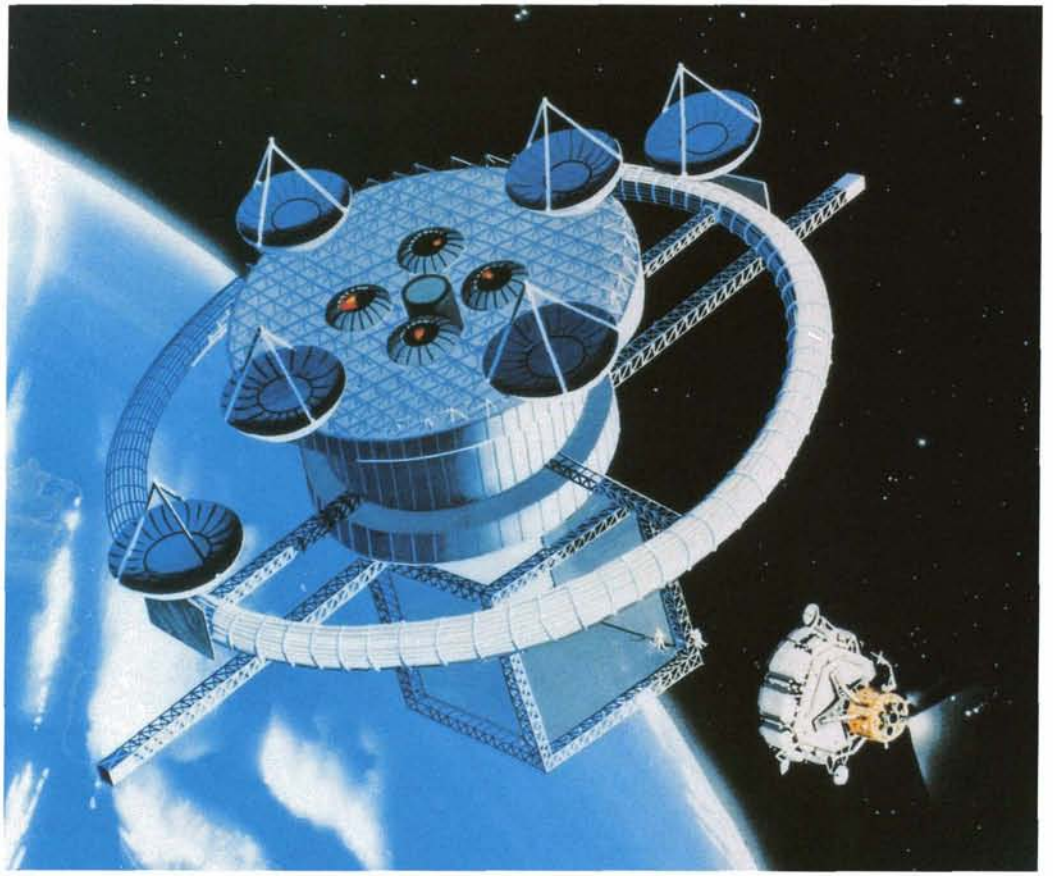
The Transfer Vehicle thrust will provide the technologies for transportation to and from the Moon, Mars and the other planets, and for transfer between different Earth orbits, for example, movement of people or cargo between low Earth orbit and geosynchronous orbit.

Among examples of program elements are investigation of both chemical and electrical propulsion systems and the technique of "aerobraking," in which the atmospheres of Earth or other solar system bodies are employed to decelerate a spacecraft in order to attain the requisite velocity for orbiting the body. Above is an artist's concept of an electrically-propelled cargo vehicle for use in supporting a manned Mars mission or robotic exploration of the outer planets.

(Continued)

Project Pathfinder *(Continued)*



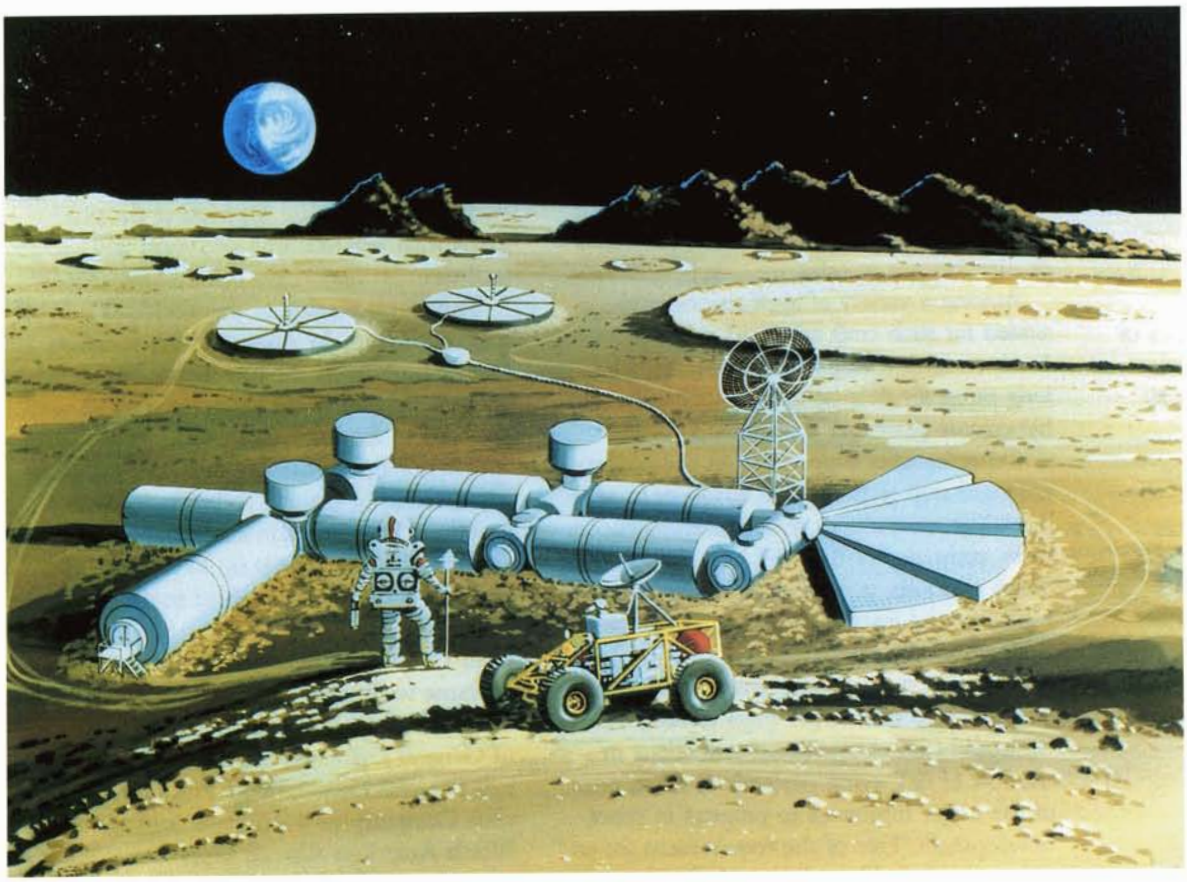


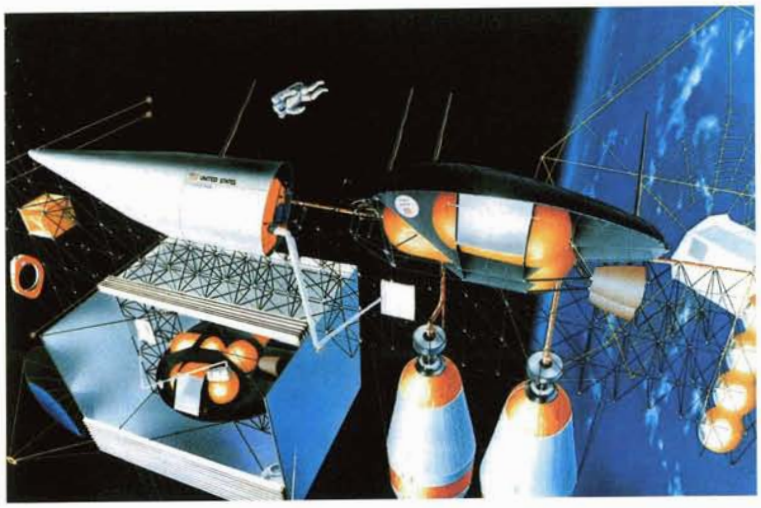
Project Pathfinder's Humans in Space thrust has three major elements. One is directed toward providing a technology base that will allow humans to operate for lengthy periods outside the protection of their pressurized habitats. It focuses on two areas of technology: EVA suits (see page 10) and portable life support concepts and components.

Another part of the Humans in Space effort involves development of technologies to help accommodate human physiological requirements and adaptive changes during long term confinement, exposure to unnatural gravitational conditions, and unaccustomed risk and stress. A third aspect of the program deals with technologies for closed-loop life support systems, intended to reduce the mass of consumables required and thus lower the cost of resupply for extended duration human space activities.

The fourth Pathfinder thrust—Operations—embraces several program elements: among them autonomous rendezvous and docking for non-piloted space systems; technologies for a pilot plant capable of processing resources on the Moon or Mars, for example, extracting oxygen for life support from locally available materials; cryogenic fluid depot technologies to enable development of efficient systems for servicing many types of space vehicles in microgravity; space nuclear power for selected Earth orbiting spacecraft, a lunar outpost, or a piloted mission to Mars; and technologies for robotic assembly and construction of large structures in space (top).

The technologies to be developed under Project Pathfinder are intended to support a wide variety of potential new NASA missions. Some possible applications, each of which would use a number of the technologies described, are illustrated: at left, an advanced Earth-orbiting space station; above, a nuclear powered lunar outpost with resource processing capability; and at right, being readied for launch from an Earth-orbiting space station, a planetary exploration vehicle that would employ virtually all of the Pathfinder technologies. ▲





Flight Plan for Tomorrow

Progress on the National Aero-Space Plane highlights selected examples of NASA aeronautical research, which is providing new technology for coming generations of better performing, more efficient aircraft.

The National Aero-Space Plane (NASP) program is a joint NASA/Department of Defense (DoD) effort to develop and demonstrate the technologies for a revolutionary class of "transatmospheric" vehicles that would be capable of airplane-like horizontal takeoff and landing, flight within the atmosphere at 4,000-8,000 miles per hour, or direct ascent to orbit.

Among a variety of applications envisioned for such craft are rapid response Earth-to-orbit transports or rescue vehicles, long range air defense interceptors and hypersonic passenger transports.

Other benefits expected from the program are giant step technological advances in aerodynamics, propulsion, materials and structures, technologies that will help the United States maintain preeminence in aeronautics in the face of intense and growing competition from abroad.

In addition, successful demonstration of a horizontal takeoff, single stage to orbit vehicle would lead to significant reductions in the cost of delivering payloads to orbit, one of the major inhibitors to progress in space development. Free of the requirement for an elaborate vertical launch complex, a future aerospace plane could boost payloads into space at a fraction of today's costs.

The NASP program began in 1984 as a Phase 1 design study effort with broad industry participation. The concept defined included a conventional takeoff vehicle, powered by an airbreathing (rather than rocket) propulsion system, capable of sustained hypersonic flight and acceleration to Mach 25, the speed necessary to attain orbit.

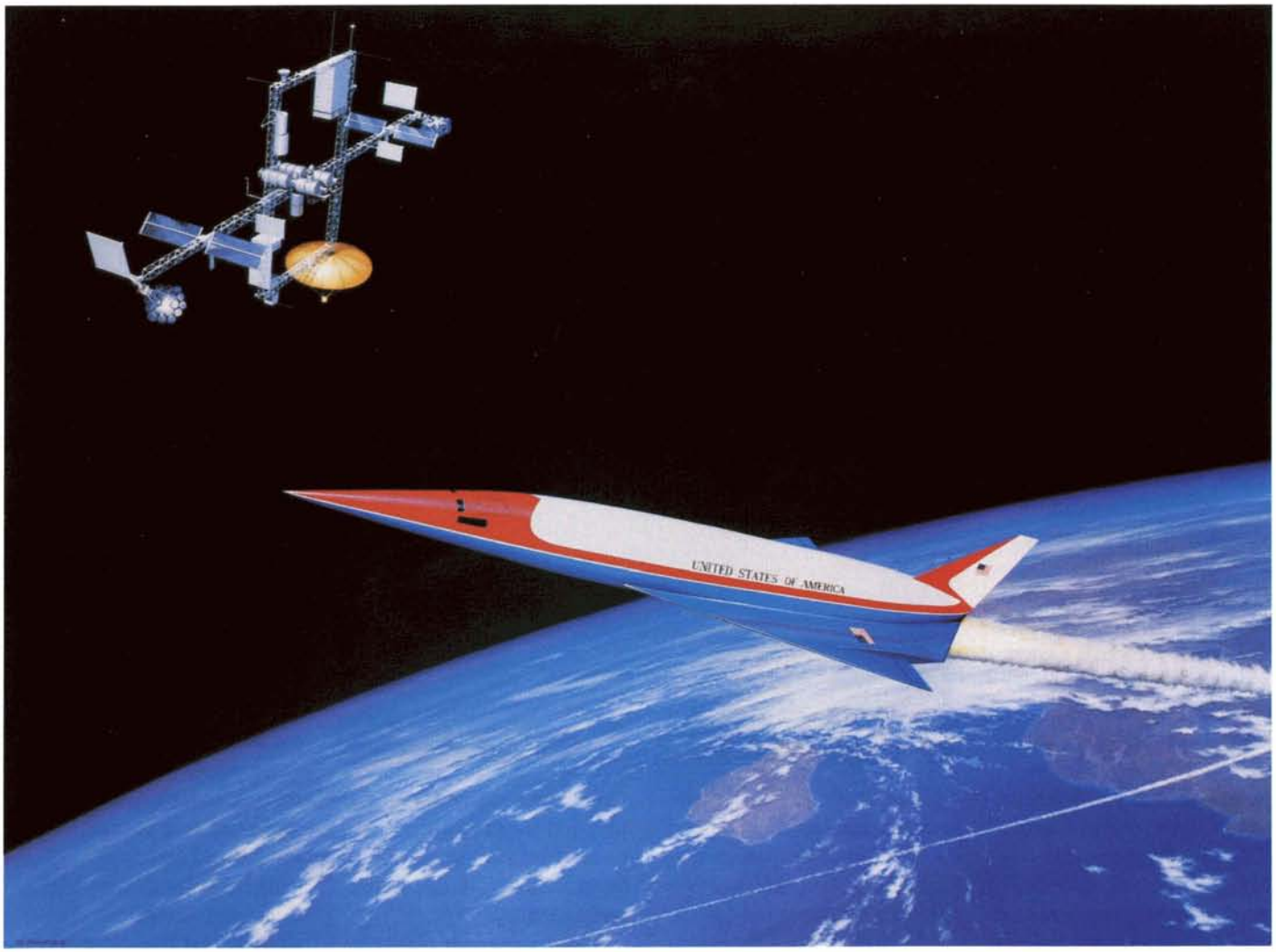
Currently under way, Phase II of the program is the technology development phase, which involves bringing to maturity certain key technologies, developing a proof-of-concept propulsion module and building the components necessary for an experimental flight research vehicle. The U.S. Air Force is managing Phase II; NASA, Air Force and Navy laboratories are supporting the program with key technical personnel and facilities.

The major portion of the workload falls to five contractors. In August 1987, contracts for the propulsion module technology development portion of the program were awarded to Rocketdyne Division of Rockwell International Corporation and Pratt & Whitney division of United Technologies Corporation. They will fabricate engine models and test them at speeds up to Mach 8, the practical limit of wind tunnel testing for propulsion systems.

In October 1987, contracts for continuing airframe technology development were awarded to the Fort Worth (Texas) Division of General Dynamics Corporation; McDonnell Douglas Corporation's McDonnell Aircraft Company; and Rockwell International's North American Aircraft Operations. These contracts call for fabrication and test of selected airframe components, plus preliminary design of a NASP experimental vehicle.

The next major milestone comes in the latter part of 1990, when NASA and DoD will assess the results of Phase II and decide whether to proceed with Phase III—design, construction and test of an X-30 experimental vehicle to demonstrate the technologies throughout the hypersonic cruise/acceleration to orbit flight envelope. Flight tests would begin in the mid-1990s.

NASA's NASP-related work exemplifies the main thrust of the agency's broad aeronautical research program: anticipating the longer range needs of future flight and developing applicable technology. Part of this effort involves research of a general nature aimed at advancing aerodynamics, propulsion, materials and structures, aviation elec-



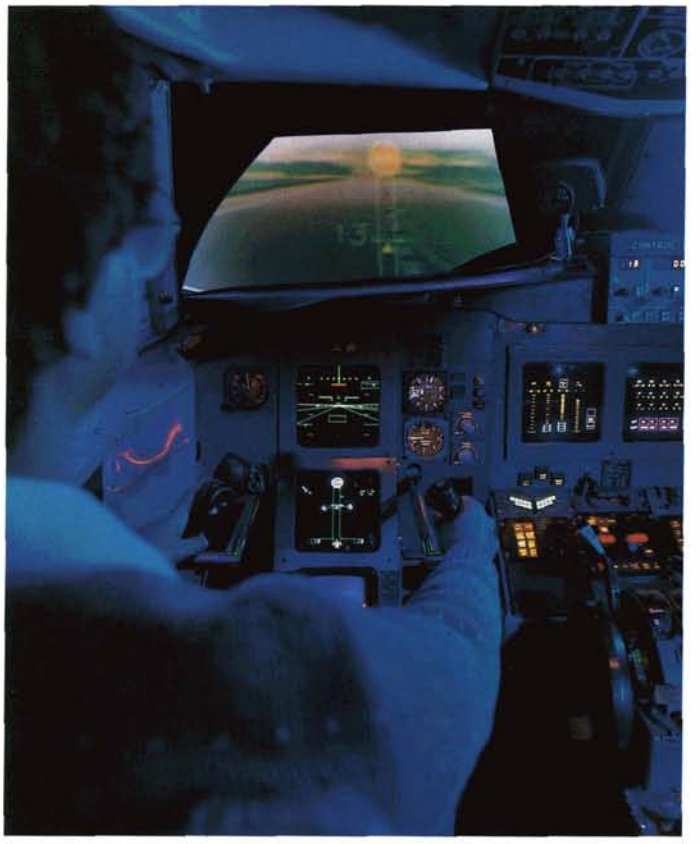
An artist's conception of a 21st century aerospace plane preparing to dock at a space station.

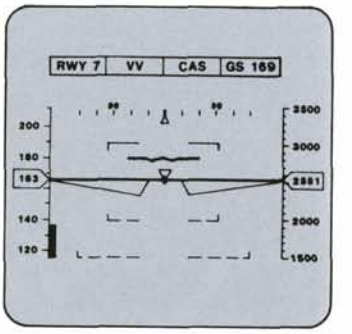
tronics and knowledge of the human factors in flight operations. The other part embraces technology development for improving the performance, efficiency and environmental acceptability of specific types of flight vehicles, such as tomorrow's general aviation planes, rotary wing aircraft, advanced jetliners and high performance military aircraft.

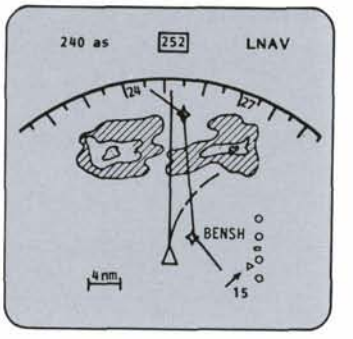
Additionally, the aeronautical research program includes development of technology for solution of current and predictable aviation problems. Examples include curbing aircraft fuel consumption, curbing airplane and helicopter noise, finding ways to alleviate congestion and a variety of safety-related investigations, such as anti-icing research, research on fire resistant materials and improved aircraft structures for better passenger protection. ▲

At right is an experimental concept installed in the cockpit of NASA's Transport Systems Research Vehicle (TSRV). In this new all-electronic flight deck concept, virtually all of the traditional display indicators have been replaced by advanced indicators such as those shown at far right; the upper display shows flight information, the lower navigation information. Electronically generated displays promise to reduce clutter, complexity and crew workload while maintaining reliability in the transport cockpit of the future.

The TSRV is a modified Boeing 737 jetliner operated by Langley Research Center in a cooperative program—with the Federal Aviation Administration—that is exploring technology for enhanced air safety and reduction of flight delays. Called ATOPS—for Advanced Transport Operating Systems—the program aims to provide a technology base for development of airborne automation aids that complement advancing ground-based air traffic control concepts for improved safety, communications and traffic flow.







The TSRV is a flying laboratory, extensively equipped with advanced experimental avionics. It has two flight decks: a conventional forward deck and a fully operational research flight deck, located in the main cabin aft of the standard pilots' compartment. From the windowless aft cockpit, research crews fly the airplane by means of computer-driven systems and informational displays, while pilots on the standard flight deck monitor the flight. The aft flight deck provides the capability to explore innovations in display format and content, and to evaluate pioneering concepts for improved aircraft operations.

On the research flight deck, information is presented to the crew by eight electronic displays representative of the technology that will be available for new commercial transports of the 1990s. Color displays, onboard computers and specially developed software make it possible to provide more clearly information that, in today's aircraft, is presented only partially or in scattered locations.

In addition to the video flight and navigation displays, center panel displays provide capabilities for monitoring engine and system status and managing aircraft systems operation. The center panel displays permit research on how additional information can be displayed to improve air traffic control communications, flight management options and traffic awareness. ▲

Propfan Progress

At top right is the Model 578-DX, a 10,000 horsepower propfan system being jointly developed by a team headed by General Motors' Allison Gas Turbine Division and Pratt & Whitney division of United Technologies. It will be evaluated in tests aboard a McDonnell Douglas MD80 twinjet. McDonnell Douglas, which plans to introduce propfan-powered airliners in the early 1990s, has similarly tested another propfan, General Electric Company's GE36 Unducted Fan, which was also flown in a Boeing 727 test bed.

The 578-DX is an offshoot of an experimental propfan system developed for NASA's Propfan Test Assessment program, which involves ground and flight tests intended to demonstrate that new technology "sweptback" propeller blades, driven by an advanced engine, can provide transport propulsion at jetliner speeds with fuel savings up to 30 percent.

Tested as the port engine of a modified Gulfstream II business jet (above), the PTA engine is somewhat different from the commercially developed engines; it is a tractor-type system rather than a "pusher," and it has a single propeller as opposed to the counter-rotating propellers of the 578-DX and GE36. It is a 6,000 horsepower unit developed by a NASA/industry team managed by Lewis Research Center. The prime contractor was Lockheed Aeronautical Systems Company-Georgia. Subcontractors included Allison, which provided the turbine engine; Hamilton Standard division of United Technologies, which designed and built the propfan;/Rohr Industries, engine nacelle. Gulfstream Aerospace modified the test airplane and Lockheed Aeronautical Systems Company-California was responsible for noise and vibration research.

PTA flight tests began in March 1987. In addition to testing the propulsion system, researchers investigated in flight a new noise control concept developed by Lockheed-California. Noise from large, uncovered propellers is not muffled by a cowling, as in a conventional jet engine. The challenge is to develop a sound insulating cabin wall, without paying a significant weight penalty, so that noise is no greater than in a jetliner cabin. In the PTA airplane, a 10-foot acoustic treatment test section replaced the cabin's regular interior wall. Between the outside structure and interior trim, the test section has new acoustic mufflers and low-frequency sound absorbing materials that provide more isolation per pound than current sound-deadening technologies.

NASA's propfan research began in 1975 as an effort to curb aircraft fuel consumption by combining the best features of the turbofan engine and advanced propellers. Lewis Research Center and Hamilton Standard initially conducted extensive computer design and wind tunnel testing of model propfans. By 1980, research was sufficiently advanced to release the technology to engine builders, who subsequently started their own propfan programs. In 1984, Lewis began the PTA project. In a cooperative NASA/General Electric program, the GE36 Unducted Fan was extensively ground tested in 1985-86, prior to initial flights in 1986. The Allison/Pratt & Whitney 578-DX, which employs a Hamilton Standard propfan, was launched in 1986 and wind tunnel testing began in 1987. In May 1988, the NASA/industry propfan development team was awarded the prestigious Collier Trophy for a major advance in aeropropulsion technology. ▲

High Performance Aircraft

An airplane's angle of attack is the angle between the wing and the air through which it moves. At high angles of attack, airflow around the aircraft becomes extremely complex and accurate information about such airflows is scant. Most aircraft handle poorly at high angles of attack, and they can fall off into dangerous spins.

Better understanding of "high alpha" conditions, as NASA refers to them, could enable prediction of the complex airflow interactions, provide design criteria to prevent spins and related crashes, and greatly increase the maneuverability of high performance jet aircraft. Those are the aims of a NASA High Alpha Technology Program under way at Ames-Dryden Flight Research Facility. The program involves use of a specially equipped and instrumented F/A-18 Hornet (right) on loan from the Navy to investigate high alpha airflows and to test post-stall maneuverability by thrust vectoring, or deflecting the engine's exhaust. Managed by Ames-Dryden, the program is a cooperative effort of Ames, Langley and Lewis Research Centers.

The High Alpha program is expected to create a data base and develop methods that will permit more efficient design of aircraft and thereby minimize costly post-production design fixes.

The F/A-18 research aircraft is equipped with systems that allow visualization of airflow at high alpha conditions in addition to instruments for collecting basic data. Smoke generators delineate vortex flows, minitornados swirling around parts of the aircraft that increase lift and can potentially be used for aircraft control at high alpha. Other flow data is gathered by injecting colored dye fluids onto the air surfaces. Thrust vector control flights are scheduled to begin next year and the program is expected to extend to autumn 1992.

Another major project at Ames-Dryden is flight testing of the X-29 advanced technology demonstrator (above right), built by Grumman Aerospace Corporation for a program sponsored by the Defense Advanced Research Projects Agency with NASA and Air Force support.

The X-29 features a unique forward-swept wing,

made of composite materials, that offers weight reduction of as much as 20 percent in comparison with conventional aft-swept wings. Among other advanced technologies 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 adjusted 40 times a second as a means of improving flight efficiency and aircraft agility. The X-29 program is intended to demonstrate that this combination of technologies makes it possible to build smaller, lighter and more efficient aircraft without sacrificing performance.

The X-29 completed the first phase of its test program in mid-1987; it included 104 flights at speeds up to Mach 1.5. In the second phase, now under way, researchers are further investigating the flight characteristics of the fore-swept wing and the overall performance of the wing and canards. Effects of the X-29's unique configuration as buffet, ground effects and structural loads are also being studied, as are the aircraft's control system and handling qualities. A second X-29 will join the program late in 1988 for high alpha tests of this configuration.

Also in second phase status, after successful conclusion of a 26-flight first phase, is the NASA/Air Force Mission Adaptive Wing (MAW) research aircraft, also known as the Advanced Fighter Technology Integration (AFTI) F-111 (right). The MAW project involves investigation of military potential for the variable camber wing, one whose camber—the fore to aft curve of the airfoil—can be changed in flight. This

enables the aircraft to fly with optimum wing curvature at subsonic, transonic and supersonic speeds, thus offering potential for greater flight efficiency.

Built by Boeing Military Airplane Company, the AFTI F-111 MAW system changes its shape by means of computer-controlled hydraulic actuators that move a series of smooth-surfaced flaps on the wing's leading and trailing edges. This is more efficient aerodynamically than the "broken" surface leading and trailing edge flaps of all modern military and commercial aircraft.

In Phase I, the MAW system was operated only in the manual mode, with preprogrammed wing curvature selected by the pilot. For Phase II, the computers were modified to enable automatic adjustment of wing curvature. Phase II involves completion of manual mode tests and evaluation of automatic MAW operation. Computer programs direct the system to adjust for optimum wing performance based on pilot inputs and other flight conditions. ▲

Performance advances envisioned for fighter aircraft of the 1990s could require costly development of new engines. But a new NASA-developed engine control system offers a possible alternative: squeezing unused power out of existing jet engines to gain major thrust and fuel economy advantages.

Using new engine/flight control integration technology, researchers at NASA's Ames-Dryden Flight Research Facility are demonstrating increased thrust of 10 percent and more in an F-15 research aircraft (right). Flight tests have also shown that fuel savings of five to seven percent may be achieved in lieu of higher thrust. This increased performance has been attained with only one of the F-15's two engines fitted with the new control system.

The research effort is known as the Highly Integrated Digital Electronic Control (HIDEC) program, a cooperative program involving NASA, the Air Force, F-15 builder McDonnell Douglas Corporation and engine builder Pratt & Whitney division of United Technologies Corporation.

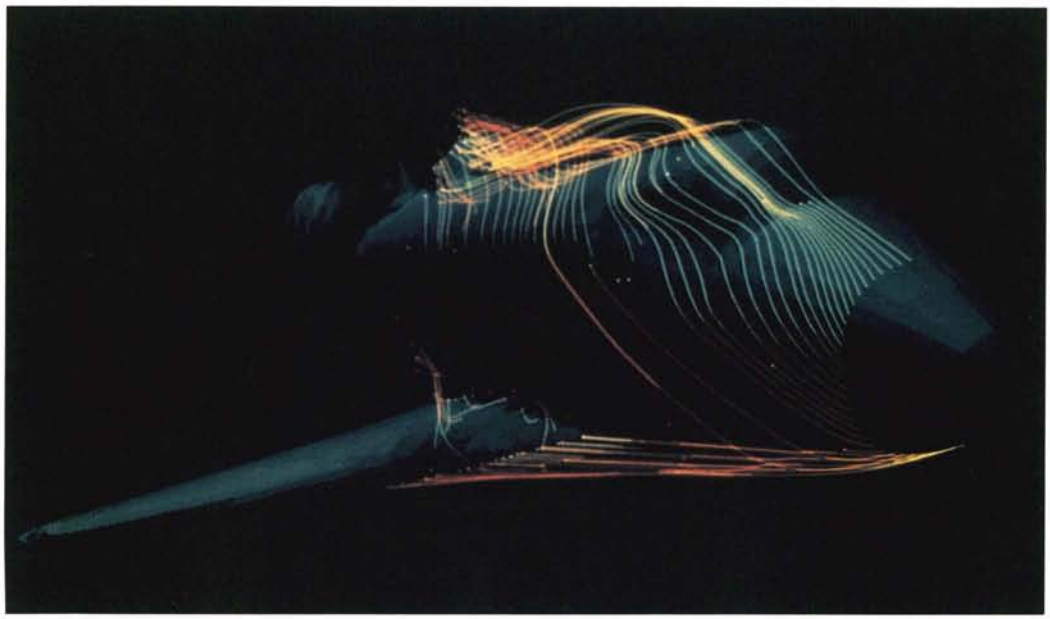
HIDEC gets increased performance by trading unneeded engine stall margin (the amount of engine operating pressure for additional thrust reduction required to avoid stall at any given instant). A typical jet engine stall margin is 25 percent, because designers have to allow for the worst combination of flight conditions the aircraft may encounter. That 25 percent margin can reduce the engine's usable power by about 15 percent.

The HIDEC system, in which engine and flight control systems communicate with each other, allows the engine to adjust itself to the minimal stall margin for any flight condition, down to about 12 percent, for a substantial gain in usable power. Flight condition information, such as attitudes, rates and pilot commands, are provided to the HIDEC and analyzed. In addition, HIDEC anticipates flight conditions in advance to select the minimal margin required for that instant of flight. The appropriate commands are then made to the digital engine control system, which adjusts the engine nozzle to provide the correct operating pressure.

The Ames-Dryden F-15 has one standard F-100 engine plus a Pratt & Whitney 1128 research engine with the digital electronic controls. In addition, the F-15 has a digital electronic flight control system. The flight test program has been under way since June 1986. ▲

Computer Design

In aeronautics, researchers create mathematical models of flight vehicles and "fly" them by computer simulation, thus allowing study of many different configurations before settling on a final design. Called computational simulation, this technique has expanded enormously in recent years to embrace calculation and visual imagery of many types of forces acting upon flight vehicles, including phenomena that cannot be realistically simulated in a wind tunnel.



The world's most advanced computational system, now operational, is NASA's Numerical Aerodynamic Simulation (NAS) facility. Located at Ames Research Center, it is a supercomputer system being developed in building block fashion toward an eventual capability of 10 billion calculations a second.

NAS is an evolutionary effort to permit realization of a major goal of aeronautical science: the ability to simulate routinely the complex three-dimensional airflow around a complete airplane and its propulsion system. Such a capability will allow solution of many previously intractable problems and make possible many of the calculations required to develop advanced aircraft with greater accuracy and reliability. NAS will not only improve the design process, providing costs savings and aircraft performance gains, it will also reduce the long and expensive wind tunnel and flight testing essential to final validation of a design.

The key to attainment of that goal is far greater computer capability than has been available. NASA is incorporating the latest supercomputing technology as it becomes available, so that NAS serves as an advanced pathfinder in supercomputing for government, industry and universities. Since 1986, when the facility went into limited operation with a capability of 250 million calculations a second, the NAS computational capability has been boosted fourfold, to one billion calculations a second. A near term goal for the early 1990s is a NAS memory of one billion words and computer power for four billion calculations a second. The long term goal of 10 billion calculations a second is targeted for the late 1990s. Such computational capability will not only provide enormous impetus to aerospace research and development, it will also permit major advances in other areas, such as non-aerospace structural design, materials research, chemistry and weather research. ▲

Icing Research

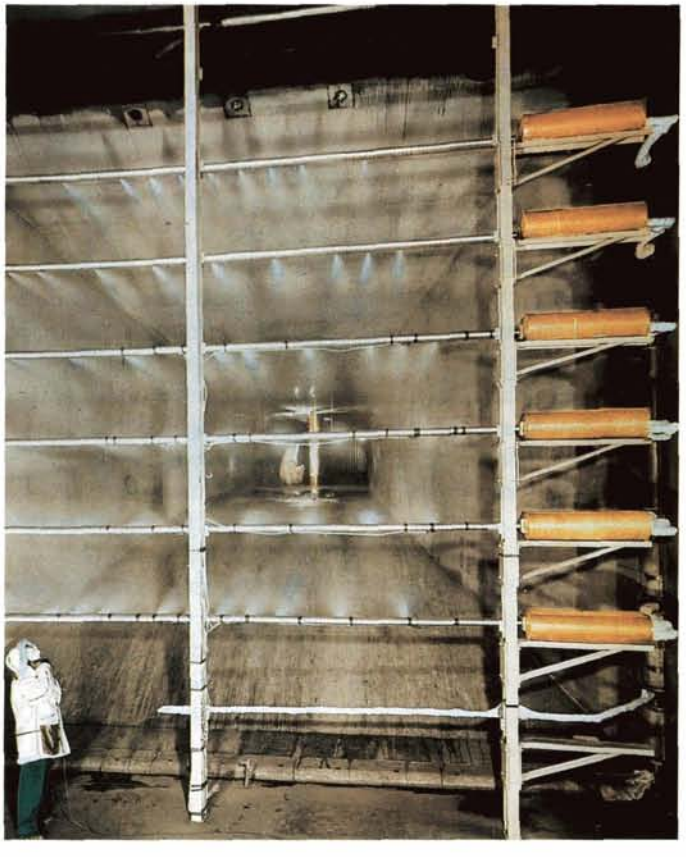
Today's commercial aircraft are adequately protected against such hazards of ice formation as reduced lift, increased drag, stall, engine power loss or other problems. But the need for aircraft icing research has not abated. In fact, it has increased in recent years for a variety of reasons.

For example, bleeding hot air from a jetliner's engine and routing it to airplane surfaces is a highly effective way of controlling icing, but it can be costly when fuel prices go up and a less expensive approach is an attractive research goal. Helicopters are finding greater use in both military and civil aviation and they exhibit unique icing problems. Similarly, advanced military aircraft require new ice protection concepts compatible with their unique designs. And there is special need for reasonably priced ice protection systems for general aviation aircraft.

Thus, NASA conducts a continuing program of anti-icing research with its focal point at Lewis Research Center. One aim is development of technology for ice protection systems that are more effective yet require less weight and power than contemporary systems. Another is simply to learn more about icing—how ice forms under different environmental conditions, how it changes the aerodynamics of an aircraft, generally how it influences flight.

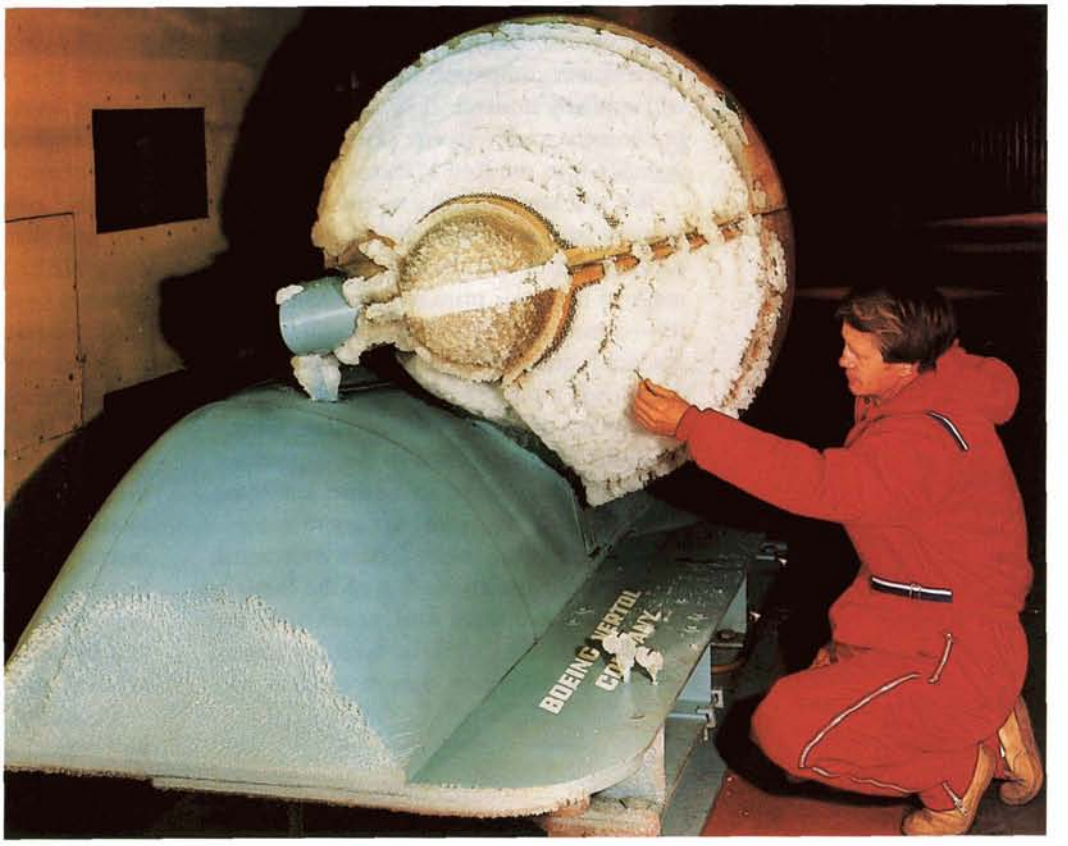
Lewis conducts laboratory and flight investigations of a generic nature toward improved understanding of icing physics that will enable better prediction of ice accretion. The center also investigates specific problem areas and experimental systems, looking for ways to prevent ice from forming, ways of removing it, or both. Among types of ice protection systems being investigated are electrothermal (heat application) systems, electromagnetic impulse deicers, helicopter rotor deicers with pneumatic boots, and special fluids that lower an aircraft component's freezing point.

For this work, Lewis has available a historic facility



that played a major role in anti-icing advances of the past four decades—the Icing Research Tunnel (IRT), which has been formally designated an International Historical Mechanical Engineering Landmark by the American Society of Mechanical Engineers. First operated in 1944, the IRT underwent a major renovation in 1986 to expand its capabilities and enable it to cope with a substantially increased workload. It is experiencing heavy demand from government and industry organizations seeking solutions to modern icing problems.

At upper left is the IRT's 4,160 horsepower fan drive system capable of generating simulated airspeeds up to 300 miles per hour while a 2,000-ton cooler lowers the temperature as far as 30 degrees below zero Fahrenheit. At left is the tunnel's icing spray system. At right above, a Lewis engineer is examining the tail of a general aviation airplane after an IRT test of glaze ice accumulation. Right, a researcher is inspecting ice buildup on the foreign object deflator screen of the engine of a Boeing CH-47 military helicopter. ▲



Exploring the Cosmos

A new NASA strategic plan for space science promises dramatic expansion of man's knowledge about Earth and its place in the universe.

By the dawn of the 21st century, advances in U.S. space science will bring about far deeper understanding of the Earth we inhabit, the solar system and the universe, an expansion of knowledge as revolutionary as that which occurred when the 16th century astronomer Copernicus showed that Earth was not the center of the universe.

Our way of thinking about Earth's and man's uniqueness in the universe will change; we will have good estimates of how many stars have planets and we will have images of at least one planet beyond the solar system. The question of whether the universe is expanding indefinitely or whether it will at some future time begin to contract may have been answered. Robotic spacecraft will have examined all the planets and moons of our solar system except Pluto and its satellite Charon. Our own Moon will have been studied in greater detail and its surface mineral and element composition determined. Mars will similarly undergo close scrutiny as a preliminary to developing plans for a human expedition to the Red Planet.

We will have peered into the early history of the solar system through space-based supertelescopes and through study at close range of the most primitive, unaltered bodies—comets and asteroids. We will have a spacecraft orbiting Saturn and it will have dispatched a probe into the thick, murky atmosphere of Saturn's moon Titan, whose evolution may hold clues to the appearance of life on Earth. From an intense, multiyear study of Earth by a great variety of space-based instruments, we will have enormously advanced our understanding of the Earth system on a global scale. And, at century's end, a probe from Earth will be speeding toward the unexplored region close to the Sun, to enhance man's capability to predict the behavior of the star that is central to the destiny of the solar system and humanity.

These are a few of many exciting views of tomorrow offered in "a clear vision of a desired future" advanced by NASA's Office of Space Science and Applications (OSSA) in its *Strategic Plan 1988*. OSSA proposes a broad scientific research and applications program designed to maintain U.S. leadership in space, reaffirmed as a fundamental objective in the revised 1988 National Space Policy directive.

The science program is based on assumptions that NASA's overall space plan will proceed generally as envisioned, that the NASA budget will continue to grow to accommodate expanded aims, and that space science will be allocated a proportion of the overall budget consistent with historical levels. However, the strategy calls for a flexible process that allows adjustment to varying budget levels.

Strategic Plan 1988 retains the traditional focus of space science activity—advancing scientific knowledge of Earth, the solar system and the universe—and additionally supports NASA's new goal of expanding human presence beyond Earth by providing the scientific research foundation essential to plan major humans-in-space initiatives.

As in the past, space science goals will be pursued through an integrated program of ground-based laboratory research; suborbital flight of instruments carried by aircraft, balloons and sounding rockets; orbital flight of instruments aboard the Space Station, the Space Shuttle and its Spacelab component, and on commercially developed facilities; and by flight operations of automated Earth orbiting and interplanetary spacecraft.

Pursuit of space leadership is best served by "major" missions that provide quantum leaps in scientific/technological advancement. When available resources do not permit a major program, NASA will pursue a scaled

down "moderate" mission that will still offer significant advancement and visibility. The plan proposes initiation of at least one major or moderate mission a year.

But "small" missions are also vital to the program, because they can be accomplished relatively inexpensively, allow quicker consideration of more innovative ideas, and they can be conducted on a short time scale, offering fast turnaround and continuing opportunity. The plan contemplates start of a small mission every year, in conjunction with a major or moderate mission.

The strategic plan is subdivided into seven divisions, including astrophysics, the study of distant stars and galaxies toward an understanding of the origin and fate of the universe; solar system exploration, investigation of the planets, moons, comets and other bodies of the solar system; and space physics, which involves investigations of the origin, evolution and interactions of plasma (ionized gases) originating in the solar system and beyond.

A subdivision that will get considerable research emphasis is Earth science and applications, which seeks understanding of the factors that influence Earth's environment and use of the knowledge gained to benefit humanity. A related applications area is development of communications and information systems technology to meet the future needs of government and the satellite communications industry.

The other two subdivisions are microgravity science and applications (see page 46) and life sciences. The latter is aimed at understanding the origin and distribution of life in the universe and at utilizing the space environment to improve knowledge in medicine and biology, with special emphasis on assuring that humans can perform safely and effectively in space.

(Continued)

Encased in thermal insulation to keep temperatures of the spacecraft structure even, the Hubble Space Telescope is shown being moved to a thermal vacuum chamber for an April 1988 environmental test. One of the keystone elements of NASA's space science strategic plan for the remainder of the century, the telescope is shown at left as it will look in orbit after its 1989 launch.

The Cosmic Background Explorer will study the radiation emitted by celestial objects seeking clues as to the earliest beginning and structures of the universe.

The year 1989 promises to be a year of unparalleled space science activity, with scheduled launches of five major new programs plus the August arrival of the Voyager 2 spacecraft at distant Neptune, one of two as yet unexplored planets.

Targeted for February launch by an expendable launch vehicle is the Cosmic Background Explorer, a two-and-a-half ton observatory designed expressly to investigate the Big Bang theory of the origin of the universe.

In April, the Space Shuttle will dispatch the Magellan spacecraft toward Venus to map the neighbor planet with unprecedented precision. In June, the Shuttle is expected to deliver to orbit the Hubble Space Telescope, widely considered to be the most important scientific instrument ever designed for use in space.

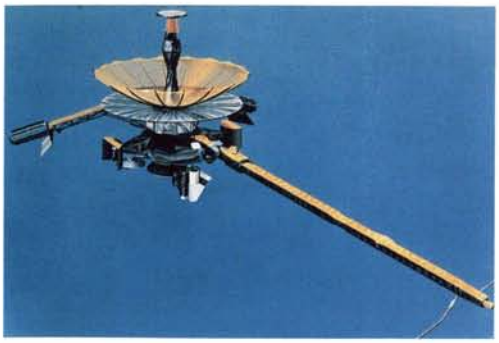
Scheduled for October Shuttle launch is Galileo, intended to probe Jupiter in the most comprehensive investigation yet conducted of a planet other than Earth. And in November the Shuttle will carry aloft a new astronomical system called the Astro Observatory, designed for ultraviolet and x-ray imaging of the universe.

During 1989, development will continue on a number of missions planned for launch from 1990 through 1993. Among them are the Gamma Ray Observatory, second—after the Hubble Space Telescope—of the Great Observatories; the Ulysses solar polar mission; the Wind, Polar and Geotail satellites of the international cooperative Global Geoscience Program; and the Mars Observer, which will conduct a long term investigation of the Red Planet. NASA also plans to start work in 1989 on the third of the Great Observatories, the Advanced X-ray Astrophysics Facility.

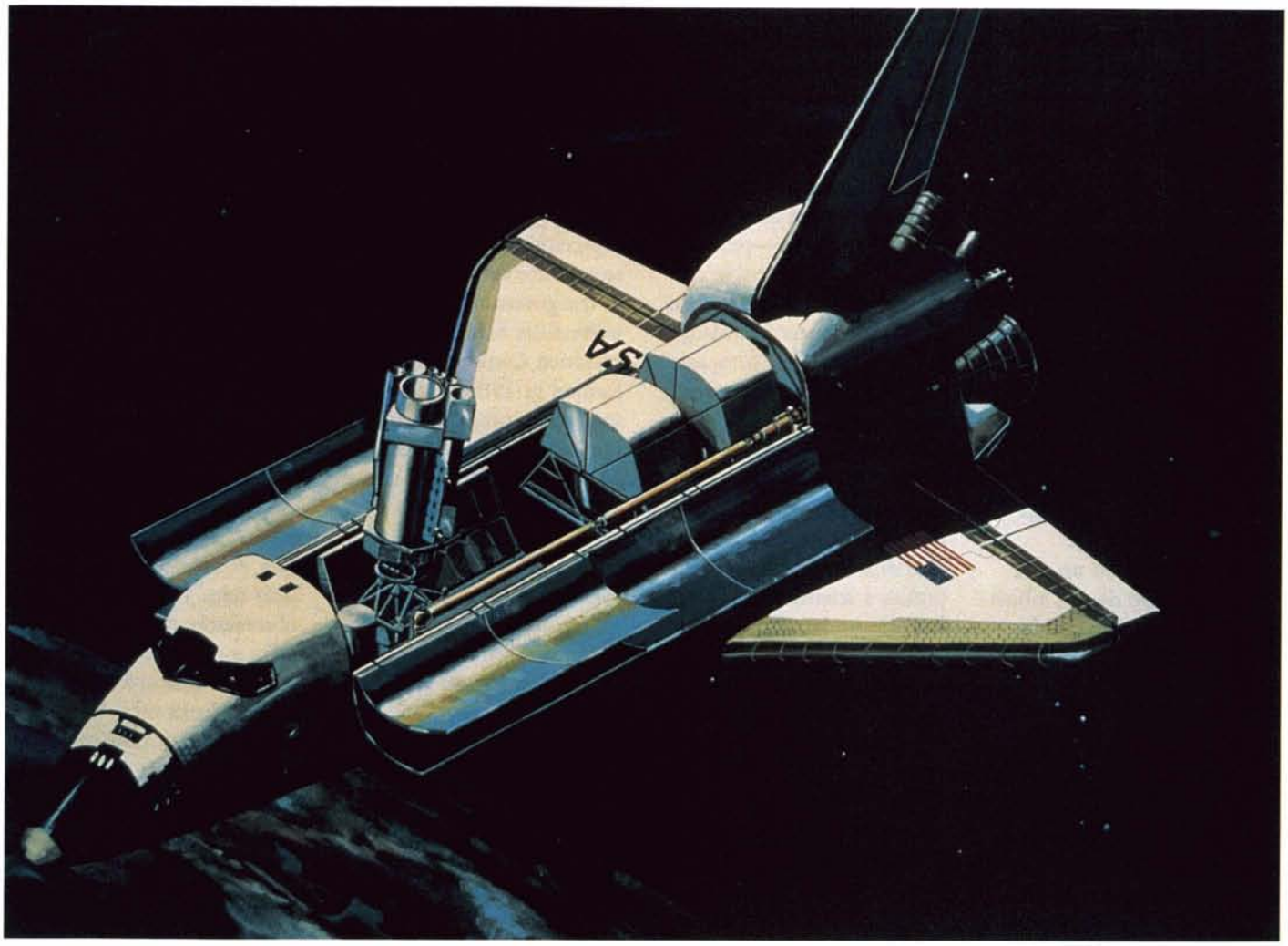
Additionally, 1989 activity will include development—for operation in 1990-1993—a series of experiment packages to be flown in the Shuttle-based Spacelab system; they include several life science missions, two microgravity research laboratories, several atmospheric science laboratories, two astronomy laboratories and two space radar laboratories.

All of the major projects in the 1989 ongoing program will have been launched by 1993. Since it takes about six years to develop a new major flight project, it will be necessary, during 1990-1994, to select and initiate the successors to the ongoing program. The strategic plan contemplates these major missions:

- The Comet Rendezvous Asteroid Flyby, a closeup look at an asteroid followed by a multiyear rendezvous with a comet.
- Cassini, a comprehensive investigation of Saturn, its major moon Titan, its rings and other moons.



One of two planetary missions planned for launch in 1989, Galileo is a two-element spacecraft that includes a Jupiter-orbiting observatory and a probe that will descend into the Jovian atmosphere.



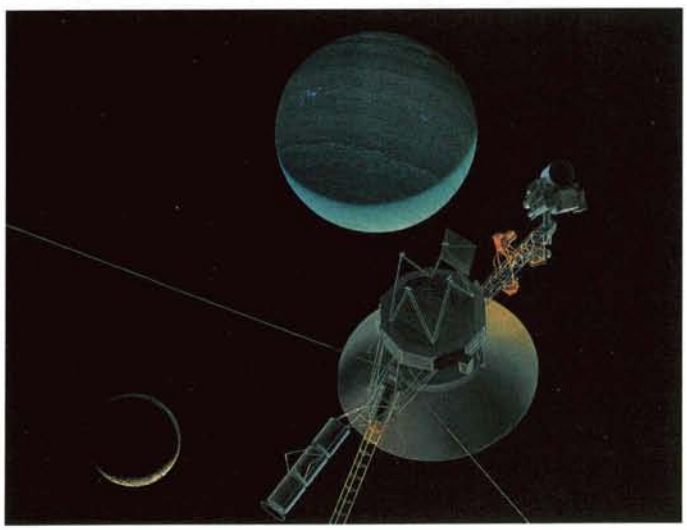
- The Earth Observing System, centerpiece of a long term integrated study of Planet Earth and global change.
- The Space Infrared Telescope Facility, fourth and last of the Great Observatories.
- The Solar Probe, man's first direct exploratory venture to the vicinity of the Sun.
- The High Resolution Solar Observatory, a platform for studying in visible light the fundamental processes of the Sun's surface atmosphere.
- The Lunar Observer, a long duration mapping mission to measure the Moon's surface composition and to assess its resources.
- Gravity Probe-B, which will test Einstein's theory of general relativity.

These programs are amplified on the following pages. ▲

The Shuttle-based Astro Observatory, scheduled for first service late in 1989, will view the sky in ultraviolet light not visible on Earth and provide high-resolution x-ray views of a recently-discovered supernova.

Solar System Exploration

In August 1989, the Voyager 2 spacecraft will make a close encounter with the planet Neptune, reaching its closest point on August 25 (below), when Earth and Neptune will be separated by 2.8 billion miles. Already a veteran of highly successful imaging encounters with Jupiter, Saturn and Uranus, Voyager 2 will be more than 12 years out of home port Earth. The images it returns will provide man's first real look at Neptune, because the planet is not visible to the unaided eye and even to large telescopes it shows up as a small, greenish disc in which no surface detail is visible.

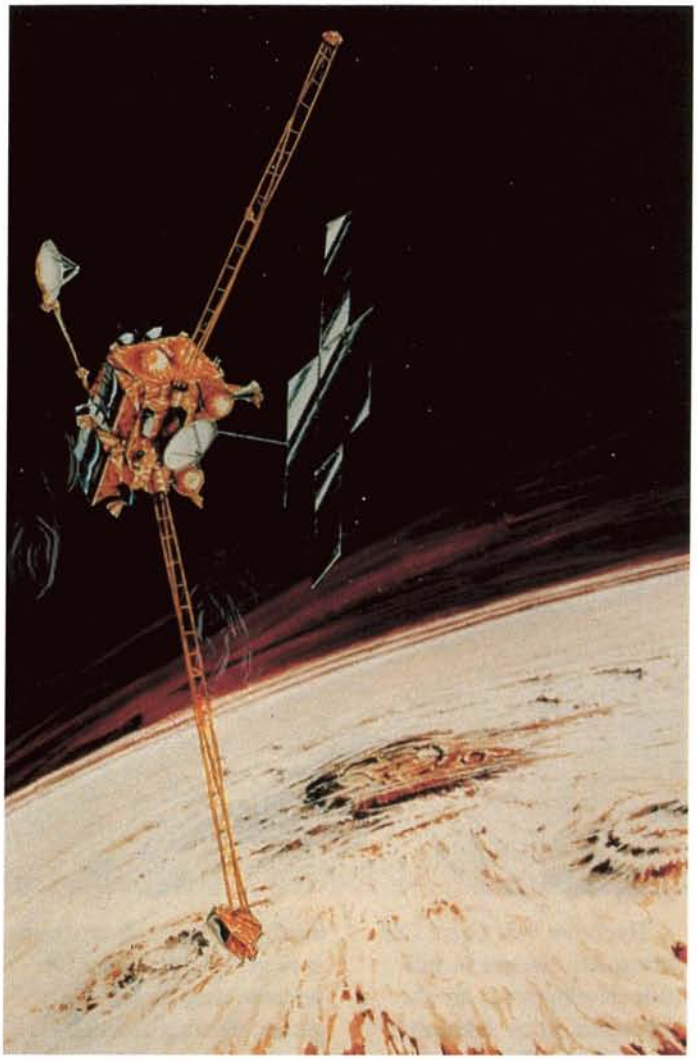


Managed by Jet Propulsion Laboratory (JPL), the Voyager project exemplifies NASA's solar system exploration program, aimed at understanding how the solar system and its objects formed, evolved and—in at least one instance—produced an environment capable of sustaining life. The program also seeks greater knowledge of Earth through "comparative planetology," the science of relating phenomena on one planet to conditions on another and learning why the planets are so different from each other. An ancillary goal of the program is to establish a scientific/technical base for undertaking major human endeavors in space; this aspect of the program involves survey of near-Earth resources, characterization of planetary surfaces and a search for life on other planets.

NASA's planetary exploration effort is built around the recommendations of the government/industry/universities Solar System Exploration Committee (SSEC), formed in 1980 to develop a long range program. Stressing cost effectiveness and use of existing technology to the extent possible, SSEC's Core Program recommended a continuing series of modest Planetary Observer missions to explore the inner planets and near-Earth asteroids, using reconfigured "off-the-shelf" Earth orbital spacecraft. Additionally, SSEC recommended a complementary series to explore the outer planets, comets and asteroids; these missions would employ a common, basic Mariner Mark II spacecraft with evolving technological capabilities for a variety of exploratory assignments.

In April 1989, NASA will launch the first planetary mission since Voyagers 1 and 2 departed Earth in 1977. Called Magellan, it will orbit Venus and image in never-before-seen high resolution views of the surface of the cloud-shrouded planet for continuing comparative studies of Earth and Venus, two neighbor planets similar in many respects that have evolved in strikingly different fashion. Using an advanced system called a synthetic aperture radar, Magellan will map more than 90 percent of Venus' surface with resolutions 10 times better than the best obtained by prior spacecraft. Magellan is managed by JPL; Martin Marietta is developing the spacecraft and Hughes Aircraft the advanced imaging radar.

On the currently planned schedule, October 1989 will see the second planetary mission of the year—Galileo, a long term Jupiter-orbiting observatory that will also carry a probe to investigate Jupiter's atmosphere. Delivered to Earth orbit by the Space Shuttle, Galileo will be boosted into a trajectory that will take it six years to reach Jupiter. As it approaches the giant planet in mid-1995, Galileo will release the probe to descend by parachute into the Jovian atmosphere. The main spacecraft will swing into orbit around Jupiter, in effect becoming a man-made moon, transmitting—for at least two years—high quality images and instrument data



from many different vantage points. Galileo is a cooperative program with the Federal Republic of Germany. JPL is project manager and builder of the main spacecraft; Ames Research Center has responsibility for the entry probe, which was built by Hughes Aircraft and General Electric Company.

A third authorized planetary mission is the Mars Observer (above), first of the Planetary Observer series. Slated for 1992 launch, the spacecraft will operate as a Martian moon, providing remotely sensed data of the planet's surface with the highest resolution yet attained and reporting data in two general areas: geoscience and climatology. JPL manages the program; General Electric's Astro-Space Division is developing the spacecraft.

The second planned (but not yet authorized) Planetary Observer is the Lunar Observer, one of the highest priorities in the space science strategic plan. The Lunar Observer is intended to conduct a one-year, polar orbit mapping mission, measure the Moon's mineral and elemental composition, assess its resources, measure surface topography and magnetic/gravitational fields. In addition to acquiring a wealth of scientific information, the Lunar Observer will contribute to NASA's goal of preparing the way for a possible human outpost on the Moon.

NASA hopes to inaugurate the Mariner Mark II series in the 1990s with the Comet Rendezvous Asteroid Flyby (CRAF). Comets and asteroids have never been observed at close range. Because they are small and "cold" bodies, comets and asteroids did not evolve as did the major bodies of the solar system, thus they remain largely unchanged from their formation four and a half billion years ago and investigation of their chemical and elemental composition offers an opportunity to observe material as it existed when the solar system was born. The CRAF plan envisions a close flyby of a main belt asteroid (above) followed by a multiyear rendezvous and closeup study of a comet's nucleus, dust and atmosphere.

The second mission planned for the Mariner Mark II series is Cassini, a comprehensive scientific examination of Saturn, including probe study of the surface and atmosphere of Titan, Saturn's principal moon.

In addition to these flight programs, the solar system exploration plan includes development of new Earth-orbiting satellites for interplanetary research, use of the Hubble Space Telescope, and interplanetary research payloads attached to the structure of the Space Station. ▲

Astronomy and Astrophysics

In 1989, the Space Shuttle will deliver to low Earth orbit the largest and perhaps most scientifically important payload ever built, the 12½-ton, 43-foot Hubble Space Telescope (HST), first of four planned Great Observatories. Managed by Marshall Space Flight Center, the HST will be able to look back in time some 14 billion years, observing the universe as it existed early in its lifetime, when galaxies were being formed.

Designed to operate well into the 21st century, the HST will enormously expand the viewable volume of the universe, will return images with extraordinary clarity and will detect very dim objects that have never been observed. The spacecraft was developed by Lockheed Missiles & Space Company and the optical assembly by Perkin-Elmer Corporation. The European Space Agency furnished the power generating array and one of the system's five major instruments. Goddard Space Flight Center will control the telescope and process its data when the HST is on orbit.

The HST is the centerpiece of NASA's astrophysics program, which seeks unprecedented understanding of the origin and fate of the universe, the underlying fundamental laws of nature and physics that govern the cosmos, and the birth and evolutionary cycles of galaxies, stars and planets.

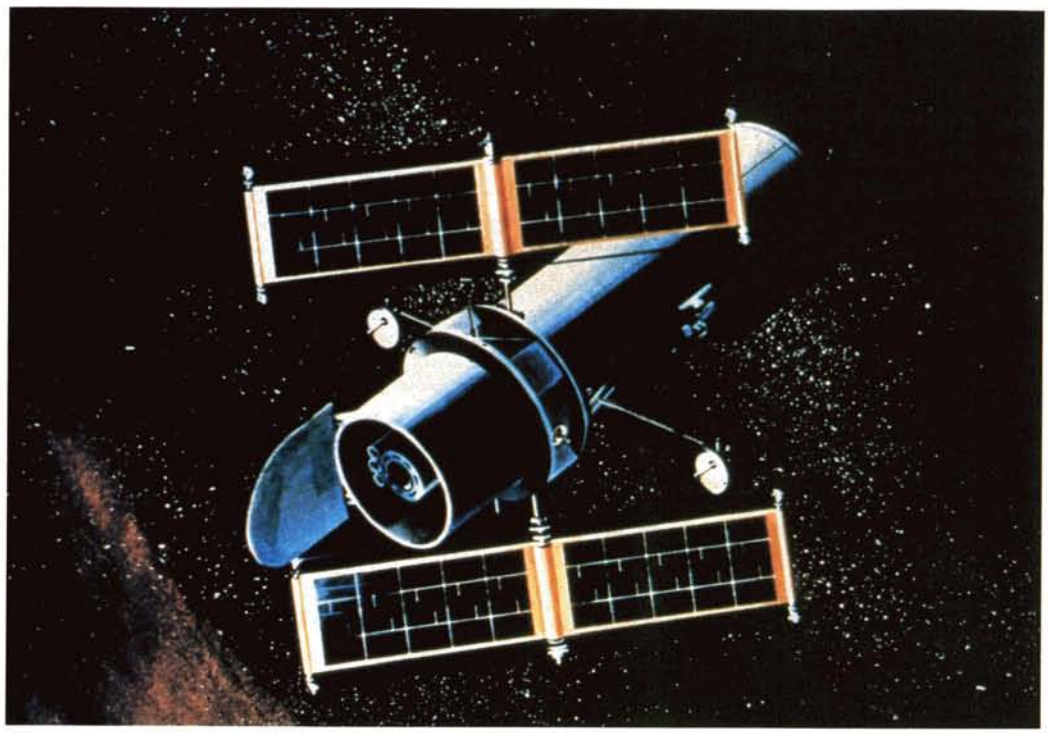
Observation of celestial phenomena from orbit, above the distorting layer of atmosphere that surrounds Earth, offers an opportunity to observe the universe not only in visible light but in other forms of radiation that are largely invisible to ground observatories because they are absorbed or filtered by the atmosphere. Thus, one of the primary objectives of the astrophysics program is to observe in all four major wavelength regions of the electromagnetic spectrum—the infrared, optical/ultraviolet, x-ray and gamma ray bands.

The HST will view in the visible and ultraviolet wavelengths. Its findings will be augmented, beginning in 1990, by the Goddard-managed Gamma Ray Observatory (GRO), a joint development of the U.S., West Germany, The Netherlands and the United Kingdom. The second of the Great Observatories, the GRO (above) will investigate gamma radiation, the most energetic of all forms of radiation, and its violent sources—pulsars, quasars, black holes and other objects that have not been identified in any other wavelengths.

The other two Great Observatories, not yet in full scale development, are the Advanced X-ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). A 10-ton observatory capable of being serviced in orbit for an extended lifetime, AXAF (above right) will have instruments 100 times more sensitive than those of any previous x-ray mission. Similarly, SIRTF will have radiation detectors 1,000 times more sensitive than those of a predecessor system to study infrared emissions from a great variety of objects from solar system bodies to galaxies at the edge of the universe. The highest priority for the astrophysics program is to get all four Great Observatories operating together, viewing throughout the electromagnetic spectrum to observe the full range of phenomena in the universe, from the most tranquil to the most violent.

Initial observations by the first two Great Observatories—HST and GRO—will be complemented by information from three major spacecraft to be launched in 1989-91.

The Cosmic Background Explorer (COBE) will kick off the post-Challenger space science flight program next February. COBE will study background radiations believed to be remnants of the primeval explosion known as the Big Bang. This monumental explosion, according to the Big Bang theory of the origin of the universe, happened some 15 billion years ago and triggered a



uniform expansion of the universe that has continued ever since. COBE, being developed by Goddard Space Flight Center, will seek evidence to support the theory.

Under joint development by NASA and West Germany for 1990 launch is ROSAT (for Roentgensatellit), an x-ray telescope and imaging system that will conduct a sweeping survey of x-ray sources and make dedicated observations of specific sources, allowing astronomers to study in greater detail many of the phenomena discovered, but not thoroughly investigated, by earlier x-ray satellites. Goddard is NASA's ROSAT manager.

For launch in 1991, NASA is developing another of the continuing Explorer series called EUVE, for Extreme Ultraviolet Explorer (right), referring to a wavelength band between the ultraviolet and x-ray ranges that has never been surveyed. The EUVE project is managed by Jet Propulsion Laboratory.

Planned for development is the Stratospheric Observatory for Infrared Astronomy (SOFIA). The SOFIA system includes a three-meter telescope mounted in a Boeing 747 transport for airborne observations in infrared wavelengths inaccessible from the ground. Since the SIRTF Great Observatory will not fly until the late 1990s, SOFIA will allow infrared research continuity in the interim and will complement SIRTF when the latter becomes operational.

In addition, the astrophysics program will be supported by a series of intermediate and small free flying satellites of the Explorer Program, which has for many years offered flight opportunities for modest scale instrument packages in astrophysics, space physics and atmospheric research. ▲

Space Physics

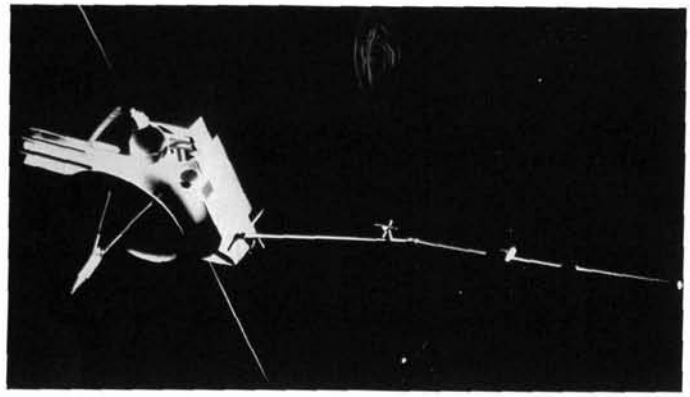
The space physics portion of NASA's space science program is concerned with investigation of space plasmas in a quest for expanded knowledge of their origin, evolution and interactions. Plasmas are ionized gases that exist in a wide variety of forms; they represent a form of matter distinct from solids, liquids or normal gases and they are believed to make up 99 percent of the material in the universe. An example of a plasma system is the solar wind, the electrified gas emitted by the Sun that courses through the solar system at a million miles an hour and interacts with the atmospheres and magnetic fields of the planets. Study and analysis of space plasma offers greater understanding of the complex processes that govern Earth and the universe.

The space physics effort seeks knowledge of plasma phenomena in the ionospheres and magnetospheres of Earth and the other planets and in the heliosphere, the area of space over which the Sun's gases and magnetic field extend. One aspect of this research is study of the Sun as a source of plasma, energy and energetic particles; another is study of how energetic particles, originating within or beyond the solar system, are accelerated, transported and distributed in space.

Information on such phenomena is obtained by instrumented probes operating within a plasma system, such as the heliosphere or a planetary magnetosphere; by investigating galactic cosmic rays from Earth orbiting spacecraft; and by remote sensing of regions not directly accessible to probes, such as the Sun's surface.

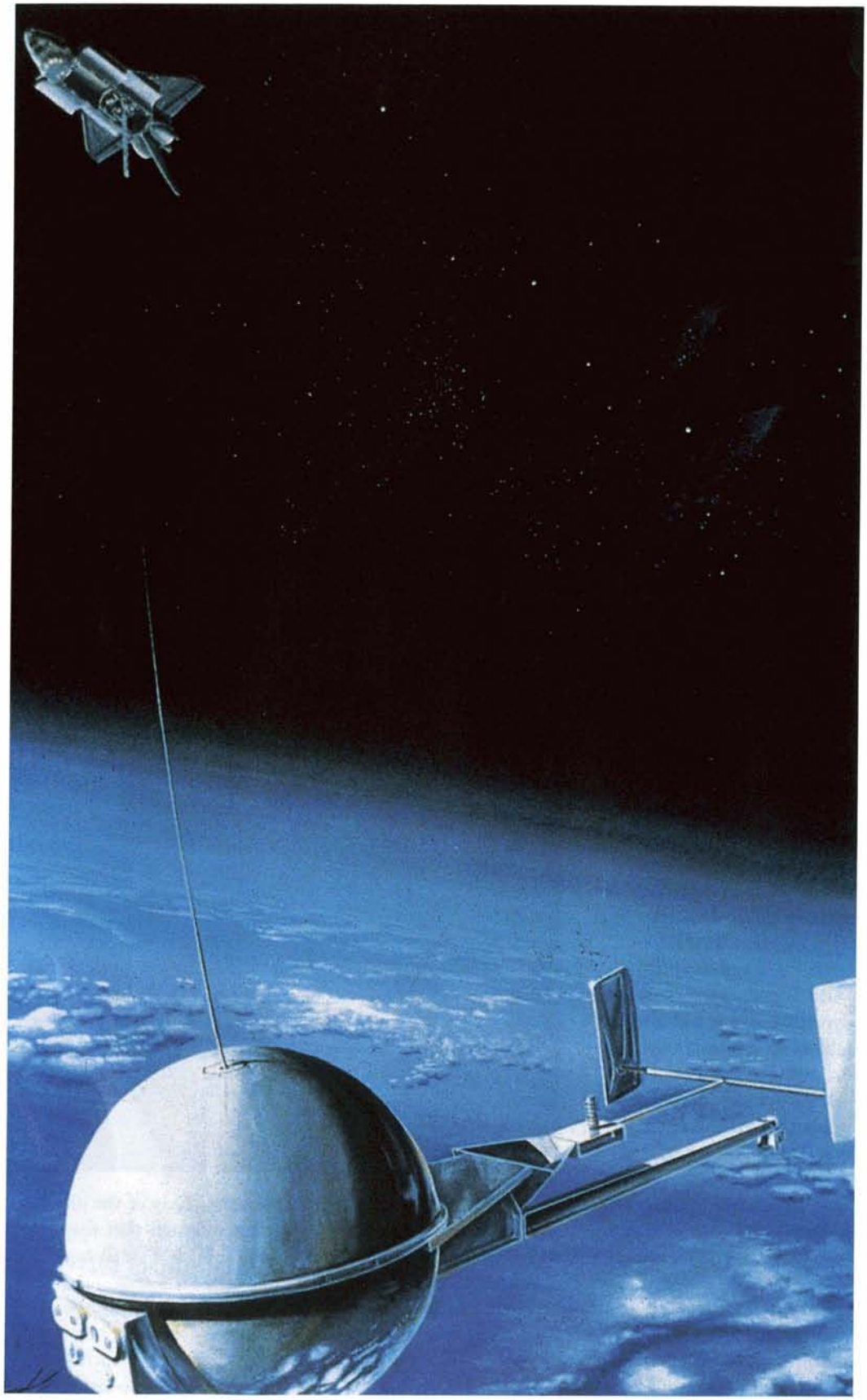
In 1988, there were five U.S. spacecraft collecting valuable information about the Sun, the interplanetary medium and cosmic rays penetrating that medium, and plasma interactions in the Sun-Earth relationship. Years of such research have led to identification and classification of a wide range of plasma phenomena and to some understanding of cause and effect relationships. NASA's space science plan builds upon that base and is moving into an advanced phase.

A mission of great importance is Ulysses, a cooperative endeavor of the European Space Agency and NASA, with Jet Propulsion Laboratory as NASA's project manager. Ulysses (above) will embark in 1990 on a multiyear mission that will take the spacecraft "out of the ecliptic." The ecliptic is an imaginary plane that approximates an extension of the Sun's equator; since all spacecraft have operated close to that plane, the space above or below the ecliptic is still unexplored and of great scientific interest. Flying a path that will take it eventually around the poles of the Sun, Ulysses will report—from the fresh perspective of a never before penetrated region of the heliosphere—on such subjects as the solar wind, solar and galactic radiation, cosmic dust and solar/interplanetary magnetic fields.



Also scheduled for launch in 1990 is the Combined Release and Radiation Effects Satellite, which will map Earth's radiation belts during a period of maximum solar activity and will also analyze the chemistry of Earth's ionosphere and magnetosphere by releasing chemicals and observing the resultant reactions. Planned for 1991 service is the Tethered Satellite System (TSS), a cooperative program with Italy, managed for NASA by Marshall Space Flight Center. The TSS (right) will be suspended from the payload bay of the Space Shuttle Orbiter by a 20-kilometer-long conducting cable, through which electrical jolts will be transmitted to enable investigation of upper atmosphere electrodynamic plasma effects at induced voltages.

A multiple flight effort to begin in the early 1990s is the international cooperative Global Geospace Science (GGS) program, which has two components: the International Solar Terrestrial Physics (ISTP) program and the Solar Terrestrial Research Program (STRP). ISTP involves two NASA spacecraft designated Polar and Wind, plus a Japanese mission called Geotail, which will study from different orbits the physical processes that link Earth and the Sun. The companion STRP will include a Solar and



Heliospheric Observatory that will study the solar wind from an orbit between Earth and the Moon, plus a four-unit team of small spacecraft, collectively known as Cluster, operating in orbit around Earth's poles. In the latter project, the European Space Agency will provide the spacecraft and NASA the instrumentation. Goddard Space Flight Center will control and coordinate all of the GGS spacecraft.

The highest priority space physics mission planned is the Solar Probe, which will investigate the unexplored region between four and 60 radii from the Sun, where the solar wind begins to flow at supersonic speeds. The Solar Probe will measure electromagnetic fields and particle frequencies, and it will study the Sun as a star, observing the structure of the solar atmosphere and making measurements relating to the stellar inner structure, gravitation and relativity. A related mission planned is the High Resolution Solar Observatory, a platform for studying the processes of the Sun's surface atmosphere.

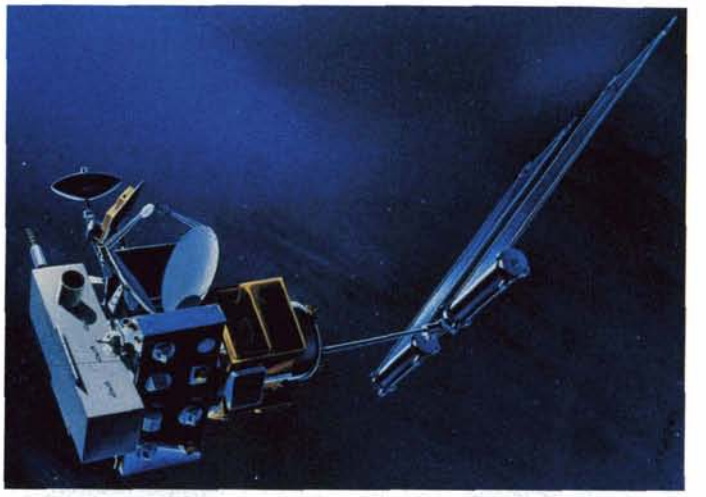
Other space physics projects include payloads to be attached to the Space Station structure, Shuttle-based systems, small satellites of the Explorer program and instrumented sounding rocket and balloon payloads. ▲

Traditionally, scientific knowledge of Earth and its environment has advanced piecemeal through separate investigations of the individual components: the planet's interior, its crust, biosphere, oceans and ice cover, the atmosphere and the ionosphere. Recent research has demonstrated, however, that all these components are interlinked, or coupled. NASA's new aim, therefore, is to study the Earth as a single unified system, to learn how the components and their interactions have evolved and will evolve in the future. The ultimate goals are a complete understanding of the Earth system on a global scale and a capability for predicting the environmental changes that will occur decades or centuries hence, whether those changes derive from natural causes or from human activities.

Major steps toward those goals are promised by two major missions already in development and intended for service in the early 1990s. One is the Upper Atmosphere Research Satellite (UARS), being developed by General Electric's RCA Astro-Space Division under Goddard Space Flight Center management. UARS (top) will report global data about the composition and dynamics of the upper atmosphere over a span of several years. Among 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.

The other program is TOPEX (Ocean Topography Experiment), an ocean observation satellite 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. TOPEX (right) will significantly expand knowledge of ocean dynamics and it will also establish an informational base for practical applications, such as weather and climate prediction, coastal storm warning, maritime safety, ship design and routing, and food production from ocean sources.

The Earth science centerpiece planned for the 1990s is the Earth Observing System (EOS), not a specific satellite but a "suite" of instruments to operate from a number of satellites and from a new generation of polar-orbiting platforms expected to be operational in the 1990s. EOS will allow, for the first time, long term (15 years or more) consistent measurements of global changes, enabling comprehensive study of the global-scale processes that shape and influence Earth as a system.



EOS findings will be complemented by new Earth science satellites, such as a proposed Mesosphere and Lower Thermosphere Explorer, by a series of small missions called Earth probes,

by Shuttle-based systems, and by aircraft-based remote sensing systems.

An Earth-related but separate subdivision of the space science program is research on communications systems. The best known example of NASA's work in the area of communications applications is the SARSAT (Search and Rescue Satellite-Aided Tracking) program. SARSAT is not a satellite but a package of electronic equipment carried aboard weather satellites operated by the National Oceanic and Atmospheric Administration. It is a component of the international search and rescue system known as COSPAS/SARSAT.

The space portion of the system, a cooperative program involving the U.S., the U.S.S.R., Canada and France, consists of monitoring payloads aboard two U.S. and two Soviet satellites. Seven other nations are participants in ground-based satellite signal reception and processing. The electronic payloads "listen" continuously on emergency frequencies used by ships and aircraft, which carry radio beacons to signal emergencies. When a COSPAS/SARSAT monitor picks up an emergency signal, it notes the direction of the signal and relays that information to a ground station, which provides a position fix for the emergency site and alerts the appropriate search and rescue agency. As of July 1988, COSPAS/SARSAT was credited with saving more than 1,100 lives.

Also in July, the four principal nations signed an intergovernmental agreement committing to long term support of the international search and rescue system, available to all nations without charge to users in distress. NASA's Goddard Space Flight Center continues to develop technology to improve the SARSAT system, experimenting with geostationary satellites as a possible means of shortening alert time and seeking better location accuracy.

The major planned effort in NASA's communications research program is the Advanced Communications Technology Satellite (ACTS), being developed by General Electric's RCA Astro-Space Division under the management of Lewis Research Center. Planned for launch in the early 1990s, ACTS (above) represents an effort to help maintain U.S. leadership in the world's commercial communications satellite market and to develop communications technology that will enhance future space missions.

ACTS incorporates several revolutionary technologies designed to make more effective use of available frequencies, to increase the message handling capacity of the individual satellite, and to provide a capability for high volume communications relay to small Earth terminals. A major innovation is the "spot beam" approach, in which advanced satellite equipment will generate multiple message carrying spot beams, each focused on a narrow Earth region, rather than the wide beams generated by existing communications satellites. Use of this technique affords significant capacity gain but it demands extensive technology development, including new types of antennas in space and on the ground, and a complex, computer-directed switching system on board the satellite to shift the beams rapidly among target spots on Earth. ▲

Commercial Use of Space

NASA seeks to stimulate interest and investment in space-related ventures to assure U.S. leadership in commercial space activity

Recognizing that development of space has broad economic potential, the Congress—in 1984—amended the National Aeronautics and Space Act to give NASA a new mandate: "Seek and encourage to the maximum extent the commercial use of space."

Responding to that mandate, NASA has forged a working partnership with U.S. industrial firms interested in the space potential. The agency has supported the privatization of space—private sector operation of activities earlier carried out by the government—and provided American companies a technological/institutional base for exploring and developing new technologies, products and services with commercial value.

In the latter area, this year marks the resumption of flight activity after a hiatus of more than two and a half years occasioned by the Challenger accident of January 1986. During that time, NASA has been laying the groundwork for a new beginning in commercial development of space by executing a series of actions designed to expand the infrastructure and broaden the range of opportunities for promising commercial ventures in space.

Many such actions were responses to President Reagan's 15-point commercial space initiative, part of a revised national space policy announced in February 1988. Reaf-

firming the belief that expanded private sector investment in space can generate significant economic benefits for the U.S., the policy provides support and direction for a vigorous space commercial program.

The policy stated these goals:

- Promoting a strong U.S. commercial presence in space
- Assuring a highway to space, and
- Building a solid technological and talent base.

Among other NASA actions to implement the President's policy, NASA took initial steps toward complying with the specification that the agency, an an "anchor tenant," lease space in a commercially financed and operated orbital facility for materials processing research and other activities. NASA also invited private sector firms to submit proposals on how the normally jettisoned Space Shuttle External Tanks might be put to commercial use. Additionally, NASA increased its activity toward development of commercial applications of remote sensing.

In the area of space privatization, NASA continued activities to encourage and facilitate commercial operation of space launch vehicles.

Among other initiatives, NASA continued to expand its network of Centers for the Commercial Development of Space (CCDS), not-for-profit joint research undertakings composed of industrial firms, academic institutions and government organizations. From the original five CCDS activated in 1985, the network has grown to 16.

In February 1988, NASA established a Commercial Programs Advisory Committee, to operate as a subcommittee of the NASA Advisory Council. The new group is charged with reviewing the NASA space commercial program and recommending changes that would enhance the overall effort. The group will also advise on specific program elements, including research priorities; the research data base structure and accessibility for optimum industry use; research facilities and hardware that would most effectively stimulate commercial space endeavors; and NASA/industry arrangements that enhance policy objectives.

NASA has also formed a Commercial Use of Space Task Team, composed of more than 100 NASA and industry experts who will study and recommend new initiatives and changes in ongoing projects.

One other major action involved initiation of a comprehensive long range strategic plan for commercial space development over the next quarter century; it will draw upon the combined expertise of NASA, industry, academic and other government agency organizations.

Many of these initiatives are amplified on the following pages. ▲

What looks like a batch of multicolored ribbon (left) is actually a research image, a computer generated representation of the molecular structure of a protein. Marshall Space Flight Center is helping U.S. pharmaceutical companies conduct space-based protein crystal growth experiments. Such crystals, superior to those grown on Earth, could lead to development of powerful new drugs for treatment of disease. Shown above is a view of protein crystals being grown in a Shuttle-based facility.

Commercial Services

In line with the government's policy to support efforts by U.S. companies to develop commercial space launch capabilities competitive with those of foreign nations, NASA is helping the fledgling U.S. launch industry in two ways: by making available NASA-controlled production and launch facilities, and by its role as a potential customer of commercial launch services.

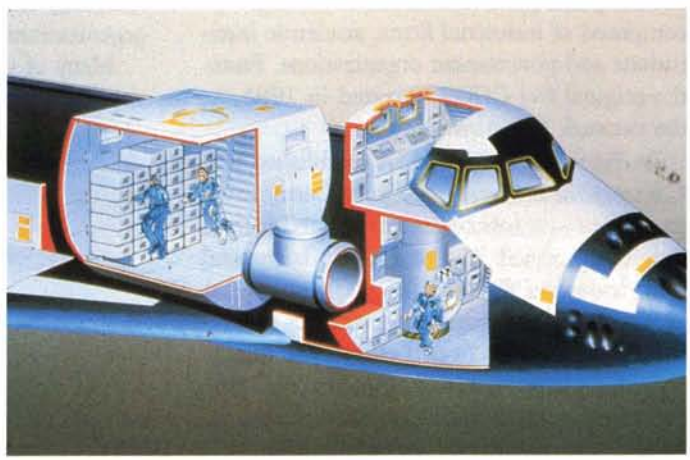
In 1987, NASA signed the first agreement transferring operation of a government-developed expendable launch vehicle (ELV) to the private sector. The agreement was with General Dynamics Corporation for operation of the Atlas-Centaur vehicle (right). NASA is negotiating additional agreements for use of payload processing and launch facilities with Martin Marietta Corporation, manufacturer of the commercial Titan launch vehicle; McDonnell Douglas Corporation, producer of the workhorse Delta; and LTV Corporation, which builds the Scout vehicle. The latter agreement also covers LTV's use of NASA-owned production tooling and special equipment.

NASA has also signed an agreement with Space Services Inc. for use of the agency's research rocket launching site, Wallops Flight Facility in Virginia, for launches of the company's Conestoga vehicle.

In addition, NASA has adopted a mixed-fleet plan in which ELV launches will complement Space Shuttle operations. A study identified a need for 30 ELV launches through 1984, to be accomplished by commercial launch services.

NASA is also taking steps to support commercially operated orbital research and manufacturing facilities. The agency is negotiating a Space Systems Development Agreement with Spacehab, Inc. that allows deferred payment for Space Shuttle flights of the company's Spacehab human-habitable laboratory. Intended for research and technology development that requires human-directed experimentation in orbit, Spacehab (below) is a cylindrical module with 1,000 square feet of pressurized volume; it fits into the Shuttle Orbiter's cargo bay and connects to the crew compartment. NASA is making arrangements to begin Spacehab flights aboard the Shuttle in the early 1990s.

Another type of orbital facility contemplated is a free-flying laboratory for use as a materials processing and space manufacturing facility, as a scientific laboratory, or as a technology development



facility for testing new space equipment. The President's commercial space initiative announced government intent to spur commercial financing, construction and operation of such a facility by leasing space for NASA experiment packages. At publication time, NASA was awaiting Congressional authorization to proceed with the program.

In May 1988, NASA began implementation of another orbital research stimulus suggested in the Presidential commercial space initiative when the agency asked industry for expressions of interest in making commercial use of the Space Shuttle's External Tank. The huge expendable tanks are normally jettisoned just before the Shuttle attains orbit, but they could be boosted into orbit for a number of possible uses. At right above is an artist's concept of a Shuttle-delivered tank in low Earth orbit.

Through 1994, approximately 40 tanks will be flown. The exact number that could be made available for commercial use will depend on a case-by-case analysis of each Shuttle mission and the proposed use for that particular tank. Where commercial use can be accommodated, NASA is offering to make the tanks available without charge, but users must pay costs associated with orbital insertion and eventual safe disposition of the tanks. Costs will include payments to NASA for unique mission engineering, planning and safety reviews, special studies, pre-launch modifications to the tank and, if necessary, on orbit handling and servicing. Proposals are being evaluated.

At right is the Geostar DS-1 communications satellite. Under a Space Systems Development Agreement, NASA will Shuttle-launch three such satellites for Geostar Corporation, which will provide as a commercial service a capability for companies to track and communicate their mobile fleets of trucks, ships, trains, or aircraft. Geostar will pay NASA for launch services on a deferred basis. The first of the Geostar satellites is scheduled for Shuttle delivery in early 1992. ▲

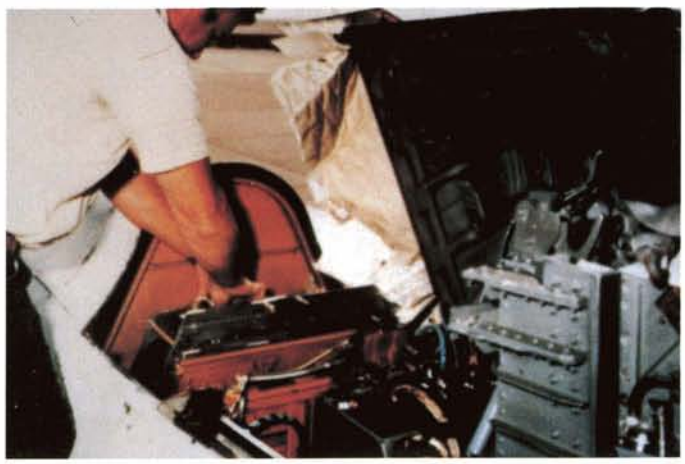
Space Industrial Research

The Earth orbital environment comprises a nearly perfect vacuum, a site of unfiltered solar radiation, a diverse "climate" with temperatures ranging from 200 degrees below to 200 degrees above zero Fahrenheit, and a place with an almost total absence of gravity.

Reachable in little more than eight minutes by Space Shuttle, orbital space offers a unique laboratory environment for materials processing research. Such research can lead to manufacture in space of products that cannot be produced effectively or in quantity in the presence of Earth's atmosphere and gravity. Among such products are high purity biological materials for more effective health care; semiconductor materials with enormously improved electrical properties for great advances in electronics; extremely pure glass for such applications as laser and optical systems; vastly superior metallic alloys for a multitude of applications; and a variety of industrial process equipment and instrumentation.

Alternatively, experimentation in the airless, gravity-free environment may identify and quantify the effects of air and gravity in Earth-bound processing, and thereby lead to revolutionary improvements in Earth processing techniques.

NASA's role is to conduct microgravity research and technology development and make available to industry new discoveries that may have commercial applicability. NASA also seeks to encourage broadest private sector participation in cooperative orbital research. One of the agency's key tools is the Joint Endeavor Agreement (JEA), in which NASA sponsors Space Shuttle flights of industry-developed, industry-financed experiments to reduce the technical and financial risks of early research, development and demonstration of promising, commercially applicable technologies.



Among the leading industrial participants is 3M, which contemplates more than 60 flight experiments over a 10-year span. 3M developed one of the two materials processing experiments for the "new beginning" STS-26 flight of the Orbiter *Discovery*; at left, astronaut James Van Hoften is operating a 3M experiment on a Space Shuttle flight.

NASA has developed a broad range of equipment and facilities, much of it generated by Marshall Space Flight Center, to support microgravity research. Examples of Shuttle-based systems include many types of furnaces for growing crystals or for melting/solidifying metals and alloys; apparatus for separating biological materials; levitators that enable processing of materials without use of containers that might contaminate the sample; systems for observing fluid processes in microgravity; computers for controlling experiments; and cameras and other data acquisition systems for recording the results.

Similar equipment has been developed for aircraft-based microgravity research, which can be accomplished by flying the aircraft through precise parabolic curves to attain zero gravity for brief periods (20-60 seconds). At left above, an engineer is checking an experiment package aboard an Ames Research Center F-104 research plane; Johnson Space Center and Lewis Research Center also operate microgravity research aircraft.

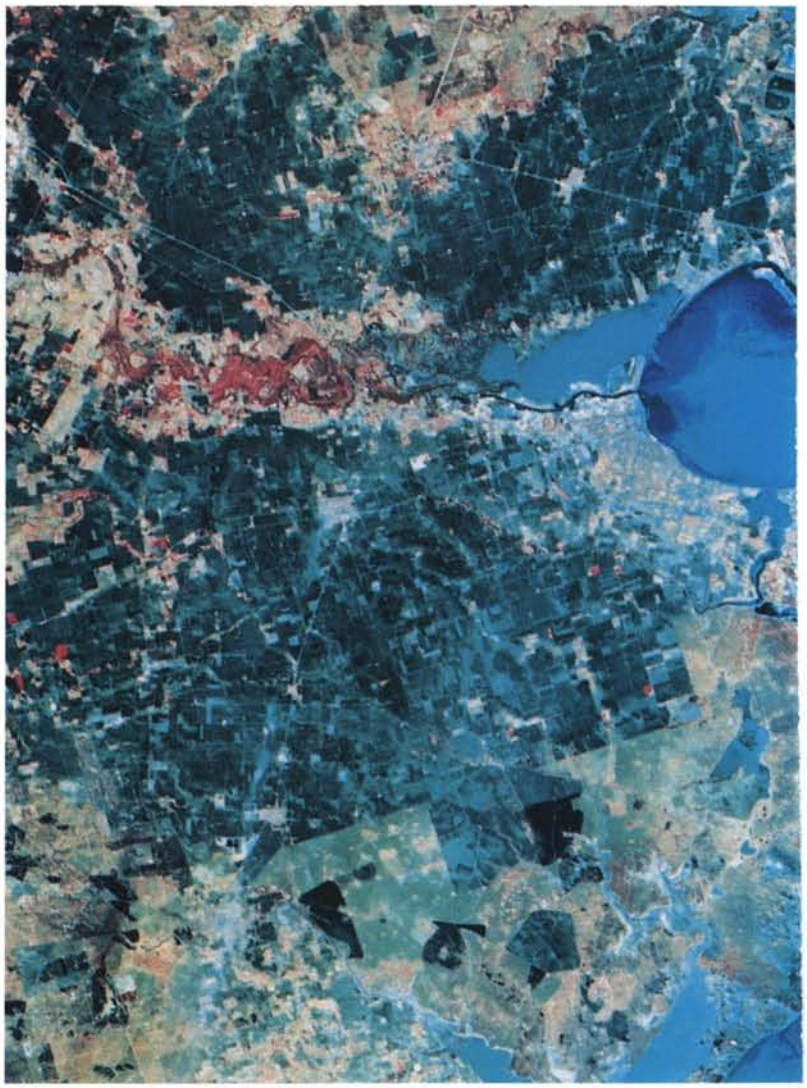
Additionally, NASA operates—at several centers—a number of ground-based drop tubes and drop towers in which microgravity conditions can be simulated for short periods (up to 10 seconds). A special facility—at Lewis Research Center—is the Microgravity Materials Science Laboratory (MMSL), which is equipped with a variety of furnaces and an instrumented drop tube. The laboratory demonstrates functional duplicates of materials processing systems flown on the Space Shuttle, allowing industrial, academic and government scientists to explore the potential of microgravity experimentation before establishing their own formal research programs. Above, a Lewis scientist is conducting research on a polymer sample at the MMSL.

A relatively new and important program intended to stimulate interest and investment in commercial space activities involves establishment of a network of NASA-sponsored Centers for Commercial Development of Space (CCDS), non-profit enterprises that combine the resources and research talents of industry and universities.

NASA established the first five centers in 1985 and the network has since grown to 16, each concentrating on a particular area of research activity with commercial potential. From a few companies initially involved, industry participation has expanded to 106 firms ranging from small businesses to giant "Fortune 500" companies.

Five of the CCDS focus on materials processing research. The other technical disciplines, and the number of centers so engaged, are life sciences (3); automation and robotics (2); remote sensing (2); space power (2); space propulsion (1); and space structures/materials (1). ▲

Earth Observation



Remote sensing of Earth's surface is a process in which satellite or airborne sensors detect various types of radiation emitted by or reflected from objects on Earth. Computer processed at ground facilities, this data can be interpreted to differentiate among a broad variety of surface features and conditions.

This information can be put to practical use in such applications as agricultural crop forecasting, rangeland and forest management, mineral and petroleum exploration, mapping, classifying land use, delineating urban growth patterns, studying floods to lessen their devastation, and plotting changes in ecology resulting from forest fires, earthquakes or strip mining activities, to mention just a few of the applications for remote sensing of land areas. A representative computer processed image is shown at right center. The scene is the Gulf of Mexico near Corpus Christi, Texas; to skilled analysts, the color codes reveal a wealth of information about land cover, vegetation, swamp areas and sedimentation.

In addition, remote sensing of oceans offers another range of beneficial applications, for example, warning of threatening coastal disasters, storm and iceberg avoidance, guiding fishing fleets to most productive waters, monitoring oil spills, and producing general information that can help improve ship design and ship routing techniques.

NASA developed the Landsat series of Earth resources survey satellites, first launched in 1972, demonstrated in government operation for more than a decade and now operated as a commercial system; below is a late model Landsat getting a final pre-launch check. Commercial remote sensing has great growth potential, but as yet only a few applications are being pursued on a consistent basis. NASA seeks to expand the list of applications by developing new technologies and demonstrating new uses of space-based and airborne remote sensing.

NASA projects for commercial development of remote sensing are managed by the Earth Resources Laboratory (ERL) at Stennis Space Center, Mississippi. ERL is conducting research and technology development, exploring ways to use exist-

ing remote sensing technology in new commercial products and services, and helping users develop their own technology; industrial investigators have access to airborne sensor data acquired by the specially-fitted ERL Learjet shown. An example is ERL's work with Union Oil of California (Unocal), which has proposed a corporative arrangement to develop and test—initially on the Space Shuttle and later aboard the Space Station—new technology for Earth-orbiting sensors designed to seek out energy resources.

In April 1988, NASA announced selection of nine commercial applications projects, to be managed by ERL, aimed at broader use of NASA-developed technology in land and ocean observations for practical benefit. To be conducted by teams of industry firms, universities and other research organizations, the projects involve, for example, commercial development of an ice data and forecasting system; development of methods for using satellite data in forest resources management; application of airborne ocean color imaging technology to commercial fishing; and use of satellite data for potato production estimates.

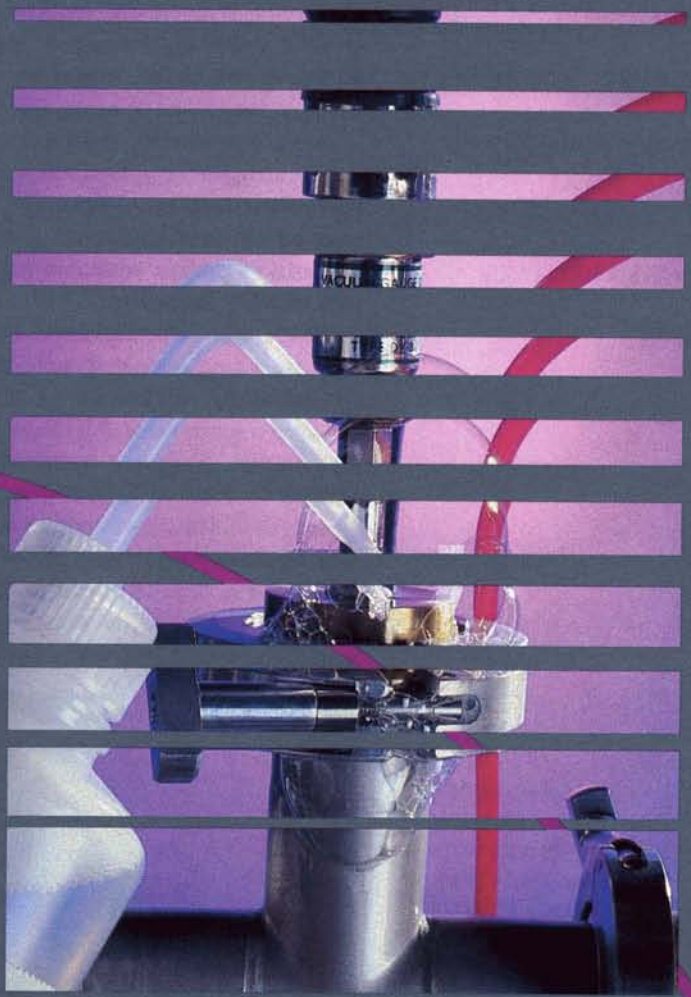
At the same time, NASA announced 11 other projects, to be managed by the Office of Space Science and Applications, involving remote sensing technology development for public sector applications. Some examples: remote sensing as a tool for landslide hazard assessment; analysis of sediment transport and land loss processes; and investigation of an automated satellite-based fire detection and monitoring system.

In addition to Stennis Space Center activity, NASA also sponsors two Centers for Commercial Development of Space (CCDS) that specialize in remote sensing. The Institute of Technology Development CCDS, Hancock, Mississippi conducts research in sensor technology, data interpretation techniques and data handling capabilities. The Ohio State University CCDS, Columbus, Ohio is developing satellite mapping technology. ▲

Technology Twice Used

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 and economic benefits they provide

Spinoff developments highlighted in this section are based on information provided by secondary users of aerospace technology, individuals and manufacturers who have acknowledged 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 particular spinoff developments



Space Software for Automotive Design

The spinoff-spurred growth of a chassis manufacturing company exemplifies the benefit potential of aerospace technology transfer

In 1971, sharp reductions in the federal defense and space budgets created what was known as the "aerospace recession" that put thousands of aerospace engineers out of work. Traditionally the state with the largest aerospace employment, California was particularly hard hit. To ease the impact, the state government established a retraining program to prepare aerospace engineers for jobs in other industries.

That's how John Thousand wound up with six young aeronautical engineers who had previously worked for a California plant of the aerospace giant, McDonnell Douglas Corporation. Thousand was president of Wolverine Western Corporation, Newport Beach, California, a company providing engineering consulting services to the automotive industry. He didn't know it at the time, but his acquisition of the aerospace group was to start a chain of events that would transform his company into a bustling design and manufacturing operation specializing in chassis for buses, trams, trucks, recreational vehicles and special purpose military vehicles. And aerospace spinoff would be the trigger.

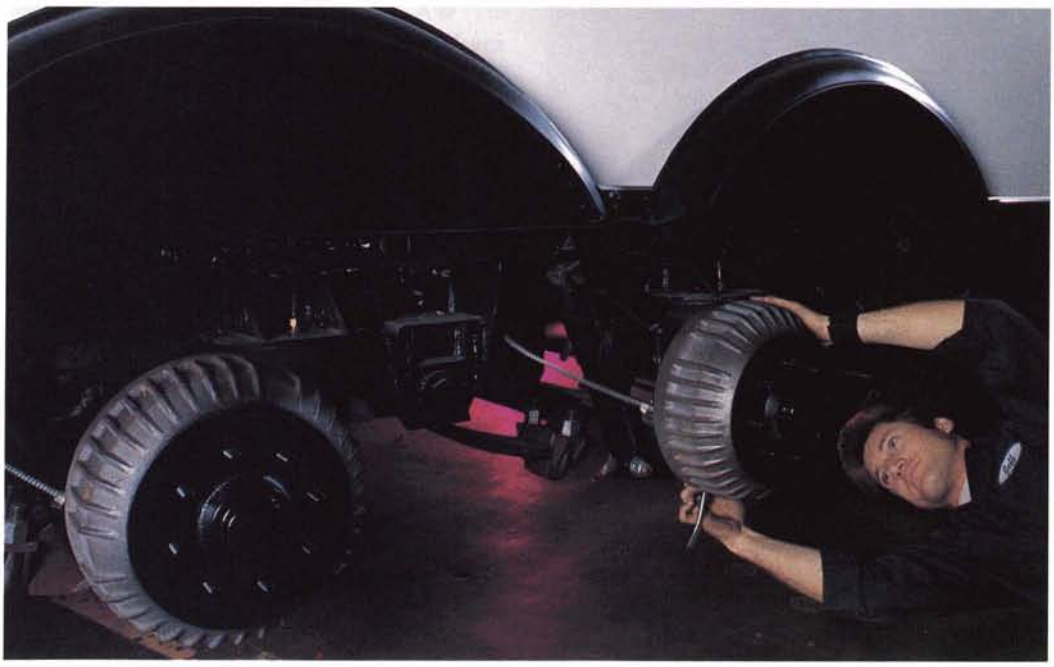
John Thousand, a consulting engineer serving the automotive industry (right), took on six unemployed aeronautical engineers who expanded and transformed his business by applying aerospace techniques and software to automotive design. Thousand's consulting firm is now a busy design and manufacturing operation producing automotive chassis and components.

Thousand put his aerospace group to work on an unfamiliar job—designing a better brake drum—using computer design techniques with which they were entirely familiar. Used in the aerospace industry since the earliest days of the computer era, computer design involves creation of a mathematical model of a product and analyzing its effectiveness in simulated operation. The technique enables study of the performance and structural behavior of a number of different designs before settling on a final configuration.

The new Wolverine employees attacked a traditional brake drum problem—the sudden buildup of heat during fast and repeated brakings. The part of the brake drum that is not confined tends to change its shape under the combination of heat, physical pressure and rotational forces—a condition known as "bellmouthing." Since bellmouthing is a major factor in braking effectiveness, a solution to the problem would be a major advance in automotive engineering.

One of the group was Richard Hagen who, at McDonnell Douglas, had worked on NASA projects. He knew of a series of NASA computer programs that seemed ideally suited to the task of confronting bellmouthing. Originally developed as aids to rocket engine nozzle design, they were capable of analyzing the problems generated—in a rocket engine or an automotive brake drum—by heat, expansion pressure and rotational forces.

Use of these computer programs led to a new brake drum concept featuring a more durable axle and heat transfer ribs, or fins, on the hub of the drum. The ribs reinforce the shape of the drum and help prevent bellmouthing. Additionally, they act as cooling



Above, the principal product of Thousand's Wolverine Western Corporation: an advanced brake drum featuring a ribbed hub, a spinoff from rocket engine nozzle design technology. The ribs reinforce and cool the drum, helping to prevent a shape distortion known as "bellmouthing" that adversely affects braking efficiency. At left, a mechanic adjusts the brake shoes.

fins, allowing the brake to remain cooler during repeated braking on grades and thereby reducing brake fade or failure.

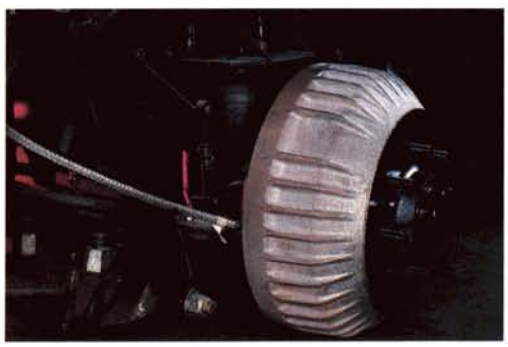
Hagen and his coworkers went a step further and applied computerized structural analysis to vehicle frames, using a computer program NASA had originally developed for early studies of an orbiting space station.

John Thousand approved the brake drum design and ordered patterns, prototypes and eventually castings. Sample drums were sent to Bendix Engineering Laboratories for test, and under intense dynamometer testing they never failed. Thousand's Wolverine Western Corporation was in the brake drum business.

In time, Wolverine's aerospace engineers moved on to other pursuits, but the innovations they left behind dramatically changed the company. In the years since, John Thousand has done less and less consulting and more and more manufacturing of the brake drums, axles and vehicle frames designed by his retrained aerospace engineers. Wolverine Western incorporates these parts in complete high quality chassis for a variety of automotive applications: for military command, control and communications centers; for intelligence vehicles; and for multipurpose vehicles that can be airlifted on military transports. In the civil sector, Wolverine chassis are used in buses, recreational vehicles and delivery trucks; they are also sold as turnkey medical diagnostic facilities, providing, for example, mobile eye examination or mammography (breast x-ray) services.

(Continued)

Above, a design conference at Wolverine Western. The aerospace engineers who revolutionized the company are no longer around, but the spinoff computer programs they introduced are still in use. They analyze the effects of various loads on each vehicle frame produced, since virtually every Wolverine vehicle is customized.



A Wolverine brake drum view from a different angle. The company's chassis employ the spinoff drum brakes on rear axles, disc brakes on the front.

"When you think about it," says Wolverine Western Corporation's John Thousand, "a rocket nozzle has the same job to perform as a brake drum. They must both resist internal pressure forces and be efficient distributors of heat."

Many other high technology systems similarly share characteristics, in a general way, with non-aerospace products or processes in everyday civil use. That's why it is possible to reuse computer programs developed by NASA and other technology generating agencies of the government. Sometimes, as was the case with Wolverine Western, they can be applied to a secondary use with little or no change; in other instances, the program may have to be modified for a new use but that can most likely be done at far less than the cost of developing a new program.

Since thousands of companies each year are joining the ranks of computer users, NASA serves the interests of national productivity by offering these newcomers to computerization a way to effect significant reduction of their automation costs through purchase of already developed computer programs that have secondary utility.

This service is provided by NASA's Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC gets a continual flow of government developed software, identifies those programs that can be adapted to secondary usage, and stores some 1,400 of them. A COSMIC customer can purchase a program at a fraction of its original cost and get a return many times the investment, even when the cost of adapting the program to a new use is considered. This service has become one of the principal areas of technology transfer, as is evidenced by the fact that COSMIC sells about 700 software packages a year (see page 140).

Although it involves software rather than hardware, the Wolverine Western story is an

A vehicle frame under construction at Wolverine Western (left). The company's frame technology also originated in NASA software, initially developed to analyze space station configurations.

excellent example of the aerospace spinoff process. It illustrates two separate spinoff routes: one, the beneficial reuse of technology developed for the space program, and two, the personnel type of technology transfer, wherein aerospace workers move to other industries, bringing with them aerospace technology and skills that can be reapplied in their new occupations.

The Wolverine Western experience represents a high value spinoff due to creation of an entirely new product line. *Spinoffs*—whether hardware or software—with values in millions are not unusual, nor is the establishment of whole new companies based on technology transfers. In other cases, spinoffs generate only moderate economic gain but provide significant public benefit in other ways, ranging from simple conveniences to important developments in medical and industrial technology.

This year NASA marks the 25th anniversary of its Technology Utilization Program, which seeks to encourage the secondary application of aerospace technology for benefit to the national economy in the form of new products, new processes, new jobs and substantial contributions to the Gross National Product. During the quarter century of the program's existence, more than 30,000 aerospace-originated innovations have found their way into everyday use. Collectively, these spinoffs represent a significant return on the national investment in aerospace research and development, in terms of economic gain, industrial efficiency and productivity, lifestyle enhancement and solutions to problems of public concern. ▲

At top is a completed Wolverine Western vehicle with its distinctive lowered chassis. Above, a military vehicle is being loaded aboard an Air Force C-130 transport; all Wolverine vehicles built for military use are designed for air transportability.

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

Moon Technology for Skin Care

Use of space-developed image processing techniques in cosmetic research heads an array of spinoff developments in the field of health and medicine

Digital image processing is the art of using computers to convert sensor data into informative images—for example, the exciting pictures of distant planets sent to Earth by imaging spacecraft.

NASA centers have led the way in developing this technology and their work has inspired a number of spinoff applications, most notably in medicine and industrial quality control. Digital image processing promises a much broader impact on everyday life because it is showing utility in a wide variety of new applications, some of them still experimental, others demonstrably practicable but not yet in widespread use.

An example in the latter category is the application of the technology to research, evaluation and demonstration of skin care products. Cosmetic and pharmaceutical firms like Estée Lauder, Ortho Pharmaceutical and Hoffman-LaRoche, and independent research/testing laboratories working for such firms, are using image processing software originally developed to provide accurate topographic maps of the lunar surface.

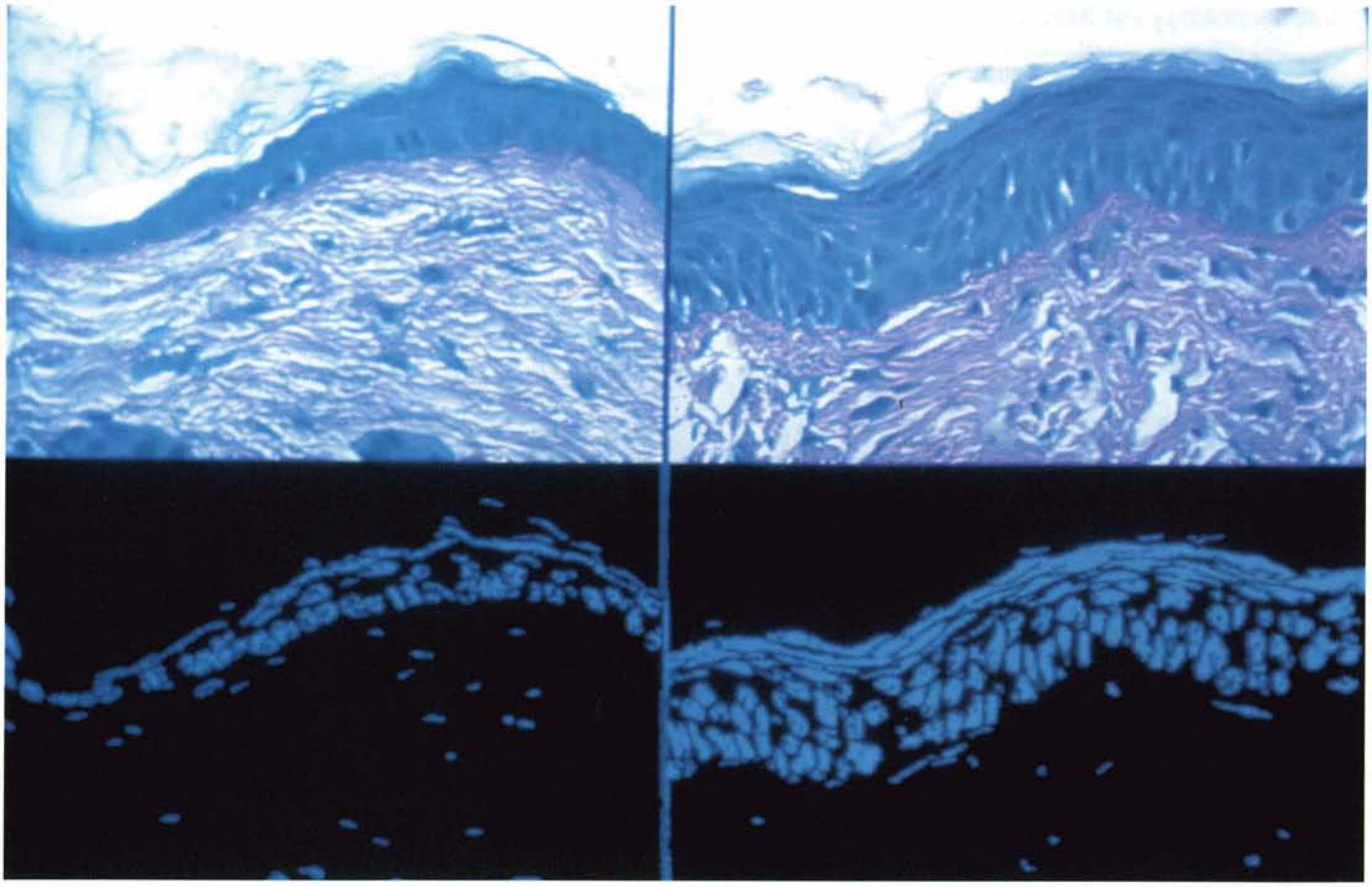
Estée Lauder researcher Paul Vallon uses a digital image analyzer and software based on NASA lunar research in evaluation of cosmetic products for skin care. Digital image processing brings out subtleties otherwise undetectable and allows better determination of a product's effectiveness.

In the early days of the Apollo program, NASA employed telescopic photography from unmanned lunar orbiting satellites to get information on possible landing sites for manned missions. The photos, however, were subject to a variety of distortions caused by camera problems or noise contamination from the spacecraft's electronic equipment. Further, the moon's shadow pattern, different from Earth's due to the lack of light filtering atmosphere, made it difficult to determine certain details essential to topographic mapping, for example, the height of a large boulder or the depth of a crater.

NASA's Jet Propulsion Laboratory (JPL) came up with an innovative solution: converting the analog imaging signals from the spacecraft to digital signals. That would make it possible to computer-enhance the images by programming the computer to adjust the imagery as directed. JPL began developing the software necessary to allow such adjustments as correction of sensor errors, changes in contrast, emphasis on certain features, in general manipulation of the satellite imagery to improve and amplify the information that could be extracted.

Included in the JPL software was a technique called "photoclinometry" to resolve the problems of depth perception occasioned by the unusual shadows of the airless lunar environment. This technique considered such factors as the location of the Sun and the reflective properties of the lunar surface in a process of "decoding" the shadow pattern to produce accurate elevation data for making topographic maps from satellite photos. That is the basis for the software used in skin care research because, odd as it may sound, the moon's topography and human skin have a lot in common.

"Close inspection of the human skin surface at any region of the body will reveal that it is not featureless but rather is characterized by geometric patterns and other topographical features," said Dr. Gary Lee Grove and his wife Mary Jo Grove in a technical paper. They pointed out that skin has folds and



This is a before-and-after composite illustrating the effects on skin surface of an Estée Lauder preparation for smoothing rough skin. The upper images are magnified photos of the skin surface before (left) and after (right) treatment. The lower images are enhanced digital representations of the same area. The digital imagery reveals skin "peaks" not otherwise visible (lower left) and shows the degree to which the peaks have been smoothed by treatment (lower right).

furrows and hills and valleys that can be approximately measured by such visual means as photo magnification, but can be more accurately measured by computerized image processing.

Dr. Grove is director of the Skin Study Center, a unit of K.G.L. Inc., Broomall, Pennsylvania. Mary Jo Grove is an image processing specialist at the center, whose researchers perform contract work for cosmetic firms, pharmaceutical companies and government regulatory agencies to evaluate the safety and efficacy of cosmetics and topically applied drugs. The Groves developed a computer program, based on the original JPL software, for non-invasive assessment of skin surface topography in evaluating the performance of such skin care products as moisturizers and antiwrinkle creams. They use it in conjunction with a Joyce-Loebel Magiscan Image Processing System.

Estée Lauder Inc., Melville, New York uses similar software with a Zeiss 2001 Image Analyzer to determine the effects of cosmetic products and ingredients on the skin. "The system," says a company spokesperson, "stores, enhances and displays images to make subtleties otherwise undetectable by the human eye or camera apparent to the scientist."

The technique allows Estee Lauder to quantify the changes in skin surface form and structure caused by application of cosmetic preparations. The structure of the epidermis, its roughness, dryness, wrinkles, cracks and other features can be translated into numerical descriptions that allow exact and unambiguous assessment.

Formerly, skin examinations and comparisons were done by panels of experts making judgments based on their own experience; that method has disadvantages in time, cost and subjective interpretation. "The use of the digital analyzer technique," says the Estée Lauder spokesperson, "allows us to perform these examinations at lower cost, with more flexibility, much more frequently and with greater assurance of reproductibility of results. It aids us in developing, screening and marketing new products that might otherwise not be made available, because the benefits of the product are not readily apparent to visual inspection or touch."

(Continued)

Above, a client at the Skin Study Center is having a silicon rubber impression made of the "crowsfeet" wrinkles around her eye for assessment by digital image processing. At right above, the impression is being photographed by a video camera.

A great many otherwise healthy adults exhibit signs of "photoaging," changes in the skin—particularly the face—that result from aging or excessive exposure to the Sun. These changes produce the stigmata of a yellowish, mottled, wrinkled, leathery, rough skin often studded with small growth.

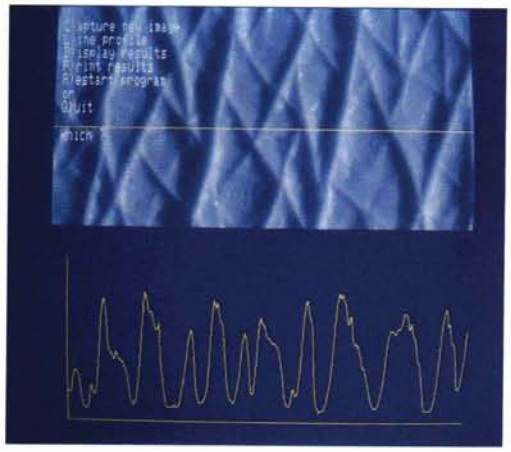
Until recently, the only routes to a more youthful appearance were cosmetic surgery to remove the flaws or makeup to conceal them. Now, however, pharmaceutical and cosmetic houses are offering retinoid preparations for smoother skin. Such drugs naturally have excited wide public attention and are getting intense scientific scrutiny to see if they really have antiaging properties.

One such product is Ortho Pharmaceuticals' Retin-A, which has undergone extensive assessment by Dr. Gary Lee Grove and the Skin Study Center, an independent testing laboratory in the Philadelphia area. This group has developed a number of pioneering non-intrusive testing procedures, some of them based on NASA technology, that have been useful in experimental studies employing human volunteers.

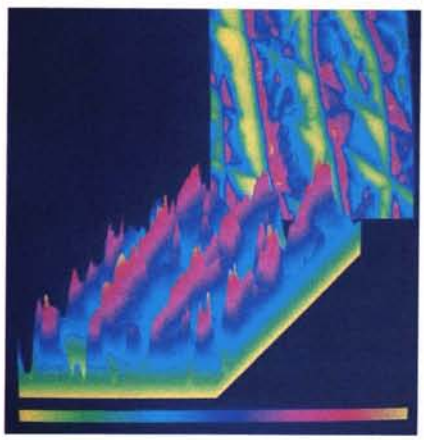
In the Retin-A studies, the Skin Study Center used a spinoff technique, developed by Gary and Mary Jo Grove from Jet Propulsion Laboratory's moon-imaging technology, called "optical profilometry." This technique employs a fiber optic illuminator to sidelight silicon rubber replicas of skin surface specimens, generating an image of assorted shadows and highlights. By computerized image manipulation, the picture of the specimen can be enhanced and analyzed to extract quantitative information regarding the degree of roughness or wrinkling. By comparing processed numerical representations over time, it is possible to determine the degree of effectiveness of drug treatment.

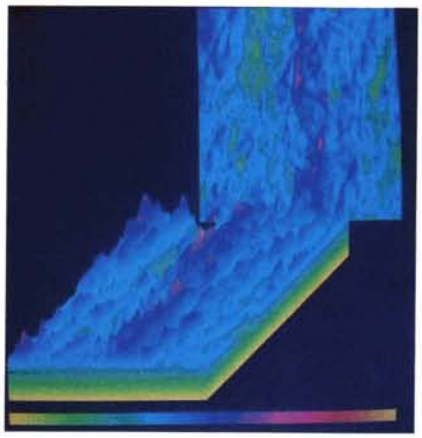
Replicas taken at various times during Retin-A therapy were matched with replicas from a placebo group of similar age. Although the Skin Study Center does not endorse specific products, it reported that it was able to document that Retin-A treatments "do lead to a more youthful appearance with less wrinkled and smoother skin, especially in the crowsfeet area."

Dr. Grove is developing new image analysis techniques based on remote sensing procedures for acquiring data from the NASA-developed Landsat Earth resources survey satellites. These new techniques, along with the earlier developed optical profilometry, will be employed in research and testing of advanced retinoids, in development by pharmaceutical companies, that are expected to be even more effective in countering photoaging changes. ▲



At far left, image processing specialist Mary Jo Grove is examining the crowsfeet impression with the help of a Magiscan digital image analyzer. She rotates the specimen through four different angles and takes measurements at each angle. At near left, the upper image is the camera's view of the specimen; below it is a computer-processed cross-section representation of the peaks and valleys of the skin wrinkles.





Before and after comparisons during treatment with antiaging drugs allow assessment of the preparation's effectiveness. Above, a "before" view showing many peaks and valleys; above right, an "after" representation in which there are significantly fewer peaks and depressions, attesting to the preparation's skin-smoothing capability.

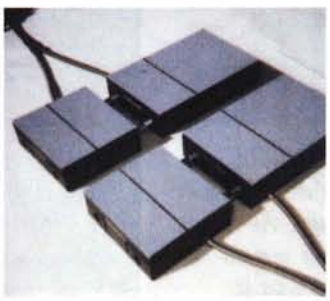
Balance System

A new system available to the medical profession is the TherEx AT-1 Computerized Ataxiameter for precise evaluation of posture and balance disturbances that commonly accompany neurological and musculoskeletal disorders. Manufactured by TherEx, Inc., Woodside, California, it is a commercial spinoff from a system developed for Ames Research Center studies of changes in posture and balance that occur after exposure to weightlessness, a potential problem of long duration space flight. According to TherEx president Dr. John M. Medeiros, the AT-1 has wide applicability in identifying and treating balance disturbances associated with such conditions as sport, orthopaedic and neurological injury, or age-related declines in postural stability.

The AT-1 makes visible otherwise imperceptible actions of the body, enabling a clinician to establish precisely the patient's level of stability, then plan a treatment program. The system serves as an assessment tool, a

treatment monitor and a rehabilitation training device. It allows the clinician to document quantitatively the outcome of treatment and to analyze data over time to develop outcome standards for several classifications of patients. The AT-1 can be used to evaluate specifically the effects of surgery, drug treatment, physical therapy or prosthetic devices.

The complete system, shown above, includes two strain-gauged footplates, signal conditioning circuitry a computer, monitor, printer, and a stand-alone tiltable balance platform. The system is available in stationary and portable versions. The footplates are shown in closeup at right above. They are four independent vertical force-



measuring transducers for measuring the pressure on the ball and heel of each foot. The footplates were separately developed by Keith H. MacFarland, president of Straindyne Engineering Company, Los Altos, California, based on his own technological expertise and an earlier development by the Hebrew University in Israel.

The footplates can be moved to adapt to various posture forms, such as standing with feet together, with feet in tandem, standing at ease or standing on a tilting platform. The footplates measure weight displacements that reflect the amount and direction the patient sways in forward-backward or left-right movements. A typical test sequence involves standing on a stable base, first with eyes open, then closed, followed by standing on the tilting platform with eyes open, then closed.

AT-1 results are displayed on the monitor in a simple graphics format. Movement of the instantaneous center of pressure over the 25-second data collection period is plotted with respect to each of the four footplate quadrants. The degree of postural instability is displayed as a single number that expresses the sway pattern, allowing easy comparison of different tests. The monitor also shows the center of pressure in terms of percent of body weight, which enables comparisons among different patients with different weights. TherEx has licensed the technology to Chattecx Corporation, Chattanooga, Tennessee for world-wide sales and marketing. ▲

Temperature Pill

Prototypes of an ingestible thermometer capable of measuring and relaying internal body temperatures are undergoing clinical testing at Maine (Portland) Medical Center and animal testing at the Johns Hopkins Medical Institutions, Baltimore, Maryland. Commercial units are expected to be available this year.

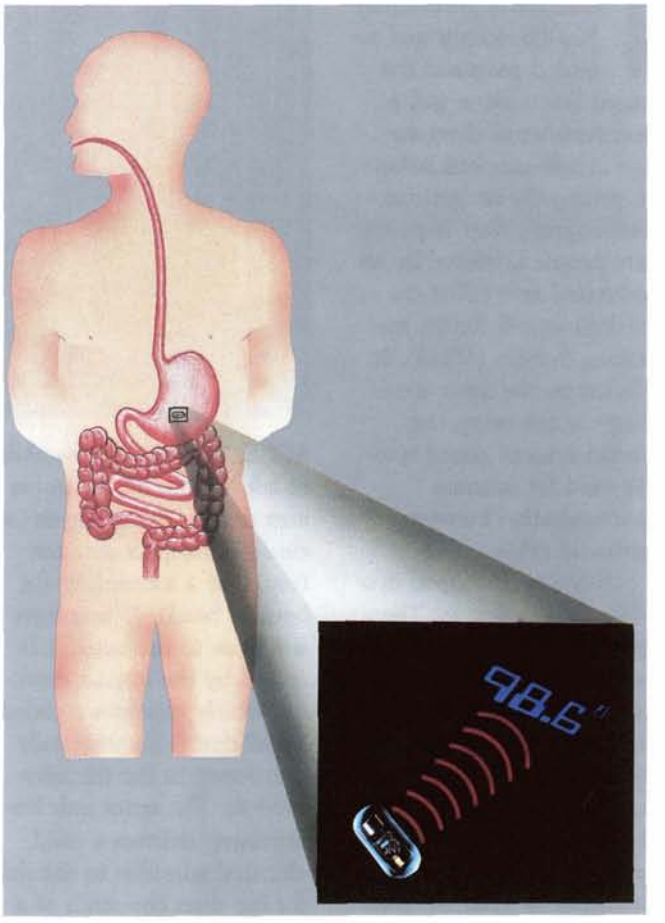
The thermometer was developed by The Johns Hopkins Applied Physics Laboratory (APL), Laurel, Maryland, under the direction of Dr. Russ Eberhart, in collaboration with NASA's Goddard Space Flight Center as a technology utilization project. Human Technologies, Inc. (HTI), St. Petersburg, Florida will manufacture and market the capsule-like system under a licensing agreement with APL.

Formally known as the Ingestible Thermal Monitoring System (ITMS), the thermometer incorporates several aerospace technologies, such as integrated circuit miniaturization, sensor and microbattery developments, and telemetry, technologies originally developed for transmission of coded data signals to Earth from orbiting spacecraft.

The ITMS was developed as a means of getting internal temperature readings for treatment of such emergency conditions as dangerously low (hypothermia) and dangerously high (hyperthermia) body temperatures. Extreme accuracy of temperature readings is important in treating such cases. Where the average thermometer is accurate to one-tenth of a degree Centigrade, ITMS is off no more than one hundredth of a degree, and it provides the only means of obtaining deep body temperature.

The system has additional applicability in fertility monitoring, incubator monitoring, and some aspects of surgery, critical care, obstetrics, metabolic disease treatment, gerontology (aging) and food processing research.

The three-quarter-inch silicone capsule, which contains a telemetry system, microbattery and a quartz crystal temperature sensor, is inserted vaginally or rectally, or swallowed by the patient to make its way through the digestive tract. The sensor "reads" the internal temperature and telemeters its information to a receiving coil outside the body, then on to the computer. ITMS monitors continuously for the one-to-three days it takes the capsule to pass through the body.



APL is working on an advanced, four-channel capsule system that will simultaneously monitor temperature, heart rate, inner body pressure and acidity. ▲

Self-injury Inhibitor

There are approximately 50,000 autistic and retarded people in the United States alone and a good number of them engage in self-injurious behavior, principally compulsive headbanging. New hope for these people is offered by an automated unit called the Self-Injurious Behavior Inhibiting System (SIBIS). It is based on the space technology of telemetry, the wireless relay of coded symbols used for accurate communication between Earth and orbit.

SIBIS was developed in a collaborative effort by The American Foundation for Autistic Children, The Johns Hopkins University Applied Physics Laboratory (APL) and Human Technologies, Inc., St. Petersburg, Florida. The system performed extremely well in clinical trials conducted in 1987-88 and it is now commercially available by prescription.

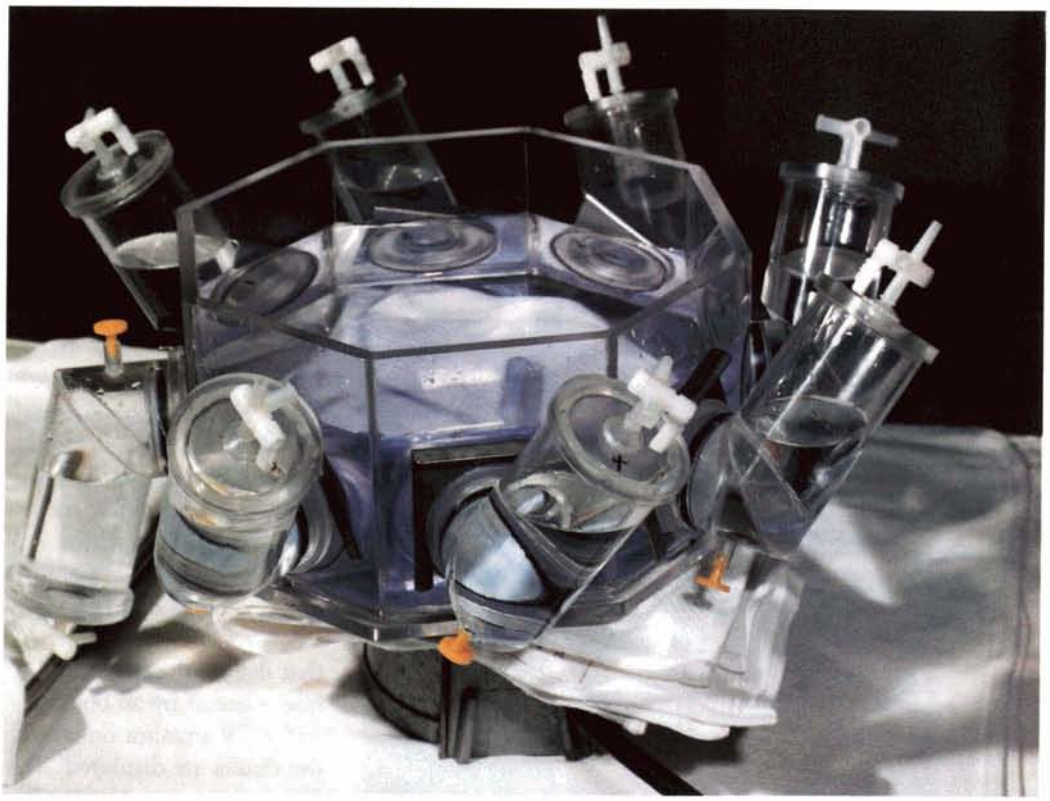
The accompanying photo shows the components of SIBIS. The stimulus module at left is worn on the upper arm or leg. The headgear includes an impact detector (top) and a transmitter (at back of head). When there is a blow to the head, it is sensed by the impact detector, which generates a coded signal that is automatically transferred to the stimulus module. The latter unit immediately delivers a mild electrical stimulus to the skin for less than one-tenth of a second. The stimulus is sufficient to halt the headbanging. A microcomputer keeps track of the number of impacts and stimulations, allowing measurement of a user's progress.

Because self-injurious behavior is potentially life threatening, it is often necessary to use physical restraints or protective equipment (such as a helmet) on these individuals. SIBIS allows the self-injurious to live without such restraints.

A predecessor device was invented by Mooza V.P. Grant, president of The American Foundation for Autistic Children and co-founder—with husband Leslie—of that organization. The Grants have two autistic daughters, one of whom is self-injurious. In 1970, after years of experimentation, Mrs. Grant developed a hard-wired device that used an accelerometer to detect headbanging and trigger a mild stimulus. The device immediately terminated her daughter's headbanging and has continued to do so ever since.

Later, on NASA recommendation, Mrs. Grant asked APL to develop a more compact, state of the art device. Under the direction of Robert E. Fischell, APL employed the miniaturization techniques for which it is widely known and designed the telemetry-based SIBIS. Development of SIBIS was funded by APL and Human Technologies, Inc., with assistance from the Public Welfare Foundation, C. R. Bard Company and the Oxford Instrument Company. ▲

Laboratory Tool

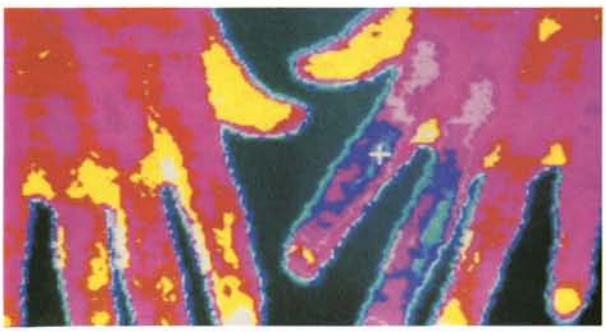


Below, Dr. Timothy Morck and an assistant, researchers at the Veterans Administration (VA) Medical Center, Hampton, Virginia, are using a "cake box" apparatus developed for the VA by Langley Research Center.

VA medical researchers are investigating the possibility that the peritoneal membrane (the lining of the abdominal cavity) can absorb nutrients and thus provide an alternative route for nutrition when intestinal function is impaired. To test the permeability of membrane samples, they had built a small dialysis chamber, but it proved complicated and difficult to use. Since the Medical Center lacked the technical expertise to construct a larger, improved version of the chamber, hospital officials sought Langley's help.

Langley undertook the task as a technology utilization project and engineering technician Bruce Little of the Fabrication Division was assigned the job. After he met with members of the VA staff and discussed the requirement, Little conceived the cake box design shown above. The apparatus consists of an octagonal chamber with eight smaller chambers attached and secured by O-ring seals. The design is simple, interchangeable and time controllable; it doubles the research capability of the earlier VA design. ▲

Thermal Video Systems



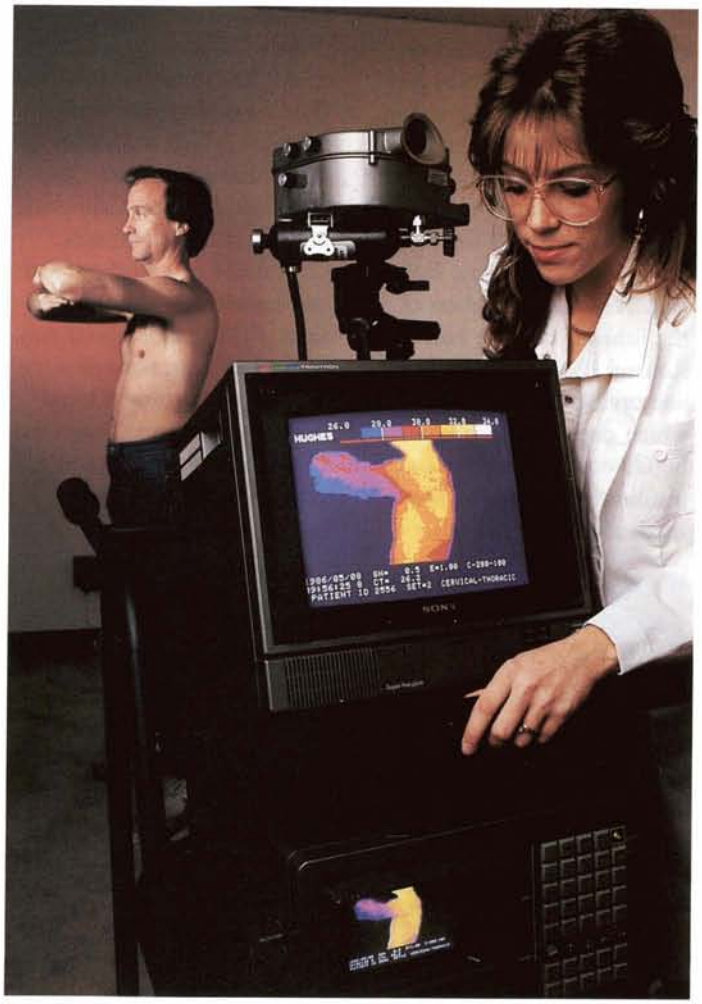
At left, is the Probeye® Model 3300 Thermal Video System, manufactured by Hughes Aircraft Company, a subsidiary of GM Hughes Electronics Company, Carlsbad, California. It consists of a tripod mounted infrared scanner that detects the degree of heat emitted by an object and a TV monitor on which the results are displayed. The latest addition to Hughes' line of infrared imaging systems intended for medical applications, it can detect temperature variations as fine as one-tenth of a degree Centigrade.

The thermographic image (left) exemplifies its utility as a medical system. This image tells an analyst that the first two fingers of the right hand emit less heat at the skin surface, thereby indicating subnormal blood circulation.

Medical thermography is rapidly gaining acceptance in health care as a noninvasive means of observing physiological problems. Where the x-ray, for example, provides indications of structural anomalies, thermography can point out functional anomalies. For instance, a thermograph showing an asymmetrical temperature pattern in the body surface serves as a visual indicator that pain exists. Mapping of dermatones (areas of skin supplied by a specific spinal nerve) makes possible accurate measurement of nerve dysfunction; sensory nerve impairment in the lower back can be evidenced by a temperature difference, from one extremity to the other, of only one degree Centigrade. At right, a patient is undergoing a nerve function test, assuming a stance so the thermal imaging scanner can sense heat differences.

Thermography is proving to be a valuable screening tool in diagnosis; thermal imaging can provide information to preclude the necessity of performing more invasive tests that might be painful or hazardous. Thermal imaging is also useful in verifying a patient's progress through therapy and rehabilitation, and it is finding special utility in sports medicine as a noninvasive means of determining the extent of injuries.

Hughes Aircraft pioneered development of heat sensing devices for military applications, such as missile guidance, under Department of Defense funding. NASA sponsored a demonstration project designed to explore the civil potential of thermal imaging under the Technol-



ogy Utilization Program.

Hughes initially focused on industrial applications of its Probeye Thermal Video Systems. More recently, company researchers were able to make the infrared detectors sensitive enough for medical thermography. Hughes now manufactures a wide range of Probeye systems and accessories, principally for such industrial uses as inspection of electronic components, fire fighting, heat profiling for nondestructive quality testing, preventive maintenance, and routine monitoring of production processes and energy losses.

Shown above is one of the newer industrial systems, the portable Probeye Model 7100, which includes an infrared imager with an integrated viewfinder and an associated image processing unit carried on a shoulder strap. ▲

®Probeye is a registered trademark of Hughes Aircraft Company.

Insulin Delivery System

At right, Robert E. Fischell of The Johns Hopkins University Applied Physics Laboratory (APL) is seen holding a Programmable Implantable Medication System (PIMS) which, when implanted in the human body, delivers precise preprogrammed amounts of insulin over long periods of time. Fischell, a staff physicist and chief of technology transfer of APL's Space Department, headed the initial development of PIMS as a technology utilization project sponsored by Goddard Space Flight Center. MiniMed Technologies of Sylmar, California, licensee of the technology, has been refining the design of PIMS since the initial development at APL. The photo at right shows a closeup of the PIMS implantable pump and catheter.

PIMS is currently rounding out its second year of clinical trials as a human-implanted system, following five years of preclinical testing under the direction of Dr. Christopher D. Saudek, director of The Johns Hopkins Diabetes Center. PIMS is also undergoing trials at a second implant center, the University of California,

Irvine. It is estimated that one million insulin-dependent diabetics in the United States will benefit from implantable infusion systems because they will not have to inject themselves daily with the pancreatic hormone.

Almost a decade in development, PIMS is an outstanding example of how space technology offers special utility in medical systems. PIMS employs several technologies derived from R&D work on NASA and military space systems, including a tiny, microminiaturized fluid control system initially used in life search experiments aboard two NASA Viking spacecraft that landed on Mars.

The Johns Hopkins Medical Institutions (JHMI) also collaborated with NASA and APL in the PIMS program. JHMI has teamed with APL since 1965 in a continuing effort to apply APL technology acquired in defense and space programs to the solution of biomedical problems.

Corporate participants in addition to Minimed Technologies include Wilson Greatbatch Company, Buffalo, New York, makers of the lithium battery; Hoecht-Roussel Pharmaceuticals, Somerville, New Jersey, which developed a special, highly concentrated type of insulin for PIMS; the Biomedical Group of Parker-Hannifin Corporation, Irvine, California, producer of the key microminiaturized fluid control system and infusion pump; and Teledyne Microelectronics Division, Los Angeles, California, makers of the electronics.

The size of a hockey puck and encased in a titanium shell, PIMS holds about two and a half teaspoons of insulin at a programmed basal rate. If a change in measured blood sugar level dictates a different dose, the patient can vary the amount of insu-

lin delivered by holding a small radio transceiver over the implanted system and dialing in a specific program held in the PIMS computer memory. A miniature two-way communications system, based on the space technology of telemetry, sends out signals from the implant with operating information such as insulin usage and pump performance. When an insulin refill is needed, about four times a year, it is accomplished without surgery by a special hypodermic needle.

In laboratory tests, the implant's lithium battery and micropower circuits have demonstrated a lifetime capability of more than five years; new batteries in development have potential for a 10-year lifetime.

The first PIMS unit was surgically implanted in the abdomen of F. Jackson Piotrow, a professor at American University, on November 10, 1986 at The Johns Hopkins Hospital, Baltimore, Maryland. At left, Piotrow is shown prior to the implantation with nurse Roslyn Polk (center) and Dr. Saudek. Since then there have been 17 additional implants.

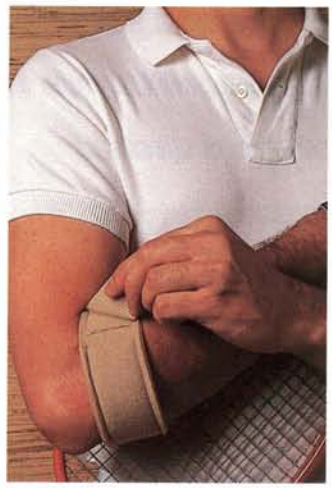
The PIMS development program continues to inspire additional spinoff products for health care. MiniMed Technologies' work on PIMS led to development and manufacture of the MiniMed Implantable Pump system (below), a second generation implantable, programmable pump with physician and patient controllers which will be implanted beginning in late 1988. In addition, Parker Hannifin's Biomedical Group is producing an external delivery device; called the Parker Micropump, it is a pocket-sized micropump for infusion of chemotherapeutic, antibiotic and anti-pain medication. ▲

Foam Cushioning

Twenty years ago, Ames Research Center conducted a research program aimed at improving crash protection for airplane passengers. One innovation developed by a contractor in that program was an open cell polymeric foam material with unusual properties. Intended as padding for aircraft seats, the material offered better impact protection in an accident and also enhanced passenger comfort on long flights because it distributed body weight and pressure evenly over the entire contact area. Called a "slow springback foam," it flowed to match the contour of the body pressing against it and returned to its original shape once the pressure was removed.

Initially marketed under the name Temper Foam®, the material has become one of the most widely used spinoffs from NASA technology. It is used for the applications originally intended, as aircraft and helicopter seat cushions for impact protection and fatigue attenuation. It is also employed as padding for furniture and for autos, trucks and offroad vehicles; in office chairs, dental stools and other types of seats that get long daily usage; as portable cushioning for travelers and attendees at the theater or sporting events; in a variety of athletic equipment, such as football helmets, body pads or chest protectors; and in a very wide range of medical applications.

Temper Foam was originally manufactured by a



company formed by the contractor's employee who had invented it, Dynamic Systems Inc. (DSI), Leicester, North Carolina. DSI subsequently sold the rights to the original formula but later returned to the slow springback foam field with different formulations. The rights for the original Temper Foam were acquired by Temper Foam, Inc., jointly owned by Kees Goebel Medical Specialties, Inc., Cincinnati, Ohio and AliMed®, Inc., Dedham, Massachusetts. DSI and AliMed have introduced a number of evolutionary innovations, spinoffs from the original spinoff.

DSI markets a line of orthopedic support cushions for reducing fatigue and improving circulation. They come in various sizes, thicknesses and pressure qualities under the trade names Sun-Mate, Pudgee and Laminar. Of particular interest is DSI's Foam-In-Place Seating (FIPS), developed primarily for severely disabled people to slow progressive deformities and to ease soreness and fatigue due to long periods in wheelchairs.

FIPS is a process wherein liquid Sun-Mate ingredients are mixed, poured and contour-molded to the individual's body and chair. At far left, a disabled child is leaving The Children's Hospital at Stanford Rehabilitation Engineering Center with a brand new FIPS chair; she is now able to sit for periods of 3-8 hours where her earlier chair caused her physical discomfort in as little as 15-30 minutes.

The photo sequence shows the step by step FIPS process at The Children's Hospital at Stanford. At upper left, opposite page, the Sun-Mate ingredients are mixed, then (adjacent photo) the mixture is poured into a plastic bag, which is used as a mold. At left center, seating specialists work with the patient and chair to be contoured to assure the most therapeutic body position. In minutes, the liquid forms and sets. After trimming, the seat is ready for upholstery. The final product is shown at left above.

In addition to The Children's Hospital at Stanford, other therapy/rehabilitation centers using the FIPS process include the O'Berry Center, Goldsboro, North Carolina and the Heinzerling Developmental Center, Columbus, Ohio. FIPS is also being widely applied in Canada.

AliMed, Inc. markets the original Temper Foam and a newer, fire retardant formulation called T-Foam™—which incidentally, is used in Space Shuttle seats. Both products are offered in several classifications of firmness and thickness for a great variety of cushioning applications, such as wheelchair cushions, bed pads, take-along portable cushions, seat inserts for any type of chair, cervical collars and operating table pads.

AliMed's foam materials are also used in many specialty items, for example, the T-Foam Pressure Wrap for reducing swelling in an injured finger; the T-Stick for padding splints and braces; T-Foam Hand Exercisers (top); and the Tennis Elbow Strap (above) designed to support forearm muscles and relieve pain. ▲

™T-Foam is a trademark of AliMed, Inc.

®AliMed is a registered trademark of AliMed, Inc.

®Temper Foam is a registered trademark of Temper Foam, Inc.

Space-Spurred Metallized Materials

A wide range of reflective insulating products heads a selection of spinoffs for consumer, home and recreational use

In the early days of the space program, NASA experimented with very large balloon-type satellites intended as orbital relay stations for reflecting communications signals from one point on Earth to another.

NASA needed a special kind of material for the balloon's skin. In order to "bounce" the radio signals, it had to be highly reflective. It had to be inflatable in orbit to a diameter roughly equivalent to the height of a 10-story building, yet it had to be folded into a beach-ball size canister for launch from Earth—thus it had to be extraordinarily thin and lightweight.

The problem was solved by development of a metallized material, a plastic film coated with a superfine mist of vacuum-vaporized aluminum to create a foil-like effect. The metallic particles provided the required reflectivity and the balloon's skin was about half as thick as the cellophane on a cigarette package. The communications "bouncing" technique worked, but the concept was ultimately abandoned in favor of the active repeater type of communications relay employed in today's commercial satellite networks.

Metallized plastics might have gone nowhere had NASA not concurrently found another application: as a reflecting insulator, or thermal barrier, for protecting astronauts and sensitive spacecraft equipment from solar radiation and extremes of temperature. That triggered an ever-increasing demand for metallized products.

NASA did not invent metallization; in fact, the concept dates to the 19th century. But the NASA requirement proved to be the catalyst that transformed a small scale operation into a flourishing industry. Before NASA came on the scene, metallized plastics were being produced on a very limited scale for decorative purposes, but there was little that could be called a metallization industry. NASA's initial needs provided a relatively large market and inspired extensive research and development toward improvement of vacuum metallizing techniques. That led to an ever-expanding role for metallized material in space applications—virtually every U.S. spacecraft, manned or unmanned, has used the material—and the impetus thus provided spurred development of a broad line of commercial metallized products, from insulated outdoors garments to packaging for foods, from wall coverings to window shades, from life rafts to candy wrappings, reflective blankets to photographic reflectors.

One of the companies that worked with NASA on development of the original space materials is Metallized Products (MP), Winchester, Massachusetts. MP continues to supply metallized materials for a variety of space applications, but over more than a quarter of a century the company has developed an even broader spinoff line of industrial and consumer-oriented metallized film, fabric, paper and foam in single layer sheets and multilayer laminates. MP markets its own products and also supplies materials to manufacturers of other products.

A widely used MP product is TXG laminate, a material that originated in a NASA requirement related to ocean survival rather than orbital flight. In all manned space flights prior to the advent of the Space Shuttle, returning spacecraft descended by parachute to an ocean landing. On the surface, the astronauts left their spacecraft, boarded inflatable rafts and waited for pickup by ships or helicopters of the recovery fleet.

Among a score of applications for a space spinoff reflective material called TXG is the Emergency Blanket, manufactured by Metallized Products, here being used by a ski patrol to protect a skier shaken by a fall; the blanket retains up to 80 percent of the user's body heat, preventing post-accident shock or chills. Carried by many types of emergency teams, the blanket is large when unfolded but folds into a package no bigger than a deck of playing cards.

Often the wait was a long one, because the spacecraft on occasion splashed down as far as 250 miles from the nearest ship. To effect the quickest possible recovery, NASA asked MP to develop a highly reflective raft canopy whose mirrorlike sparkle could be seen at great distances or more readily detected by radar. MP's answer was the non-porous, waterproof, rotproof, superreflective TXG.

Subsequently, Winslow Company Marine Products, Osprey, Florida obtained a license for commercial production of the survival raft and, in cooperation with MP, improved the strength and thermal characteristics of the material so that the raft canopy would provide maximum protection from heat, cold, wind or rain. Winslow now offers TXG canopies on its line of oblong and circular survival rafts ranging in size from four to 12-person capacity.

(Continued)

Shown above is an example of Thermoguard heat shields, windshield and window curtains that reflect the Sun's rays and protect long-parked aircraft from "greenhouse" heat buildup and ultraviolet radiation that could damage the plane's sensitive and expensive avionic equipment. Thermoguard shields are custom-tailored—by Connecticut Advanced Products—from TXG metallized fabric. The company also provides curtains for use on autos (above right). Late model cars have electronic equipment that needs protection, but the Thermoguard shield also protects against upholstery fade and dashboard splitting caused by a breakdown of chemicals in plastic dashboards from long exposure to the Sun. At top is a closeup of a TXG sample, shaded gold for extra reflectivity.

The TXG laminate has found broad and diverse employment. For example, it is used by Connecticut Advanced Products (CAP), Glastonbury, Connecticut for Thermoguard heat shields, custom-tailored reflective curtains that cover the windshield and windows of closed, parked aircraft to protect avionics equipment and upholstery from "greenhouse" heat buildup and ultraviolet radiation. CAP similarly uses TXG for protection of boats and road vehicles, and it manufactures a reflective survival blanket made of TXG.

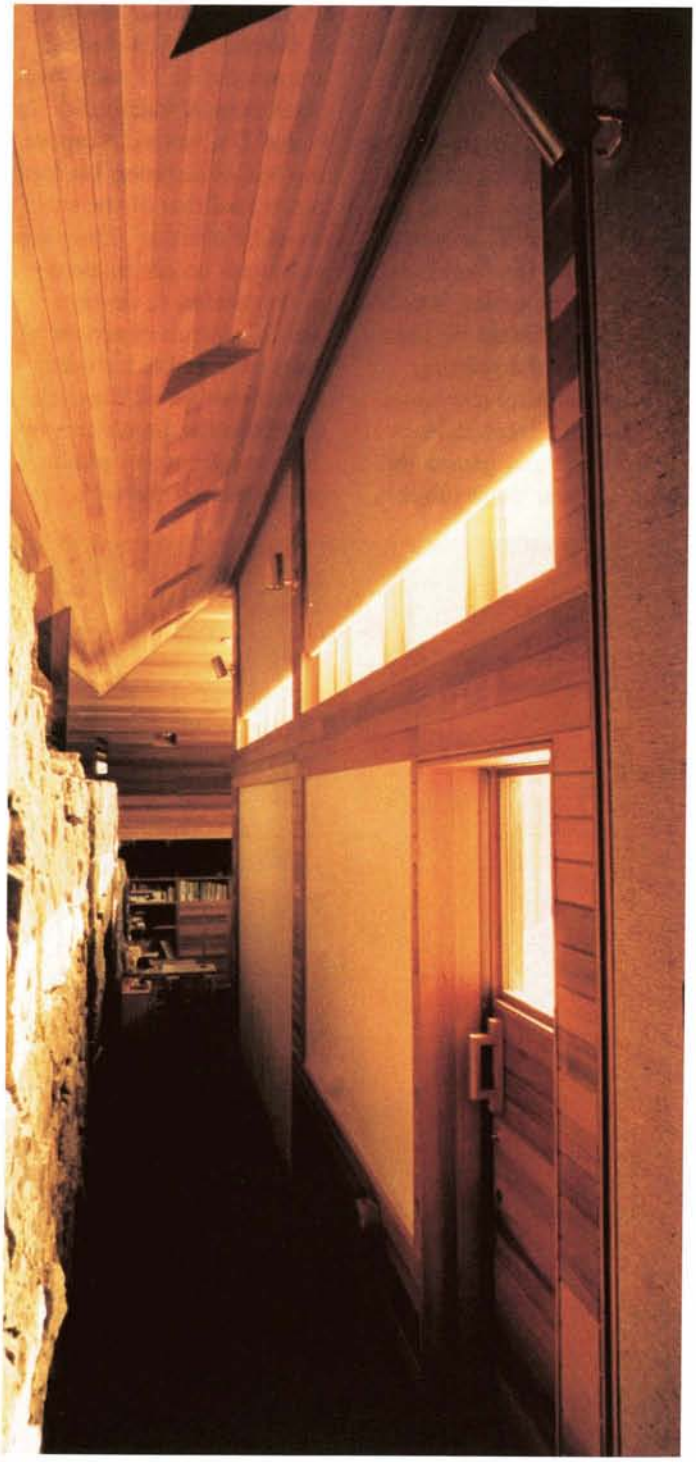
Star Technology Corporation, Carbondale, Colorado employs TXG as a thermal barrier in its Starshade™, a multilayered automatic shade system for large windows in commercial or residential buildings. The standard system features an electric drive motor to raise or lower the shade, a flameproof fiberglass outer fabric and three layers of TXG, which combine with the fiberglass to provide exceptional insulation value.

Among the many other types of materials MP supplies to manufacturers is SP 27 Thermal Interlining, a material long used in space suits; it features a reflective barrier that prevents the passage of radiant energy, thus keeps heat from escaping from clothes or sleeping bags. It is used by many manufacturers of outdoor wear, such as jackets, pants, gaiters or gloves for climbers, campers and skiers.

Among MP's own products are a quartet of protective fabrics with different names but similar purposes: the Emergency Blanket, the Space® Brand Emergency Bag, the All-Weather Blanket and the Marathon Blanket; they reflect and retain up to 80 percent of the user's body heat, thus help prevent post-accident shock or post-exercise chills, or keep a person warm for hours in cold weather crisis situations. All are remarkably compact. The Space Bag, for example, opens into a three by seven foot personal tent/blanket but folds into a three-ounce package the size of a deck of playing cards. MP also produces the Even-Up® Tanning Blanket, which reflects the Sun's rays and disperses them to the hard-to-tan parts of the body.

Manufactured by Winslow Company Marine Products, the Winslow Radar Reflector Life Raft features a canopy made of TXG metallized nylon. The canopy serves dual purpose: it reflects the Sun's rays like a mirror, enabling radar or satellite sensors to spot survivors of a maritime accident at great distances, and it also provides thermal insulation to keep the occupants warm until rescued.

The windows of this home are fitted with Star Technology Corporation's Starshade automatic insulation system that includes an electric motor to raise or lower the shade. Intended for large windows in commercial or residential buildings, Starshade is a thermal barrier that bars or retains heat. The shade is made of three interior layers of TXG encased in an outer shield of flameproof fiberglass.



An example of an industrial-type product is MP's NRC-2 Super Insulation for handling of cryogenics, fluids—such as liquid hydrogen—that must be maintained at supercold temperatures. NRC-2 is an aluminum-coated polyester film with exceptional insulating qualities, used on the walls of cryogenic storage tanks, on pipes and valves, and on road tankers used to transport cryogenic fluids. ▲

[TM]Starshade is a trademark of Star Technology Corporation.

[®]Space Brand and Even-Up are registered trademarks of Metallized Products.

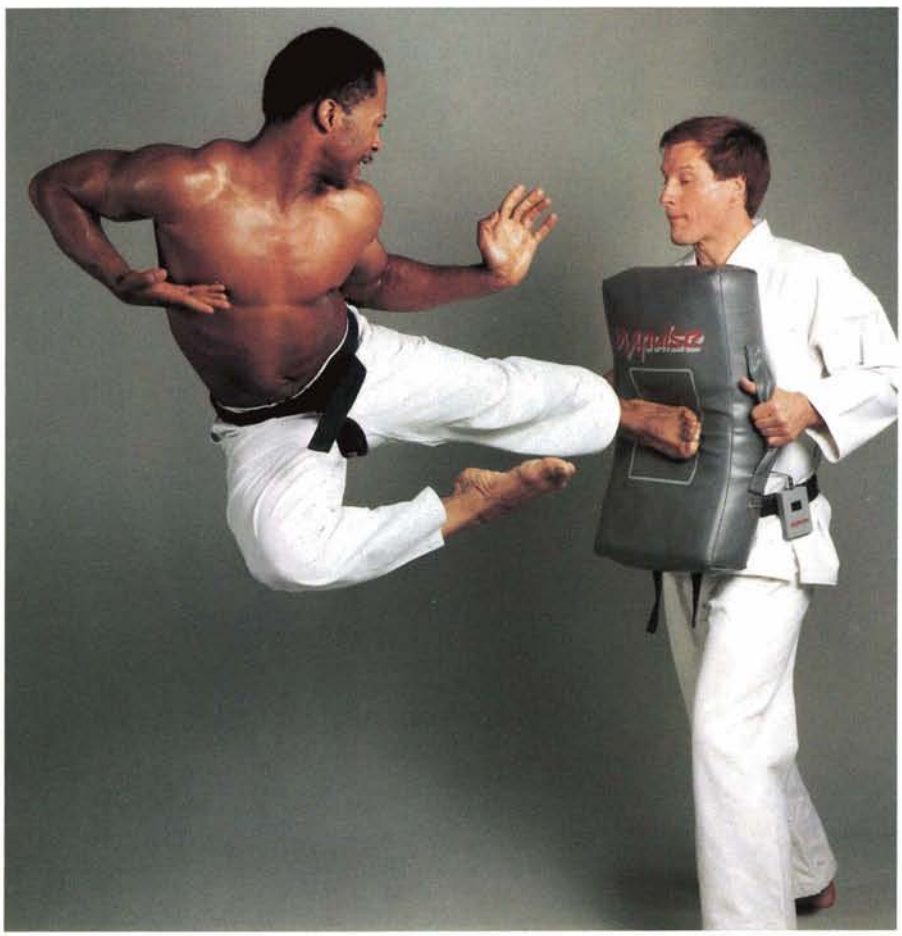
Practitioners of the martial arts have long seen a need for a precise method of measuring the power of a karate kick or a boxer's punch in training and competition. In the customary approach, an instructor estimates the force employed in splintering boards or smashing bricks by sight and sound, or a sparring partner considers the sound and feel of a blow to his body shield and gauges the blow's power. Such subjective judgments are inexact.

Barry French, a martial arts veteran of 17 years with black belts in karate and Tae Kwon Do, wanted a precise method of assessing his own power and that of the students he instructs. There was no system on the market—so he decided to develop one. The result of several years of research, including input from Lewis Research Center, is the Impax line of force measurement products, which has excited wide attention and favorable comment among the martial arts community. The equipment is marketed by Impulse™ Sports Training Systems, Bay Village, Ohio, a company formed by Barry French.

At the start of his development effort, French sought assistance from Lewis Research Center on available technologies that might be applicable to martial arts force measurement. During development, Lewis provided what French terms "invaluable technical assistance," advising on such matters as sensors, materials and optimum structures, directing French to firms with expertise in such technologies, and offering guidance toward problem solutions.

The Impax sensor is a piezoelectric film less than one thousandth of an inch thick, yet extremely durable. Similar to sensors that measure microscopic particle impacts in space, it gives out a voltage impulse when struck—the greater the force of impact, the higher the voltage. The impulse is transmitted to a compact electronics package, where the voltage is translated into a force-pounds reading and shown on a digital display.

Mounted on a sheet of plastic for protection, the sensor is affixed to several martial arts training products —for example, a body shield, a hand mitt, a heavy punching bag or a wall pad. The accompanying photos illustrate the use of Impax gear.



At left, Barry French (white jacket) holds an

Impax Body Shield while former European middleweight kickboxing champion Daryl Tyler delivers an explosive jump side kick; the force of the impact is registered precisely and shown on the display panel of the electronic box French is wearing on his belt. A closeup look at the Body Shield is shown at left above, where French's wife Mary Ellen (also a black belt) and son Barry are the demonstrators. Above, Tyler high kicks an Impax mitt worn by French.

Among Impax users are martial arts instructors who are generally enthusiastic about the equipment's utility for generating competitive excitement among students, for testing and for charting students' power performance over time. Impax equipment is also used by serious martial arts practitioners as a means of measuring and developing their own punch/kick power. The Sports Medicine and Science Group at the U.S. Olympic Committee Training Center is using Impax products for evaluation and training of boxers and Tae Kwon Do teams. The technology has been licensed to the largest manufacturers of football blocking sleds. Additionally, French reports that Impax Sports Training Systems have been well received as training tools for police defensive tactics, providing a means of evaluating the performance of recruits (below). ▲

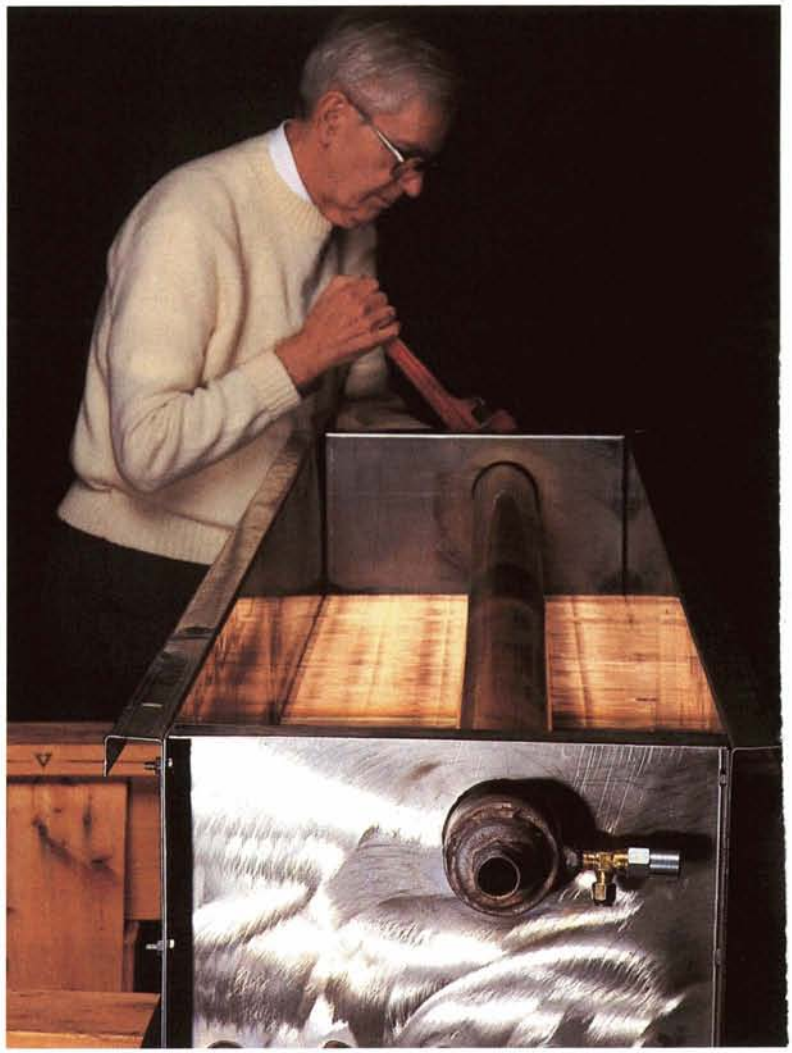
™Impulse is a trademark of Impulse Sports Training Systems, Inc.

Heat Pipe Systems

Below, inventor James M. Stewart stands beside the externally visible portion—the solar panels—of a solar hot water system that employs space-derived heat pipe technology; it is used by a meat packing plant to heat water for cleaning processing machinery. The novel system, which won 1986 awards for energy innovation, was developed by Solar Fundamentals, Inc. (SFI), and is marketed by SFI and by The Solar Works, Dewey, Oklahoma. At right, Stewart, who founded and is president of SFI, is checking the final assembly of another heat pipe system for recovering excess heat from a cookie company's baking ovens and using it to heat water for equipment cleaning.

The heat pipe is a heat transfer mechanism developed for NASA by Los Alamos Scientific Laboratory (LASL) to solve a problem in the early days of the space program: the Sun-facing surfaces of a non-rotating satellite became excessively hot while surfaces not exposed to the Sun became very cold, producing a situation that could cause failure of electronic systems. LASL's answer was a simple device with no moving parts that extracted heat from the hot parts of the spacecraft and used it to warm cool parts.

Stewart learned about heat pipes more than a decade ago through contact with NASA's Technology Applications Center (TAC) at the University of New Mexico. Stewart incorporated the heat pipe technology into his own development of patented "heat tubes," which found application in the manufacture of plastic products. Stewart has since maintained contact with TAC and obtained updated NASA reports on advances in heat pipe technology. The NASA input assisted him in development of his HPCoil, the focal element of SFI solar hot water systems. The HPCoil is a bundle of heat pipes that extract thermal energy from an air-based solar collector; heated air passes over fins to evaporate a fluid, which condenses and heats water.



SFI's unit is a complete system with water heater, hot water storage, electrical controls and auxiliary components. Other than fans and a circulating pump, there are no moving parts. SFI's citation from the National Awards Program for Energy Innovation stated that the use of heat pipes "significantly increases system efficiencies" and added that the system's unique design eliminates problems of balancing, leaking, corroding and freezing. ▲

Thermoelectric Products

Shown below is an office use high purity water delivery system with a two cubic foot thermoelectric refrigerator. Manufactured by United States Thermoelectric (UST), Chico, California, it is one of a line of UST products based in part on NASA thermo-

electric technology. Among the company's products are portable heating and refrigeration units called precision temperature chambers (PTC), commercial versions of systems developed for use in spacecraft under contract to Ames Research Center.

Instead of the bulky coils and compressors used in conventional refrigeration systems, UST design engineers drew on thermoelectric technology. UST's precision temperature chambers (PTCs) feature small thermoelectric modules that measure not much more than one square inch and operate on a unique phenomenon of heat exchange: when electric current flows through specialized metallic crystals, heat is produced, and when the current direction is reversed, cooling is produced. At right above an engineer is inspecting a thermoelectric assembly.

PTCs have been used in medical and scientific applications. Powered by the battery of an auto or airplane, they offer a typical temperature range of 35 to 150 degrees Fahrenheit; a digital keypad or a thumbwheel switch offers temperature selection in one degree increments. UST's chambers can refrigerate for up to 48 hours on a single charge powered by a 16-ounce battery pack.

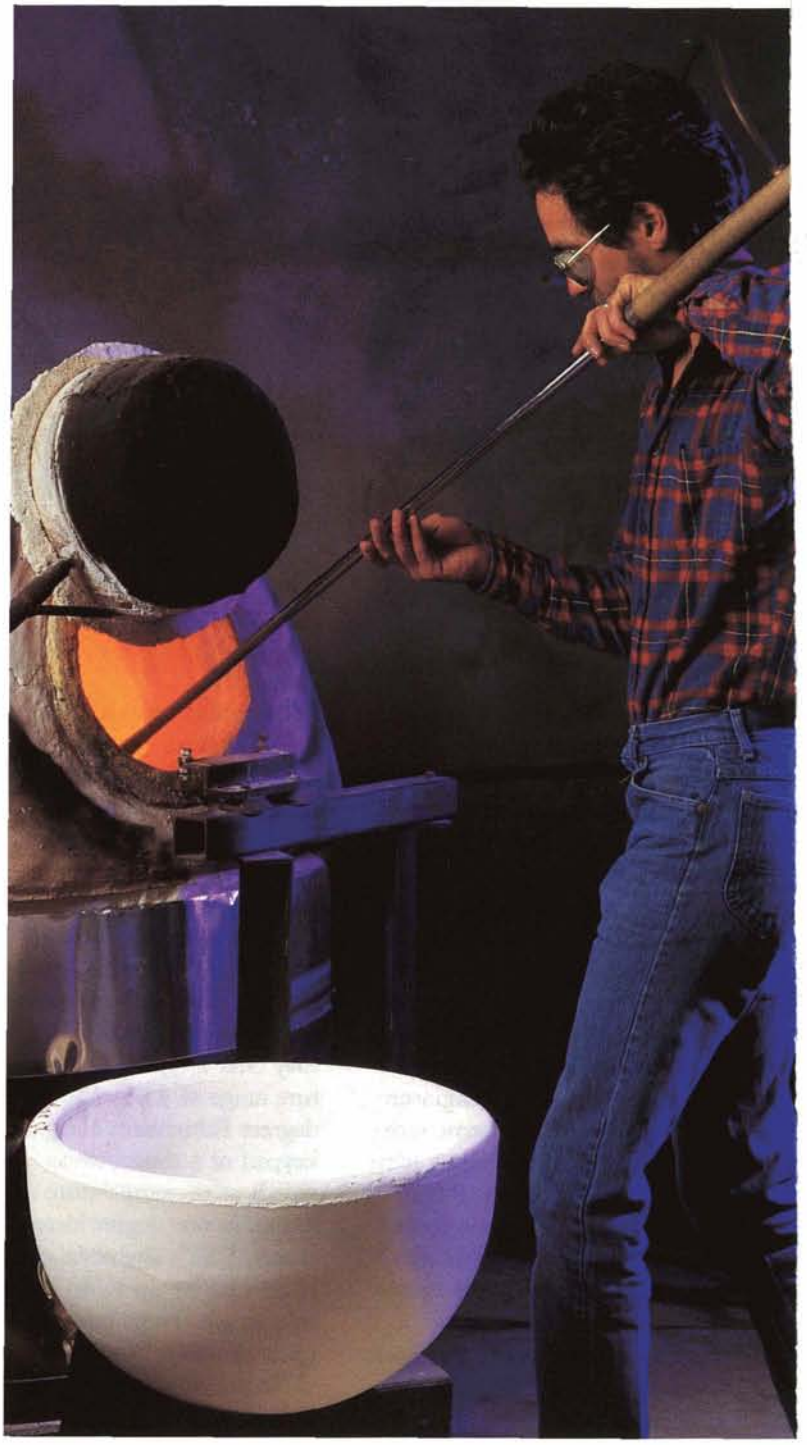
As the company's name indicates, UST specializes in R&D focused on creation of proprietary thermoelectric systems for consumer, commercial, industrial and aerospace use. Products include heating and cooling systems, power generators and thermoelectric systems operated by solar power sources. UST chief executive officer and general manager James M. Kerner states that his company has benefited from NASA technology in several areas. NASA crystal growth technology has proved valuable. In designing advanced thermoelectric power generation systems, UST employs NASA technology developed for the radioisotope thermoelectric generators aboard several long duration spacecraft. The company also benefits from NASA solar power technology.

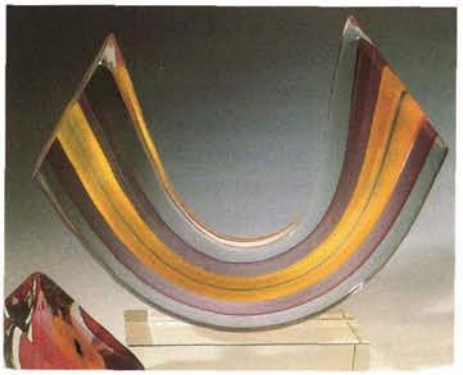
Other UST products include thermoelectric solar driven refrigerators; a Third World refrigerator that can operate on very low power or on solar power; a Refrigeration Conversion Module that can convert any insulated container into a refrigerator; and several types of PTCs. Scheduled for release this year or early in 1989 is an Undercounter Water Delivery System for the home that delivers purified hot and cold water to the household sink at the touch of an electronic faucet. ▲

Glass Artworks

Shown below is a magnificent Rocking Combination Arc, a glass artwork by Harvey K. Littleton, father of what is known in art circles as the studio glass movement. Before Littleton, the technological demands of working hot glass dictated that such artworks be produced by skilled technicians in factories with an array of special equipment. In the 1960s, Littleton popularized the techniques that enabled an artist working alone in a studio to create high quality glass artworks. Littleton passed on his technology to groups he taught at the University of Wisconsin; many of his students formed their own university glass art programs and helped advance the technology. Today there are estimated to be more than 1,000 glass studios in the U.S.

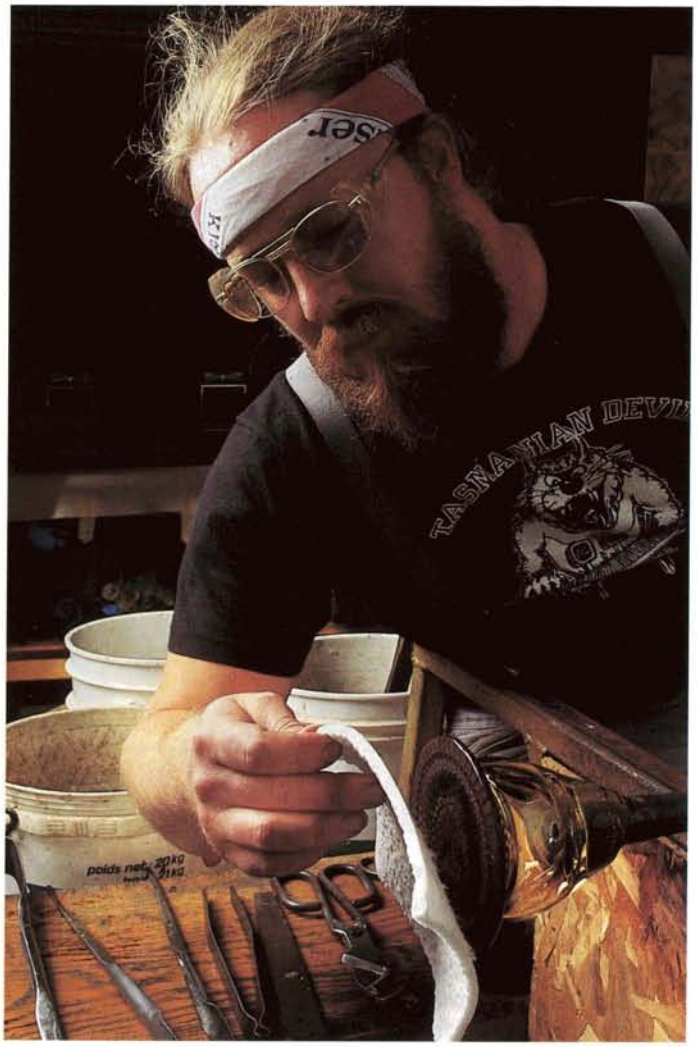
Several NASA technologies have played a part in the growth and cost containment of studio glass art, among them a foam-type insulation developed to meet a need for a lightweight material that would reduce flame spread in an aircraft fire. The foam comes in several forms and is widely used by glass artists, chiefly as an insulator for the various types of ovens used in glass working. The principal advantage is economy; other insulating materials absorb much of the heat energy and require three to four times the amount of fuel.





Another spinoff is the use of alumina crucibles to contain molten glass. A fabrication process for alumina crucibles was developed by Marshall Space Flight Center for use in experiments on inorganic crystals. Prior to that time, glass tanks were made of firebrick, which tended to erode under high temperature and cause impurities. The use of alumina crucibles not only improved quality but made the process more cost effective.

One more NASA technology that has found its way into glass artworking is a material known as graphite board, a special form of graphite originally developed for rocket motor applications by Great Lakes Carbon Corporation, Briarcliff Manor, New York. An example of the utility of this kind of graphite is found in the work of artist Mark Peiser, who machines it in his studio to exact compound angles and creates molds for poured-glass artworks of dramatic design. At upper left on the opposite page is a graphite mold in the foreground and the resulting artwork (cost $11,000) in the background.



At top left center, the husband-wife team of John and Kate Littleton is creating a blown glass artwork. In the left center photo, John Littleton is dipping a blowpipe into an alumina crucible inside a gas-fired oven; a new crucible is shown in front of the oven. The glass formula is melted and kept liquid for days and even weeks, throughout the production of the artwork. Once the piece is completed, it must be cooled to room temperature very slowly, only a degree per hour. This is done in an electric annealing oven such as the one (top left) in which Kate Littleton is placing a completed work. The electricity cost for the long period of cooling would be enormous except for the superinsulating qualities of the insulator lining the oven.

The top right photo illustrates another use of the foam insulator—as a base for a fused glass design. The foam is the white material set on a ceramic plate; on top of it artist Gary Beecham has arranged colored glass rods to form a desired design. The whole package is then placed inside an electric oven and heated to about 1800 degrees Fahrenheit; then the glass rods melt together into Beecham's predetermined design. At left, Beecham peels away the foam support sheet, which is easily removed and leaves no residue or impurities. ▲

At right is the award-winning Renaissance Telescope for high resolution photography and visual astronomy. Below it are five 82° Field TeleVue Nagler Eyepieces, some of the accessories that contribute to high image quality. The telescope and eyepieces are representative of a family of optical equipment manufactured by TeleVue Optics, Inc., Pearl River, New York. TeleVue's devices incorporate space technology developed for NASA's Gemini and Apollo projects.

TeleVue products represent examples of the personnel type technology transfer, wherein people who work for NASA or its contractors move to another industry, bringing with them aerospace-acquired skills and know-how applicable to non-aerospace use.

The instrument of technology transfer in this instance was Al Nagler, president and founder of TeleVue Optics. From 1957 to 1973, Nagler worked as senior optical systems designer for Farrand Optical Company, Valhalla, New York. Under contract to NASA, Farrand developed visual simulators for several NASA programs. Nagler's particular responsibility was displays for the Gemini and Apollo Lunar Module spacecraft. The visual simulators used large mirrors to project images of Earth orbit, docking and lunar landing. The latter was simulated by a complex "optical probe," a TV camera and lens that "flew" down onto a scale model of the lunar surface.

Nagler's experience in these and other space technologies provided the technical basis for the Renaissance Telescope, his patented wide angle eyepieces and other optical systems. In 1977, Nagler founded TeleVue, which designs and manufactures projection TV lenses as well as telescopes and eyepieces, and additionally performs consulting and optical design for the military services, aerospace firms and commercial businesses. ▲

Plant Minders

Architects and interior designers are increasingly using indoor arrangements of live plants to enhance the attractiveness of office suites, hotel lobbies, restaurants, lounges, banks and homes. Plants are generally installed by contractors called "plantscapers," who also perform contract maintenance functions—watering, inspection, cleaning, rotation and replacement. By one estimate, watering accounts for 25-60 percent of the time spent on-site by maintenance technicians. Therefore, maintenance costs can be substantially reduced by an automated system for watering indoor plants, says Stuart Snyder, president of Aqua/Trends, Boca Raton, Florida, who invented a family of computer-controlled Micro-Irrigation Systems.

At upper right is a Palm Beach (Florida) condominium lobby whose plants have been automatically tended for five years by an Aqua/Trends system. In the center photo, Snyder is pictured with some of the elements of his system in a home installation. The Aqua/Trends system draws water from building outlets or from a pump/reservoir module and distributes it to the plants via a network of tubes and adjustable nozzles. A key element of the system is an electronic controller programmed to dispense water according to the needs of the various plants in an installation. At far right is a closeup of an adjustable nozzle that meters out exactly the right amount of water at the proper time to the plant it is serving. More than 100 Aqua/Trends systems are in service in the U.S.; they come in various sizes, from a simple residential system that takes care of up to 12 houseplants to a Mirage III system integrated into a structure to water all the greenery in a large office or apartment building.

NASA provided Snyder assistance during development of the Aqua/Trends line through the Southeast Area Office of the Southern Technology Applications Center (STAC), located at Florida Atlantic University, Fort Lauderdale. STAC furnished pertinent NASA technical reports, advised Snyder of seminars useful in product development, and put him in contact with NASA's National Space Technology Laboratories (NSTL). NSTL conducts an ongoing research effort in plant use for water purification and pollution control (see page 94) and it made available to Snyder reports of this work. ▲

Pool Purification

Shown above is a Florida pond cluttered by algae. At right above is the same pond 48 hours after treatment by a new water purification system—no algae and very clear water, evidenced by the clouds reflected on the mirror-like surface of the pond. These before and after photos were made to demonstrate the efficacy of the Caribbean Clear Automatic Pool Purifier, which utilizes NASA technology developed to sterilize the water supply of long duration spacecraft.

In the 1960s and early 1970s, Johnson Space Center conducted a research program aimed at development of a small, lightweight water purifier that would require minimal power and no astronaut monitoring. This program produced an electrolytic silver ion generator only slightly larger than a cigarette pack and weighing only nine ounces. One or more units, mounted at various locations in the potable water supply and wastewater system of Apollo or future spacecraft, would dispense silver ion concentrations of 100 to 300 parts a billion, sufficient to eliminate bacteria in the water within hours.

Caribbean Clear, Inc., a Leesville, South Carolina manufacturer of electronic products, used the NASA technology as the basis for its

Automatic Pool Purifier, a system that offers an alternative approach to the use of conventional purification chemicals. Caribbean Clear's principal markets are swimming pool owners who want to eliminate chlorine and bromine. The purifiers in the Caribbean Clear system are the same silver ions used in the Apollo system to kill bacteria, plus copper ions to kill algae. They produce pool and spa water that exceeds the Environmental Protection Agency's standards for drinking water.

At lower left is a residential swimming pool with a built-in hot tub, both serviced by the Automatic Pool Purifier; the system is effective in both units despite the difference in temperature. Shown above is the key element of the system, two silver-copper alloy electrodes which generate the silver and copper ions when an electric current is passed through them. The rest of the system includes a microcomputer that monitors water condition, water temperature and electrode wear, and a controller that automatically introduces the correct amount of ions into the water; the upper right photo shows the controller with the electrodes and their housings.

Caribbean Clear maintains that purifying a pool with its system costs less than treating the same pool with chlorine and algaecides. The Automatic Pool Purifier requires only a once-weekly test to measure the level of copper ions in the pool; a twist of a knob in the control unit increases or decreases output as required.

Caribbean Clear works with Departments of Health throughout the world and with independent testing laboratories to assure safe, non-toxic water (right).

The system is now available in the U.S. through some 200 franchises, and in 42 foreign countries; there are more than 10,000 units in operation. The company makes units in different models for purifying everything from a small residential hot tub to a six million gallon commercial pool. In addition to private pool owners, Caribbean Clear numbers among its customers the U.S. Navy, Holiday Inns, Marriott and Sheraton hotels, YMCA facilities and many health clubs. Other applications include killing algae and bacteria in fish ponds, fountains and cooling towers. ▲

Racing with the Sun

An experimental solar electric car with remarkable performance highlights a sampling of technology transfers in the field of energy

On the morning of November 1, 1987, 25 odd-looking vehicles departed Darwin on Australia's North Coast in the inaugural World Solar Challenge Race, a competition for solar-powered autos with entries from Australia, Denmark, Germany, Japan, Pakistan, Switzerland and the United States.

Five and a half days later, General Motors' *Sunraycer*, one of four American entries, crossed the finish line near Adelaide, South Australia—more than 600 miles and two and a half days ahead of its nearest competitor after a grueling, 1,950-mile run through tropic heat and humidity in northern Australia, through a thousand miles of desert heat in the Central Australia outback, and finally into a temperate climate in the last stages of the race.

The little one-seater covered the north-south transcontinental route at an average speed of 41.6 miles per hour. Its *average* speed was considerably better than the prior world speed record for land vehicles powered by direct energy from the Sun—35.22 miles per hour, a record also held by *Sunraycer.*

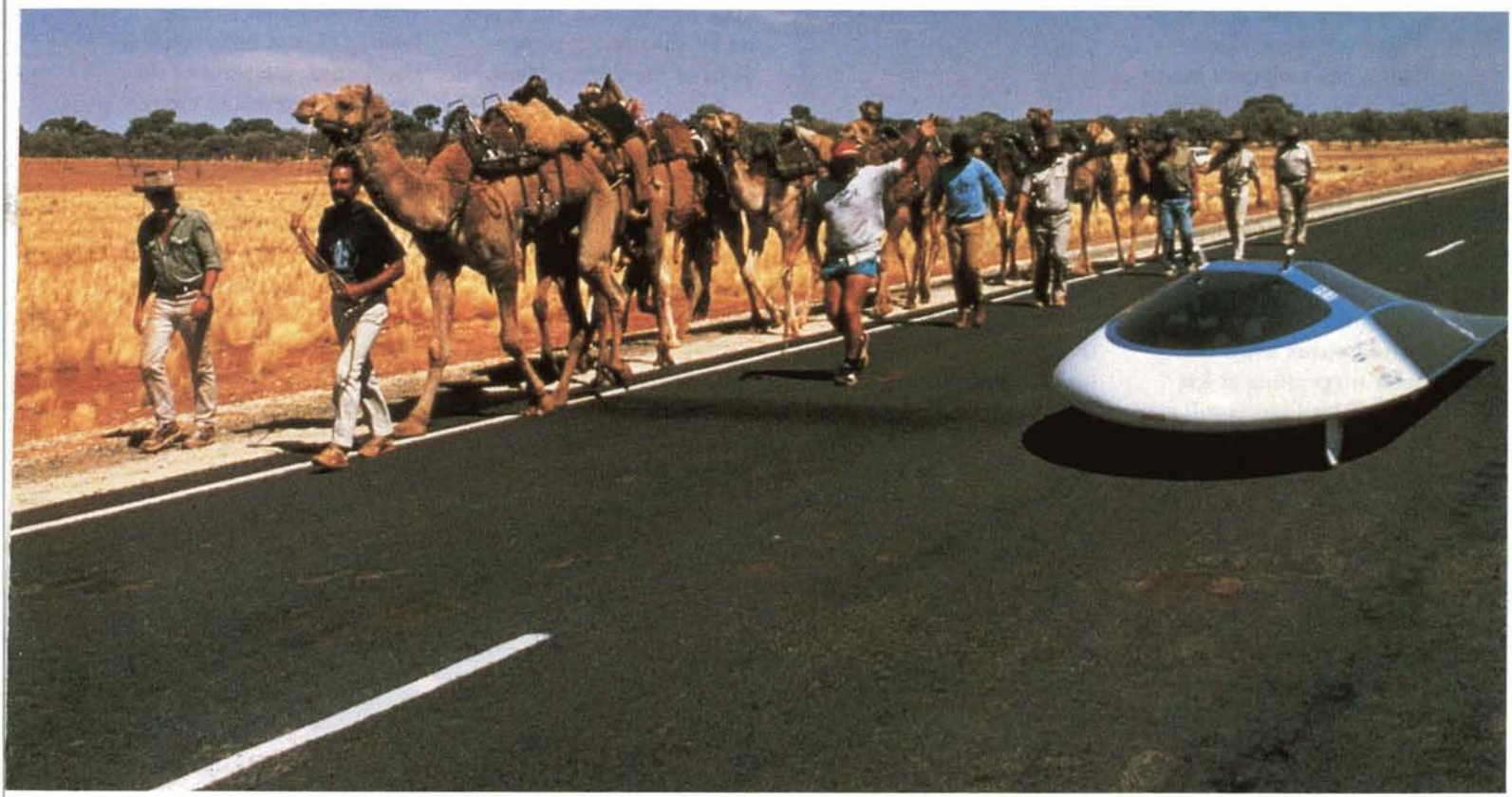
Sixteen General Motors operations and several suppliers joined forces to design, build and drive the sleek *Sunraycer.* One of the prime movers was Hughes Aircraft Company, a subsidiary of GM Hughes Electronics Company and a longtime NASA contractor. Hughes designed and built the solar arrays, composed of 1,400 Hughes silicon solar cells and 3,800 gallium arsenide cells each from Applied Solar Energy Corporation and Mitsubishi Electric Corporation. These photovoltaic cells convert the Sun's rays directly into electricity. Development of photovoltaic power was pioneered by NASA and its contractors—including Hughes—and it has been used to power most of the spacecraft sent into orbit.

The *Sunraycer* project embraced a number of other advanced technologies, including a revolutionary electric motor, developed by GM Research Laboratories and Delco Remy, and several aerospace-related technologies, such as microelectronics, optics, lightweight materials and communications. In addition, the vehicle was designed with the help of a NASA-developed computer program called VSAERO, used to calculate the aerodynamic characteristics of the *Sunraycer.*

The *Sunraycer* features a welded aluminum tube "spaceframe" chassis, designed by AeroVironment Inc., Monrovia, California, and a body of lightweight honeycomb sandwich material. The low-slung teardrop shape is designed to achieve extremely low aerodynamic drag, with low side forces during crosswinds, while providing a suitable surface for the solar cells and adequate space for the driver (six drivers alternated, four to five hours at a time, in the Solar Challenge race).

Less than 20 feet long, the *Sunraycer* weighs only 547 pounds with driver. The canopy is goldplated to reflect 90 percent of the visible light and 98 percent of infrared radiation, which holds down temperatures in very hot climates.

The solar array spreads over 90 square feet of the vehicle's aft curved surface. It was de-



Near the midway mark of the 1,950-mile trans-Australia race, the General Motors *Sunraycer* passes a camel train in Central Australia's outback. Powered by space-derived solar cell technology and incorporating a number of other aerospace technologies, the 547-pound one-seater averaged better than 41 miles an hour and finished 600 miles ahead of its nearest competitor.

veloped by Hughes' Space and Communications Group, which has special expertise in fabricating curved solar arrays; a hallmark of Hughes satellites is the technique of installing solar cells on the exterior surface of a cylindrical spacecraft body, rather than on flat-panel solar wings. Although the intensity of the Sun's rays and the temperature of the environment affect output, the solar array typically operates at 150 volts, providing up to 1,500 watts of power at noon. The electricity generated flows to the motor or to the storage battery system, composed of 68 rechargeable silver zinc cells producing a total of 102 volts. The batteries weigh 60 pounds, one-fifth the weight of a lead acid battery of the same capacity. In the race, battery power was used early and late in the day to supplement the reduced solar power available at those times. ▲

Motor Controller

Several years ago, Marshall Space Flight Center engineer Frank Nola came up with a way to curb power wastage in AC induction motors caused by the fact that such motors operate at a fixed voltage, the voltage necessary to handle the heaviest loads the motor is designed to carry. The wastage occurs when the motor is operating at less than full load but is still getting full load power. Nola's answer was a device called the Power Factor Controller (PFC) that matches voltage with the motor's actual need. Plugged into a motor, the PFC continuously determines motor load by sensing shifts between voltage and current flow; when it senses a light load it cuts the voltage to the minimum needed. It offers potential energy savings ranging from eight percent all the way up to 65 percent, depending on the type of application.

Considering the millions of electric motors in service and the rising cost of energy, it was not surprising that Nola's invention excited broad interest and became one of the most widely used NASA spinoffs. A user example of particular interest is

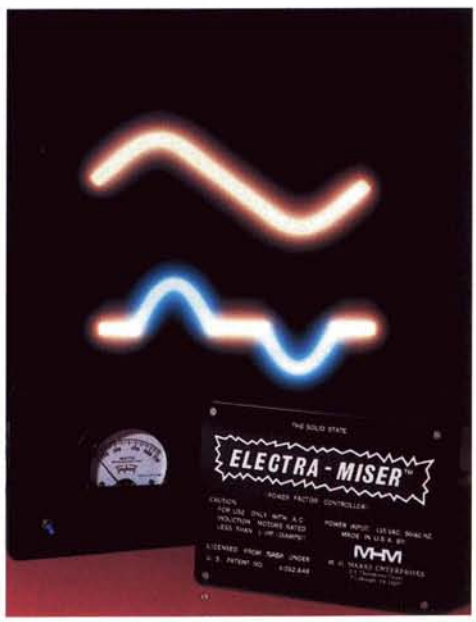
the experience of Myles H. Marks, then a Pittsburgh (Pennsylvania) television broadcast engineer who started out with the notion of doing a magazine article about the PFC and wound up with a thriving garage industry selling controller kits in volume.

Marks learned of the PFC from a TV broadcast and hit upon the idea of writing an article for *Popular Electronics* magazine and at the same time offering to furnish kits to readers interested in assembling their own PFCs. The editor of *Popular Electronics* was enthusiastic about the project, so Marks began gathering information.

He contacted the NASA Industrial Applications Center at Pittsburgh, which supplied him a detailed technical information package and advised him how to obtain a NASA license. Marks got the license, developed his own prototype and patented it as the Electra-Miser™, a unit designed to cut power up to 40 percent in typewriters, washing machines, refrigerators and similar equipment. With NASA help, he also lined up suppliers for the various components of the Electra-Miser kit.

When the *Popular Electronics* article appeared, Marks was stunned by the response. Within two weeks he had orders for 500 kits and the orders kept coming over a three-year span. He used his garage as a kit assembly plant and the rest of the house as a warehouse, and turned out some 2,500 kits. Marks is shown above with an Electra-Miser (black box) installed on a home heating blower unit; below is the normal sine wave of the electrical current and the power savings (blue) the Electra-Miser makes possible by interrupting the cycle.

In time the PFC technology spread widely and, as many new suppliers entered the field, demand for the Electra-Miser fell off, but Marks still maintains a supply of parts and builds Electra-Misers on special demand.



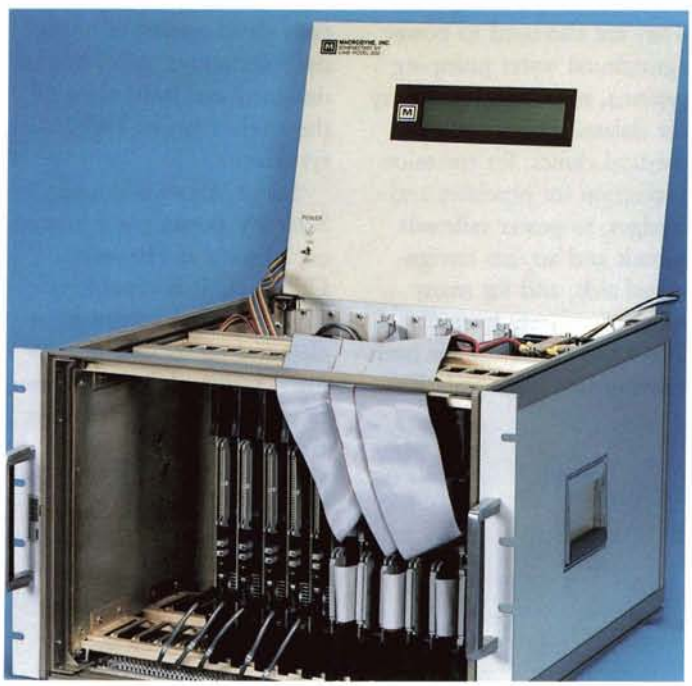
™Electra-Miser is a trademark of M. H. Marks Enterprises.

Flow Measurement

A laser velocimeter (LV) is a system used in wind tunnel testing of aircraft, missiles and spacecraft. It employs electro-optical techniques to probe the flow field as the tunnel blows air over a model of the flight vehicle, and to determine the velocity of the air and its direction at many points around the model. The LV makes measurements at rates up to one million per second and reports them to a computer.

Current state-of-the-art minicomputers, however, cannot handle the massive flow of real time data from several sources simultaneously. To compensate for this limitation, Langley Research Center developed an instrument with the impressive name of Laser Velocimeter Autocovariance Buffer Interface (LVABI). The LVABI is an interconnecting instrument between the LV and the computer. It acquires the data from as many as six LV channels at high real time data rates, stores it in its memory, and sends it to the computer on command.

The LVABI can also acquire data from other instrumentation used in conjunction with the LV. In wind tunnel testing, the LVABI can therefore provide a complete analytical picture of the flow about a model each time a measurement is made.



Langley began developing the LVABI in 1976 and, in 1980, initiated work on a more advanced second generation instrument in cooperation with Macrodyne, Inc., Schenectady, New York. Langley and Macrodyne also teamed in a technology utilization project to commercialize the technology. At left is the LVABI instrument; above, a Macrodyne engineer is testing its circuitry.

The LVABI has application in a variety of research, industrial and defense functions that require precise flow measurement. It is, for example, used in parametric measurements of fluid flow in chemical processing and electricity flow in utility operations. Customers include a number of government and private research laboratories, university research centers, industrial companies and electric power utilities. ▲

Solar Electricity

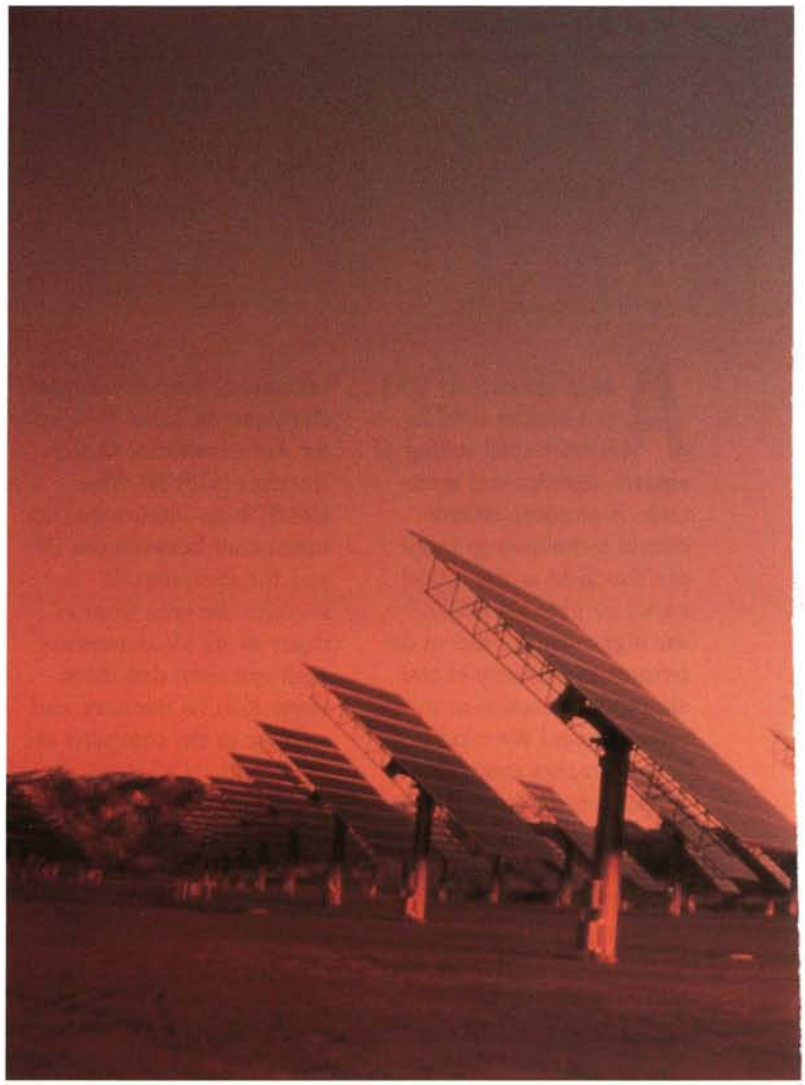
When sunlight strikes certain materials—such as silicon—electrons are set in motion. These moving electrons can be drawn off as electricity. That is the basic principle of photovoltaic conversion, or PV, the method of providing power to nearly all the satellites launched into space. In recent years, PV has been getting more of a foothold in practical Earth applications.

The first step in producing a PV system is to make the solar cells, very thin, treated wafers of extremely pure silicon sliced from cylindrical crystals "grown" from molten silicon. Then the cells are electrically connected and encased in weatherproof packages called modules. Several modules join together to form a panel and any number of panels can be assembled to form a PV array.

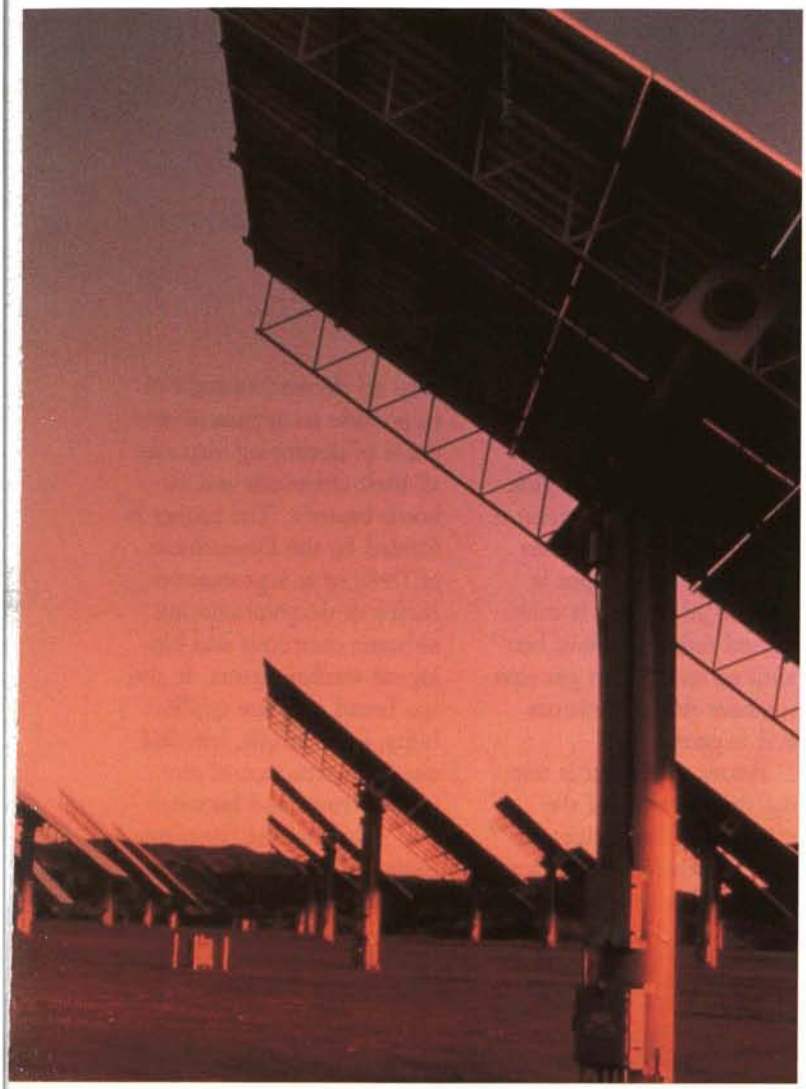
NASA pioneered PV power for spacecraft and has been very active in support of Department of Energy (DoE) programs designed to expand Earth applications. Lewis Research Center supports DoE by conducting demonstrations of the advantages of this type of power generation. NASA's Jet Propulsion Laboratory (JPL) is the organization primarily responsible for developing advanced PV technology and finding ways to cut costs. Research has gradually reduced the cost to the point where PV is in practical use in a number of Third World areas where no established energy network exists. In developed countries, it is still too expensive for widespread commercial, industrial and residential applications but it is making an appearance as a working component of the U.S. utility grid.

"People have traditionally thought of photovoltaics as a technology with promise of becoming a source of utility scale energy in the more or less distant future," says James H. Caldwell, president of ARCO Solar, Inc., Camarillo, California, a subsidiary of Atlantic Richfield Company. "The fact is, photovoltaics is already a business, using today's technology to supply power *today*."

ARCO Solar manufactures PV systems tailored to a broad variety of applications. PV arrays are routinely used at remote communications installations to operate large microwave repeaters, TV and radio repeaters, rural telephones and small telemetry systems that monitor environmental conditions. They are also used to power agricultural water pumping systems, to provide electricity for isolated villages and medical clinics, for corrosion protection for pipelines and bridges, to power railroads signals and air/sea navigational aids, and for many types of military systems. Since 1982, ARCO has been moving into large scale PV power generation for utilities. A JPL contractor since the early development of Earth-use solar arrays, ARCO Solar designed and built some of the world's largest PV systems.



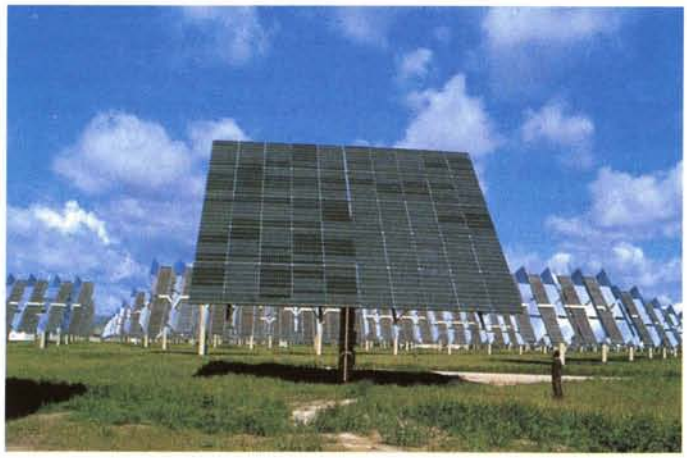
Shown above is an ARCO Solar PV power plant located on 20 acres at Hesperia, California. It is capable of generating one megawatt of electrical power and supplying 3 million kilowatt hours of electricity annually; at the time of the plant's dedication in 1983, its rated capacity was three times greater than any PV system in the world. The system makes maximum use of available sunlight by means of automatic, computer-controlled



trackers that continually point the PV panels directly at the Sun for efficient acquisition of solar radiation.

The Hesperia station has 256 PV modules on each of 108 tracker pedestals. Its electricity, enough to serve 300-400 homes, is purchased by Southern California Edison Company (SCE) and fed to SCE's utility grid. Between the plant and the utility grid is an inverter station that converts the electricity from direct current (DC), the type of current generated by PV systems, to alternating current (AC), the current to which the U.S. utility grid is geared.

ARCO Solar also built a one megawatt facility for the



Sacramento (California) Municipal Utility District. But the granddaddy of all PV systems is ARCO Solar's 6.5 megawatt plant at Carrisa Plains, just west of Bakersfield in California's Kern County. The 160-acre plant, part of which is shown above, has 756 solar trackers, each with 16 PV panels. It produces almost 14 million kilowatt hours a year, enough to serve 2,300 average homes, and feeds it to the grid of Pacific Electric Company. It is planned to boost the Carrisa Plains capacity eventually to 16 megawatts.

ARCO Solar has PV installations on five continents and the company's broad product line ranges from mammoth systems like Carrizo Plain to simple units that provide power for recharging recreational vehicles batteries. An in between example is pictured at left; it is a three-acre, 300 kilowatt municipal utility financed by the city of Austin, Texas. ARCO Solar won the bid for the plant, provided the design and the PV modules. ▲

Research Help

The experience of The Electrosynthesis Company, Inc., East Amherst, New York illustrates the benefits available to industry through a network of NASA assistance centers that provide information retrieval services and technical help. NASA operates 10 such centers serving different geographical areas; the one in this instance is NERAC, Inc., Tolland, Connecticut.

Electrosynthesis is a small entrepreneurial firm that receives research and development funding through the Small Business Innovation Research (SBIR) program. Company president Dr. Norman Weinberg states that he uses NERAC's services to advantage in preparing each SBIR proposal. NERAC prepares customized literature searches, provides helpful technological background and current awareness information—including pertinent NASA technology—and helps participants investigate patents, gain competitive intelligence and identify qualified technical experts.

NERAC also provides information about commercial possibilities and market conditions. Electrosynthesis plans internal manufacturing and marketing of certain of its products and expanded marketing through licensing agreements with larger manufacturers.

Among several projects in R&D or limited production status is a family of carbon/graphite materials known as Specifically Fluorinated Carbons or SFC™. Shown in various forms above, SFC materials offer efficiency improvement and extended lifetime for batteries, fuel cells and electrodes due to superior stability and electrocatalytic properties.

Electrosynthesis is also investigating other chemically modified carbons for use in lithium batteries. The bottom photo shows a test of a lithium/carbon battery bathed in thiomyl chloride solution. The composition is readily decomposed when oxygen or water vapor is present, so the test is conducted inside a "glove box" with an inert argon gas environment free of moisture and oxygen.

Below, a scientist is testing the efficiency of the company's Electrocinerator™ System, which integrates a highly effective air scrubber with an electrochemical cell to provide an apparatus capable of destroying virtually all toxic chemicals and airborne bacteria. The project is funded by the Department of Defense as a prospective means of decontaminating airborne chemicals and biological warfare agents. It also has broad civil use applicability, for example, hospital use for destruction of airborne viruses and bacteria and industrial use for eliminating toxic solvent vapors and malodorous emissions. ▲

™SFC and Electrocinerator are trademarks of The Electrosynthesis Company, Inc.

Light Reflector

At right, a fluorescent lighting fixture is getting a boost in reflectivity through installation of Lightdriver®, a thin, tough thermoplastic film plated with aluminum capable of reflecting 95 percent of the visible light striking it. Lightdriver is marketed by Ultra Sales, Inc., Colonia, New Jersey.

Lightdriver increases brightness without adding bulbs and allows energy savings by removing some bulbs, because the mirrorlike surface cuts the light loss generally occasioned by the conventional low reflectivity white painted surface above the bulbs in many fluorescent fixtures. With Lightdriver, says Ultra Sales, a 45 percent reduction in electricity usage is attainable by removing two of the bulbs in a four bulb fixture; the remaining two will still provide excellent lighting.

Additional savings accrue from lower air conditioning bills due to fewer heat-producing bulbs in use and from bulb replacement costs. Bonus advantages include even lighting throughout a work area, less glare and eyestrain, and the fact that Lightdriver does not reflect most ultraviolet light.

Sold in sheets and cut to fit fixtures, Lightdriver is made in three layers: the thermoplastic film, which protects the reflective surface from corrosion and insulates it electrically; the aluminum reflector, which provides greater reflectivity than a standard mirror; and a permanent adhesive with removable backing (top) for simple installation.

Lightdriver is one more adaptation of a spinoff metallization technology that originated in a 1960 NASA project involving development of a lightweight, highly reflective skin for a balloon type satellite. The need was met by Metallized Products (MP), Winchester, Massachusetts (see page 70), which developed a metallized plastic film coated with a mist of aluminum particles. That development triggered extensive R&D by MP and other companies on metallized materials, which found broad application as reflecting insulators and radiation barriers in space systems and in a broad range of commercial products. ▲

®Lightdriver is a registered trademark of Ultra Sales, Inc.

Wastewater Treatment: The Natural Way

A system employing aquatic plants as water purification agents highlights spinoffs in environmental control and resources management

In the spring of 1985, the town of Haughton, Louisiana, faced a problem: the state Department of Environmental Quality had notified Mayor Harold R. Lee that Haughton's wastewater treatment facility was in violation of environmental protection standards.

It looked at first as though Haughton would have to lay out $1.2 million for add-on modifications to its activated sludge facility—and also pay considerably more to operate the expanded facility. That would have been a heavy financial strain for the community of 2,000.

But Mayor Lee had an idea. He had read of the research of Dr. Billy C. Wolverton, head of the Environmental Research Laboratory at NASA's John C. Stennis Space Center (SSC) in Mississippi. Wolverton is widely acclaimed for his innovative work in natural water purification, which involves use of aquatic plants to remove pollutants from wastewater at relatively low cost. Wolverton and his SSC group had developed a new and advanced technique known as the artificial marsh filtering system, which seemed a possible answer to Haughton's dilemma. Haughton officials contracted Wolverton, visited an artificial marsh test site and learned details of the operation. When they looked into relative costs of the two options, "The choice was clear," said the mayor; the NASA technology would permit development of a wastewater treatment facility that would allow for growth to almost double the town's population at a cost less than one-third the estimate for improving the old system.

Not a floral display, but a practical wastewater treatment facility—a field of floating water hyacinths that absorb and digest pollutants in wastewater, a technology that stemmed from NASA studies of water reclamation systems for long-duration spacecraft.

The facility Haughton built is an 11-acre sewage lagoon with a 70 by 900 foot artificial marsh called a vascular aquatic plant/microbial filter cell. In the cell, microorganisms and rooted aquatic plants combine to absorb and digest wastewater pollutants, thereby converting sewage effluents to relatively clean water. Raw wastewater, after a period in the sewage lagoon, flows over a rock bed populated by microbes that digest nutrients and minerals from the sewage, thus partially cleaning it. Additional treatment is provided by the aquatic plants growing in the rock bed, which absorb more of the pollutants and help deodorize the sewage.

The Haughton facility went on line early in 1987. A year later, Haughton was able to reduce its sewer user fees by 25 percent. The facility was easily meeting the more stringent wastewater cleansing standards and there was a bonus: the system won an award in the *American City and County* magazine Awards of Merit.

At Haughton, Louisiana, town officials installed a second-generation version of NASA's natural wastewater treatment system. This one employs a combination of sewage-digesting microbes living in a gravel bed and pollutant-absorbing plants—bulrushes in foreground and canna lilies in background.

"To say that we are extremely pleased and proud of this facility would be an understatement," says Mayor Lee. "The artificial marsh rock-reed filter cost less to build, costs less to maintain and operate, and is much more efficient than any other system we could have built."

Haughton was among the first communities to employ the new artificial marsh technology but many other U.S. municipalities have benefited from SSC aquaculture techniques, which Wolverton and his group have been researching since 1974.

The program was initiated as a possible means of cleansing, detoxifying and reusing wastewater in space stations or long-duration spacecraft. Although a number of mechanical purification systems were—and are being—studied, SSC focused its effort on the ability of aquatic plants—notably the water hyacinth, which literally thrives on sewage—to absorb and metabolize astonishing amounts of nutrients and pollutants from wastewater. Use of water hyacinths offered potential bonus value because they could be harvested and used as fuel, fertilizer or as a protein/mineral additive to cattle feed.

After successful tests at SSC, the facility's neighboring community of Bay St. Louis, Mississippi, became—in 1975—the first municipality to employ aquaculture filtration. At the request of city officials, SSC fenced off part of the town's 40-acre wastewater lagoon and planted water hyacinths. The plants flourished on a feast of sewage and in short order the once noxious lagoon became a clean aquatic garden.

SSC continues to work toward the primary goal of natural purification for space applications, but it is also engaged in assisting communities interested in aquaculture as part of NASA's Technology Utilization Program, which seeks to expand spinoff applications of NASA-developed technology. After the Bay St. Louis demonstration, SSC published a report of its work that attracted broad attention and inspired other communities to investigate aquaculture. Today, a number of southern U.S. towns, with populations ranging from 2,000 to 15,000, employ aquaculture as their year-round primary method of treating wastewater. Other towns —and one major city, San Diego—use aquaculture as a supplementary process in sewage treatment applications.

Because municipalities all over the nation are of necessity tightening their budgets, interest in the potential cost reductions afforded by aquaculture wastewater treatment is growing. And SSC's new aquatic plant/microbial filter process will allow a broader range of communities to take advantage of the technology. In fact, that is one reason why it was developed.

(Continued)

In this windowless, highly insulated facility, Stennis Space Center (SSC) is investigating the potential of natural air/water purification systems—plants—for facilities with reduced ventilation, such as space stations and energy-efficient homes/offices.

Water hyacinths are almost the ideal natural wastewater purification system. This free-floating freshwater plant grows prolifically, digests enormous amounts of pollutants and, in Earth applications, offers cost-effective sewage treatment with potential byproduct bonuses.

But for water reclamation and recycling in future spacecraft or space stations, the hyacinth's utility is limited. In closed environment facilities such as manned spacecraft, there must be a better means of removing potentially toxic chemicals from reclaimed water. SSC's extensive research pointed to the plant/microbial filter as a more effective technique for in-space wastewater treatment, toxic chemical removal and water reuse.

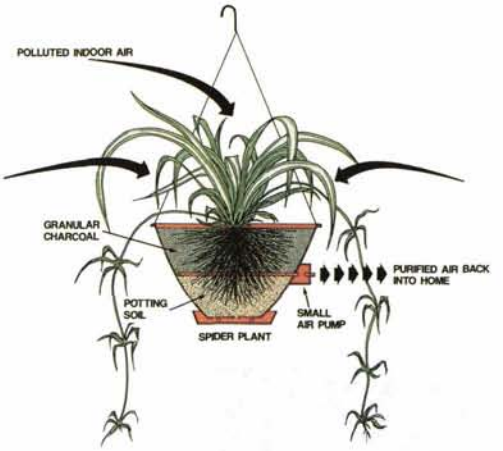
For Earth applications, the water hyacinth is similarly limited. It is a warm climate plant, not suitable for practical use in northern latitudes except with greenhouse protection, which reduces cost-effectiveness and is not always effective. All operating aquaculture systems are in the southern U.S.

However, the types of plants used in the artificial marsh system—bulrush, reed, soft rush, cattail, canna lilies and others—are cold and salt-tolerant, thus usable in wastewater systems in colder climates. The first community demonstration of that potential is underway in Monterey, Virginia.

Monterey, population 249, is technically a southern town but it is perched in a high valley of the Allegheny Mountains at 3,000 feet, thus has colder than average winter temperatures. Monterey creates no significant pollution, but like all U.S. municipalities was required by the federal Clean Air Act to provide secondary sewage treatment by July 1, 1988. The estimated cost for a conventional facility was $500,000, far beyond the means of the town's 149 sewer users.

Looking for an alternative, Monterey contacted SSC's Dr. Bill Wolverton and learned of aquaculture. Initially, it was thought that a water hyacinth lagoon, protected by a greenhouse cover, would serve Monterey's purposes. But after a summer's test of a hyacinth pond met with limited success, Wolverton recommended the still-new plant/microbial filter.

After much study and discussion with NASA participation, the Virginia Health Department and State Water Control Board approved experimental operation of the artificial marsh and Monterey won an extension of the deadline for compliance. Conversion of the hyacinth pond to a plant/microbial filter system got under way in 1988 and the town expects its system to be fully operational by 1993. Monterey Mayor George E. McWhorter Jr. thanked NASA for the work done by Wolverton and SSC, adding that



The spider plant is one of several decorative houseplants that show promise for absorbing gaseous pollutants to clean indoor air.

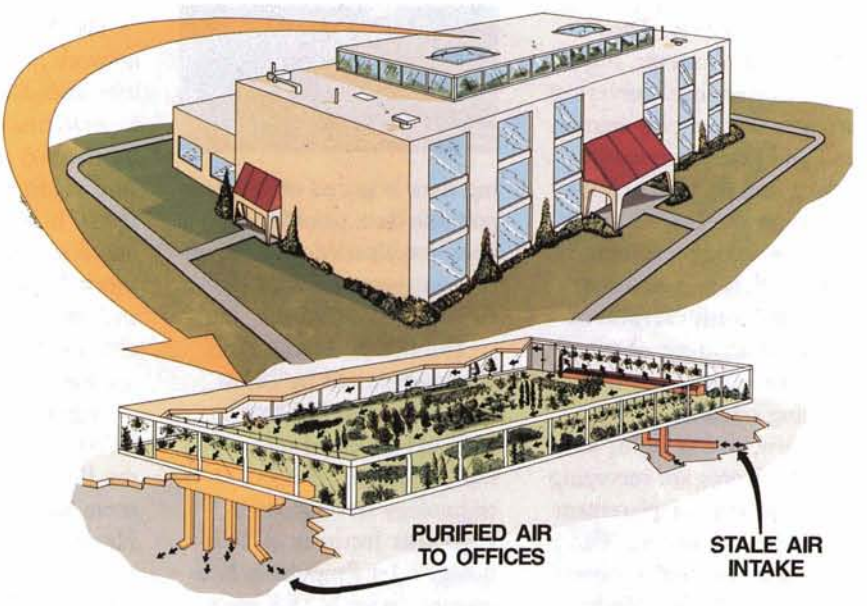
the technology "will enable the Town of Monterey and many other municipalities with the same problems to meet mandated standards at a cost far less than conventionally accepted methods."

Meanwhile, Wolverton's work has produced another spinoff technique, this one for purifying air as well as water in indoor environments. A substantial air pollution problem exists when ventilation is significantly reduced, as in pressurized long-duration spacecraft or highly insulated Earth buildings. In an effort to develop a practical means of preventing buildup of gaseous toxic substances in space stations or in airtight homes and office buildings, SSC is again evaluating the natural approach—in this case the use of common houseplants as air cleaners.

The potential health hazard in energy efficient homes stems from reduced ventilation and increasing use of resins and solvents in modern construction; they cause an increase in such indoor air pollutants as formaldehyde. Additionally, combustion of fossil fuels —as in cooking—and tobacco elevates home and office levels of carbon monoxide and nitrogen dioxide.

Branching off from its research on aquatic plants for wastewater treatment, SSC studied the use of foliage plants for air filtration and purification. The common spider plant was found to be particularly efficient in absorbing formaldehyde, nitrogen dioxide and carbon monoxide; other plants showed potential.

At a special facility at SSC, Wolverton's environmental research group is testing a number of plant types and developing concepts for Earth-use natural air purification systems. Commercial businesses are watching the effort and independently looking into ways of combining natural and mechanical filter systems to remove both particulate and gaseous indoor pollutants; two companies are now selling filter systems. ▲



A penthouse green garden serves as a natural purification system for "atmospheric revitalization" of an office building in this SSC concept. Efficient insulation designed to save energy may cause a health hazard in buildup of potentially toxic gases; a recycling system channels all indoor air through the garden, which absorbs the gaseous pollutants and returns clean air to the offices.

Surveying System

At right, Chuck Muncy and Werner Brutsch of Sunrise Geodetic Surveys, Mesa, Arizona, are setting up their equipment for a town survey. Their equipment, however, differs from conventional surveying systems that employ transit, rod and chain to measure angles and distances. They are using the ISTAC Model 2002 positioning system, which offers fast, accurate surveying with exceptional orders of accuracy, obtained by processing signals from orbiting satellites.

Below, and at right, Sunrise employees are surveying a remote area for placement of microwave towers. This illustrates a particular advantage of the ISTAC Model 2002. In mountainous terrain or in areas of dense vegetation, the surveying team would normally have a long and difficult job clearing the line of sight pathways between two siting points that are essential for operating conventional systems. The 70-pound ISTAC system can easily be backpacked or helicopter-transported into remote locations and its only requirement is a line of sight to the sky. Satellite-referenced position-

ing data is stored on site in a portable data recorder and later downloaded into the office computer for analysis (far right).

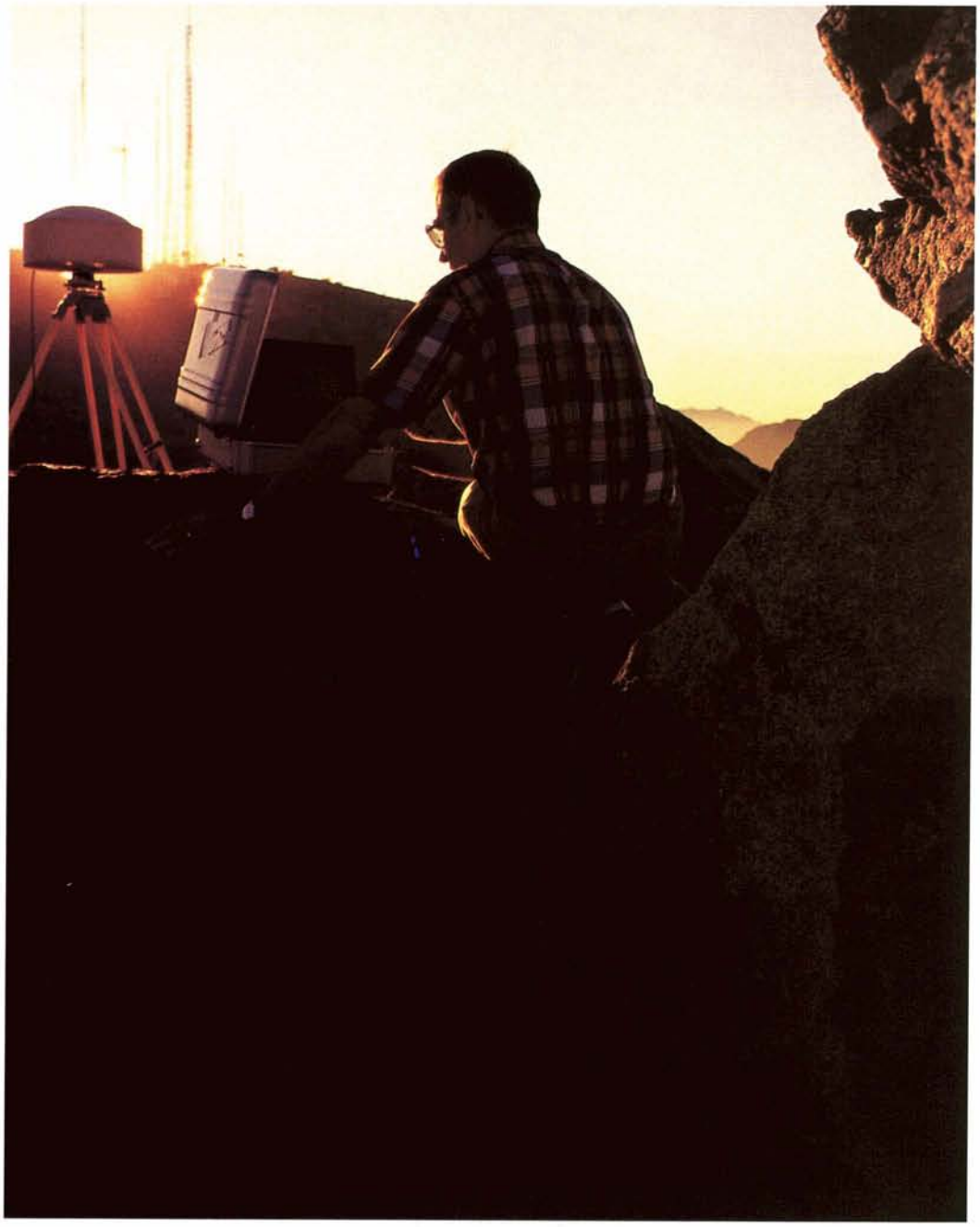
The ISTAC Model 2002 is manufactured by ISTAC, Inc., Pasadena, California, and sold or leased to surveying companies. It is based on technology developed by California Institute of Technology's Jet Propulsion Laboratory under NASA sponsorship. Inventor of the technology was Peter MacDoran, now president of ISTAC.

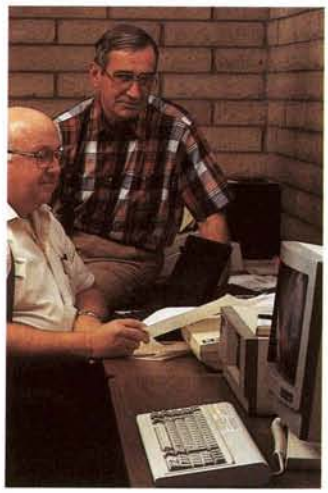
Working on a way to provide highly precise measurements of Earth's crust for tectonic studies and earthquake prediction, MacDoran conceived SERIES, a package consisting of satellite receiving hardware and signal processing software that produces positioning data with accuracies as fine as five centimeters (two inches). MacDoran was subsequently granted a NASA waiver assigning him commercial rights to the technology. He formed ISTAC to develop the technology further and adapt it as a surveying tool using reference signals from the U.S. Air Force Navstar Global Positioning System (GPS).

The Navstar GPS is a network of navigation satellites intended to provide superaccurate position fixes for military aircraft, ships or land vehicles anywhere on Earth. It is currently operating as an interim, part-time Block I system for testing and user familiarization; civilians are authorized to use the Block I system.

Beginning next year, the USAF will begin to replace the Block I satellites with more advanced Block II Navstars in what will ultimately be an 21-satellite constellation. However, the advent of Block II will pose a problem for civilian users. The Block II Navstars will send signals on two channels, the superaccurate Precise Positioning Service (PPS) and a less accurate Standard Positioning Service (SPS). For reasons of military security, PPS signals will be encrypted and the code will not be available to civilian users except by special approval of the Department of Defense. The SPS channel will be available to civil users, but its accuracy will be intentionally degraded.

The special utility of the ISTAC Model 2002 is that it can provide positioning of the highest accuracy from Navstar PPS signals because it requires no knowledge of the secret codes. It operates by comparing the frequency and time phase of a Navstar signal arriving at one ISTAC receiver with the reception of the same set of signals by another receiver. The data is computer processed and translated into three dimensional position data—latitude, longitude and elevation. This technique does not





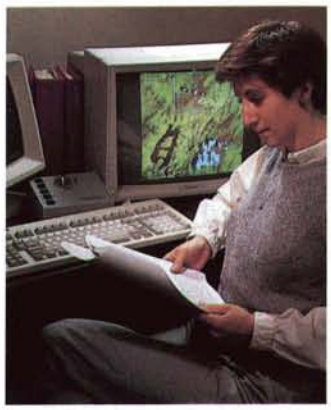
compromise military security and is, in fact, welcomed as a viable means of civil use of the GPS.

The ability of ISTAC Model 2002 and other codeless receivers to use the military network opens up a broad range of civil applications. ISTAC Model 2002 is used by a number of surveying firms in the U.S. and the United Kingdom for city surveys, construction surveys, and geodetic surveying.

A future application (when 24-hour global satellite coverage is available), is seismic surveying for exploration of hydrocarbon resources. ISTAC receivers—one on the seismic ship, one on a trailing buoy and one on land—can acquire position data from four different Navstar satellites; positioning computations are handled by a computer aboard the seismic vessel. ▲

Forest Damage Assessment

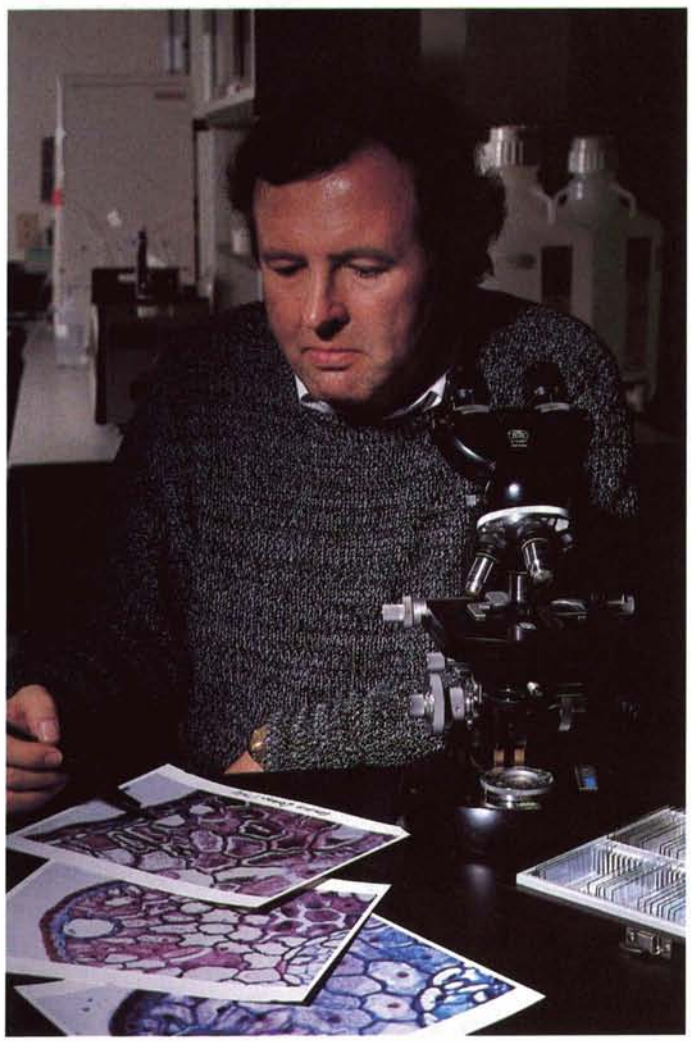
At right, scientist Nancy Defeo of the University of New Hampshire's Institute for the Study of Earth, Oceans and Space (EOS) is processing Landsat Thematic Mapper data as part of an investigation to determine the efficacy of satellite information in detecting forest decline damage which may be due to acid rain or other atmospheric pollutants.



Defeo is part of a vegetation remote sensing group that has been investigating the matter for several years under the sponsorship of NASA's Jet Propulsion Laboratory (JPL). The research is headed by Dr. Barrett Rock (center), former leader of JPL's Geobotanical Remote Sensing Group, now with EOS.

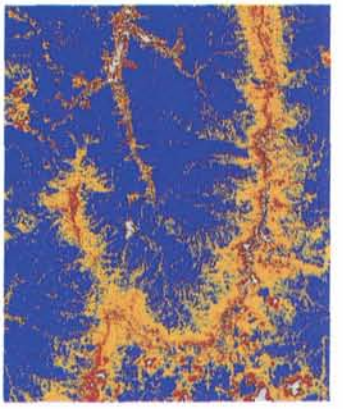
The Thematic Mapper (TM), developed by Hughes Aircraft under NASA contract, is an advanced scanning instrument aboard Landsats 4 and 5, which were initially developed by NASA and are now operated as a commercial remote sensing system. The TM detects radiations reflected and emitted from Earth objects—such as trees—in seven bands of the spectrum. Since each object has its own unique spectral "signature," the TM can distinguish among surface features and generate computer-processed imagery identifying specific features of importance to resources managers.

Since the early 1960s, the high-elevation spruce/fir forests of the northeastern United States have undergone a marked decline in growth rate and state of health. During the same period, there has been similar decline in central European forests of spruce, fir and beech. Remote sensing satellites are capable of detecting, identifying and quantifying forest decline to make possible forest monitoring and assessment on a global scale. Advanced satellite instrumentation planned for the 1990s may even be able to identify spectral "fingerprints" that would enable investigators to identify specific causes of forest damage and decline. Scientists at EOS are trying to demonstrate how accurate satellite observations may be in detecting specific levels of forest damage.



Toward this goal, Dr. Rock's NASA group has conducted multiyear forest decline investigations using satellite and aircraft-acquired imagery. This work was coordinated with "ground truth" field investigations to check the accuracy of scanner data.

The NASA group, which included Dr. James E. Vogelmann (EOS), Dr. Ann F. Vogelmann (EOS), Takashi Hoshizaki (JPL), and Darrell L. Williams of Goddard Space Flight Center, has conducted research on New York's Adirondack Mountains, the Green Mountains of Vermont and the White Mountains of New Hampshire. In addition, Dr. Rock's group and scientists from North Caro-



lina State University have conducted a joint study, sponsored by the U.S. Forest Service, to assess forest decline damage on Mt. Mitchell in North Carolina.

Shown above is a TM damage assessment image of Mt. Mitchell; the green areas are healthy conifer (evergreen) and hardwood (broadleaf) trees, yellow shows moderate damage, orange severe damage. At upper right, the same image has been computer manipulated to help identify specific problems; here blue represents healthy trees and the other colors show increasing levels of damage in yellow, orange and white. At right, a group is conducting a ground truth check of a white-colored (highly damaged) area identified in the image. At far right, some of the researchers compare notes, left to right, Nancy Defeo, Barrett Rock and James Vogelmann.

The group's research has been "very encouraging." The levels and distribution of forest damage detected using satellite and aircraft imagery corresponded very well with conventional ground-based measurements of forest health. "We are now confident," said Dr. Rock, "that satellite imagery can be used accurately and efficiently to detect, quantify, map and monitor areas of forest damage on a regional scale."

Satellite imagery has been incorporated into the U.S. Forest Service's routine damage assessment fieldwork in the southeastern United States to further check the accuracy of satellite damage assessment imagery and to acquaint foresters with the use and potential of such imagery. ▲

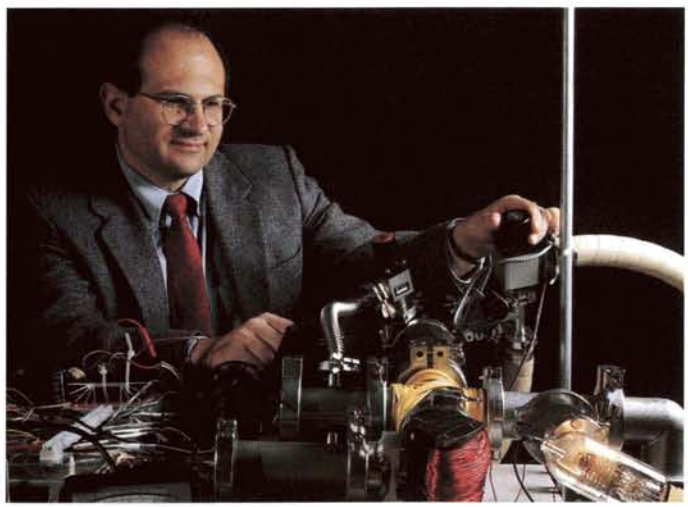
Environment Monitor

In 1976, two NASA Viking Landers touched down on the surface of Mars, equipped with a variety of systems to conduct automated research. Among this equipment, each Lander carried a compact but highly sophisticated instrument for analyzing the Martian soil and atmosphere.

NASA requirements dictated that the instrument—called a Gas Chromatograph/Mass Spectrometer (GC/MS) and developed by Jet Propulsion Laboratory—be small, lightweight, shock resistant, highly automated and extremely sensitive, yet require minimal electrical power. These same characteristics offer wide utility in Earth applications.

In 1983, Dr. Thomas J. Kuehn and Dr. Russell C. Drew, both of whom have extensive experience in R&D management, founded Viking Instruments Corporation, Sterling, Virginia to commercialize the GC/MS technology under an exclusive license from NASA. They targeted as their primary market environmental monitoring, especially toxic and hazardous waste site monitoring. Waste sites often contain chemicals in complex mixtures and the conventional method of site characterization—taking samples on-site and sending them to a laboratory for analysis—is time-consuming and expensive. Viking Instruments sees wide acceptance of its Micro GC/MS products (left below) because they combine the power and sensitivity of a laboratory GCMS in a portable, valise-sized package. The first prototype instruments were completed in 1987 and Viking expects to have commercial production prototypes in 1988.

Among other terrestrial applications are explosives detection at airports, drug detection, industrial air monitoring, medical metabolic monitoring and, for the military services, detection of chemical warfare agents. Viking is also planning to develop the technology further for new space applications aboard the Space Station, for example, chemical analysis of experiments or monitoring crew compartment atmospheres for contaminants.

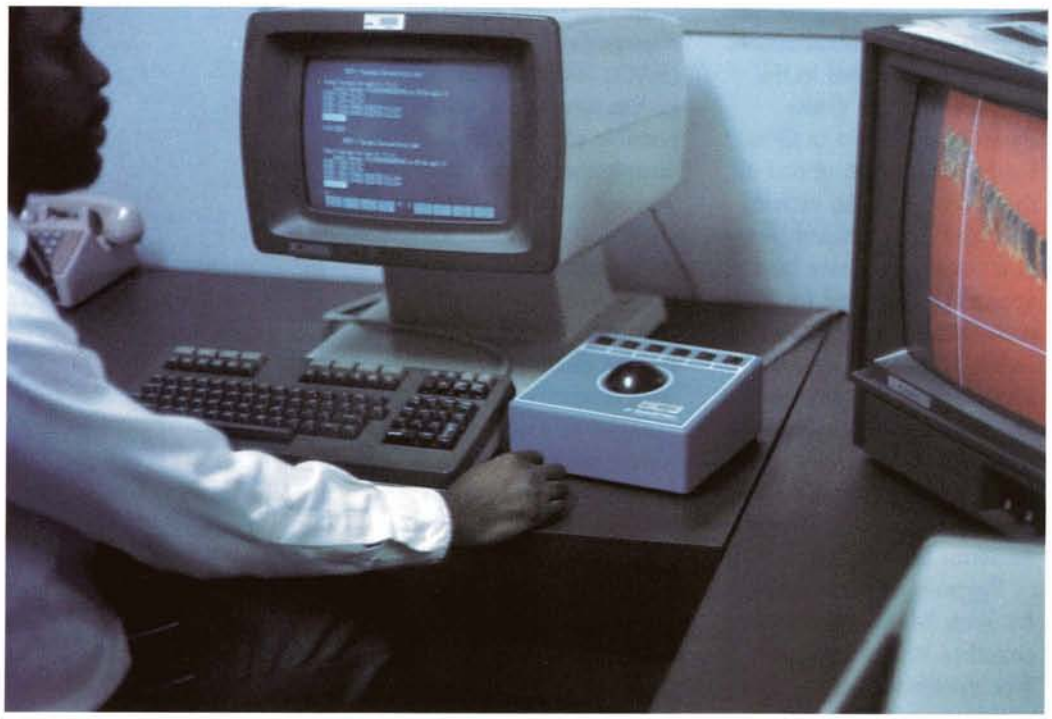


In the top photo, Dr. Kuehn, Viking executive vice president, is using a laboratory high vacuum system to check out the ion source, a key component of the GCMS. In the lower photo, Dr. Drew, president, stands beside a larger Viking industrial plant monitoring system that would continuously sample air at multiple points, analyze it and warn of contaminants. ▲

Marine Life Study

As a result of widespread ocean dumping and other pollution problems, marine scientists are studying the populations of various marine organisms in an attempt to determine the effects of pollution. Marine biologists, ecologists and fishing industry investigators are compiling data on aging of marine organisms, including such factors as the relationship between the size and age of the organism, its longevity, its rate of growth and growth differences among species. These factors hold clues to many questions of importance.

Of particular interest because of its great economic value is the surf clam that inhabits the U.S. Atlantic Coast. There exists a method of determining the age of the surf clam: examining photographic blowups of a section of the clam that contains annual rings or growth bands, like a tree. Though useful, this technique has shortcomings, among them difficulty in finding the often faint initial ring and difficulty in getting an accurate count in older clams, whose rings become crowded and run together.



Professor Ernest G. Hammond and a group of students at Morgan State University, Baltimore, Maryland, in cooperation with Goddard Space Flight Center, have been conducting research for several years on a way to apply space developed digital image processing techniques to age determination in clams.

Digital image processing is the use of computers to convert sensor data into informative images. The idea of applying it to clam-aging investigations came from Kevin Peters, a Morgan State graduate student who is shown in the accompanying photograph viewing a high resolution clam image on a monitor. The Morgan State/Goddard technique involved development of a computer program to create digitized images of clam sections with annual rings. The computerized image can then be enhanced—manipulated to emphasize certain features—in order to improve and amplify the information that can be extracted from the image.

A lengthy series of tests established that the technique offers a number of advantages in aging studies not only of clams but of other shellfish and marine organisms that have growth bands. Among these advantages, with respect to clam studies, are greater contrast between each annual ring, making it easier to get an accurate count, clearer delineation of the initial ring and the ability to create adequate separation of the crowded ring areas of older clams by enhancing and enlarging the image. The technique also showed promise for being able to reveal information regarding the rate of the organism's growth during seasonal and environmental changes that the organism undergoes. ▲

Space Age Archeology

In 1954, archeologists discovered two subterranean chambers carved in the bedrock near the Great Pyramid of Khufu in Giza, Egypt. Excavation of one of them uncovered an exciting find: the disassembled pieces of a wooden funerary boat apparently intended for Pharaoh Khufu's use in the afterlife. Incredibly, the boat's timbers were in a near-perfect state of preservation after 4,600 years. The boat was painstakingly assembled and put on display (right) in a museum built on the site.

Egyptologists wondered for years whether the second chamber, roofed by a five-foot thickness of limestone, contained another royal boat—and whether the air sealed in the chamber for 46 centuries had some property that helped preserve the wood of the boat, because the original boat was showing signs of deterioration and information on the chamber's environment might lead to a way of preserving it longer.

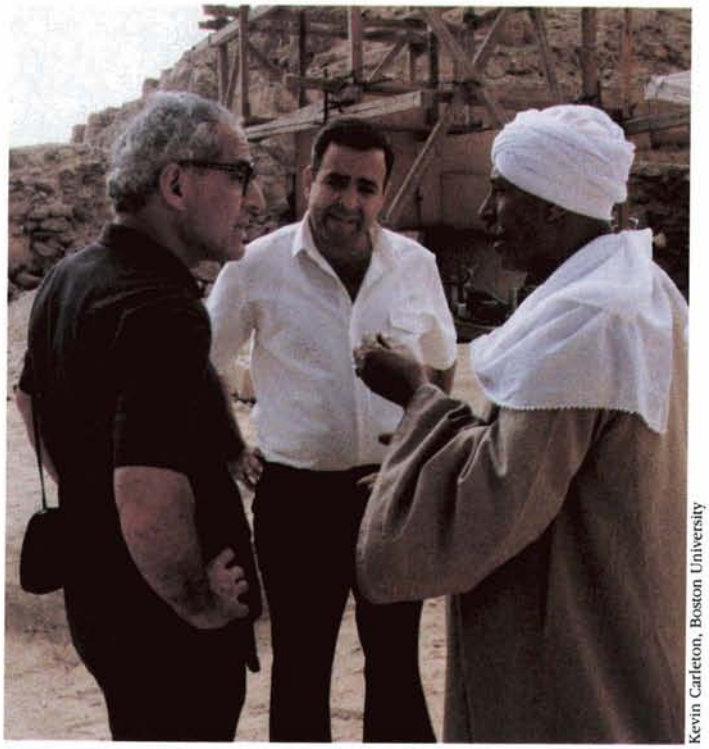
In 1985, the Egyptian Antiquities Organization (EAO) asked Dr. Farouk El-Baz whether it would be possible to examine and sample the second chamber without admitting people, air or contaminants. El-Baz, an Egyptian-born geologist, felt it could by applying space technology to the task; he was thoroughly familiar with a number of space technologies as a one-time lunar science planner on the Apollo program and, more recently, as director of the Boston University Center for Remote Sensing, Boston, Massachusetts.

The initial contact led to a two-year project in which El-Baz organized and headed a team, co-sponsored by EAO and the National Geographic Society, to apply space technology in an effort to examine and photograph the Giza chamber. National Geographic had for a number of years been investigating means of photographing unopened tombs without entering or contaminating them. In Washington, D.C., the Geographic's photographic division modified and tested a remotely controlled video system and a 35-millimeter camera, and developed a lighting system that would not elevate the chamber temperature; the team established that all this equipment would work if it could successfully be inserted into the chamber.

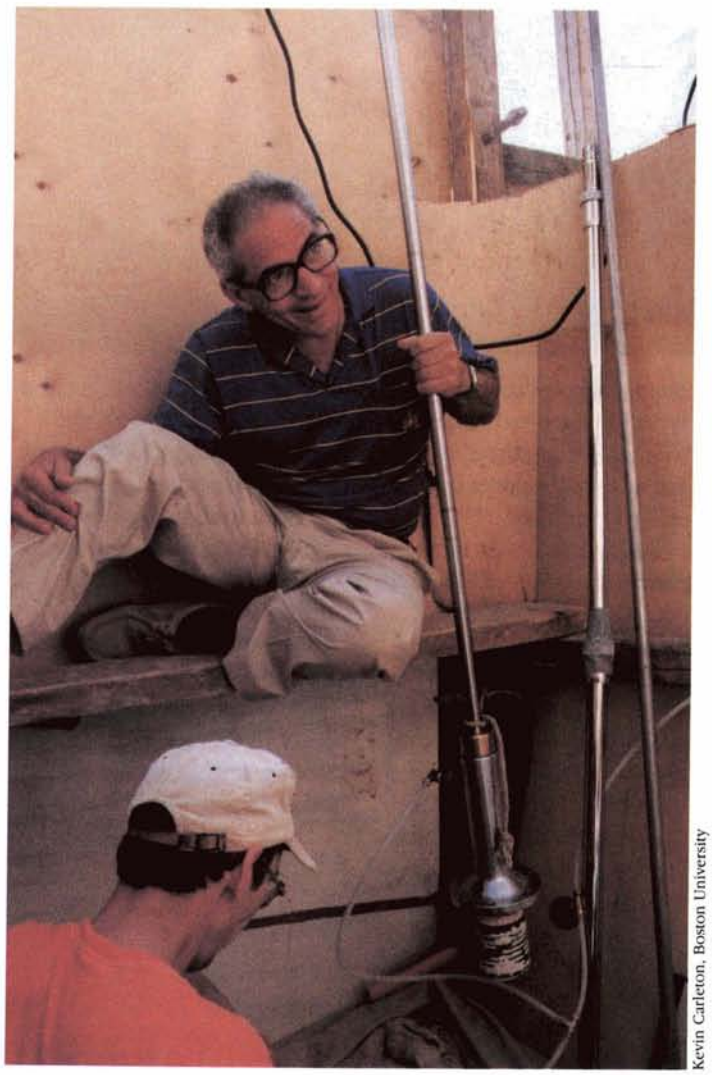
Kevin Carleton, Boston University

That left two big requirements: a drill to cut through the limestone cap without using lubricants or cooling fluids that might contaminate the chamber, and an airlock that would admit the drill shaft and photo equipment but not air. For this job, El-Baz brought to the team Bob Moores, a drilling technology engineer with Black & Decker Corporation, Towson, Maryland, which had developed for NASA in the 1960s a drill capable of boring 10 feet into the moon's surface and extracting soil samples without contamination. Moores used much of this knowledge to select a new drill tailored to the Giza exploration.

In October 1987, work began at the site, shown at upper right. In the foreground, from left are Farouk El-Baz, EAO's Dr. Kamal Barakat, and work crew foreman Touhamy Mahmoud Ali. The drill pit, evidenced by the scaffolding, is in center background; the tent at right housed the electronic equipment for operating the cameras and viewing their findings.



Kevin Carleton, Boston University



Kevin Carleton, Boston University

For 48 hours off and on, Moores drilled through the limestone until, at a depth of 63 inches, the drill bit broke through into the chamber. At lower left, El-Baz, holding the drill shaft, grins triumphantly after the breakthrough; in red is engineer Bob Moores. At right, the science and support teams assemble in the drill pit for a victory photo.

A stainless steel tube was lowered through the airlock to take samples of the chamber air at several levels. But there was disappointment—even before the samples were scientifically analyzed at laboratories, there were indications that the chamber was no longer airtight if ever it had been.

But on the morning of October 20 there came a compensating discovery when the video camera started sending images from the chamber: there was indeed a second royal boat, disassembled like the first in stacks of wooden panels, planks and oars.

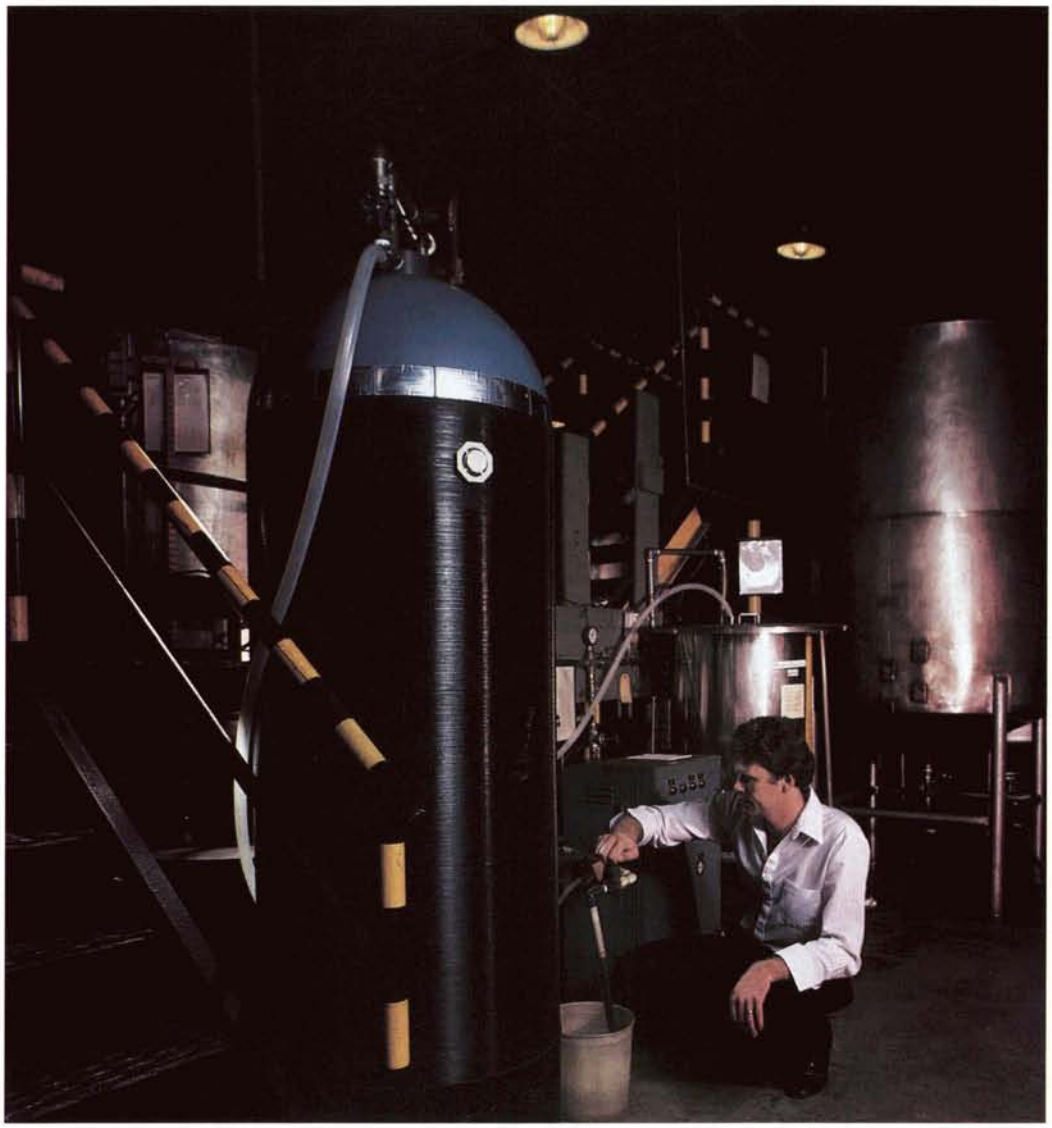
The watching team members were the first to view the boat since the 26th century B.C. And the last, for a while. It had been decided to leave the chamber intact. So, after six days of recording the chamber's contents on film and tape, the team removed the airlock and replaced it with a seal fitted with sensors that would periodically monitor chamber temperature and humidity indefinitely.

The space technology that made possible unviolated inspection of the Giza chamber has wide applicability in other archeological investigations and Dr. Farouk El-Baz is looking into additional space technologies that might be used in archeological applications.

"In the past," he says, "some archeological work was blind. Where to dig and how to approach a site was pretty much left to chance. From now on, any archeological excavation can be based on a tremendous amount of information by using our technology and methodology." ▲

Kevin Carleton, Boston University

Water Filters

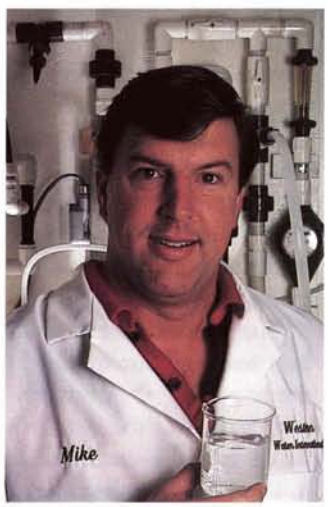


The black cylinder at right is an Aquaspace® industrial filter used by a pharmaceutical company to ensure the purity of the water it uses. It is one of a line of filtration products manufactured by Western Water International (WWI), Forestville, Maryland. Below, company founder and president Paul M. "Mike" Pedersen is shown in WWI's laboratory sampling water filtered by a WWI system.

Aquaspace filters combine company technology with NASA technology developed to sterilize the drinking water of the Apollo spacecraft. The filters provide clear, good tasting water by removing toxic contaminants, organic chemical compounds, chlorine and other water processing agents, unpleasant taste, color and odor.

The key is Aquaspace Compound, a proprietary WWI formula that scientifically blends various types of glandular activated charcoal with other active and inert ingredients. The filtration material is shown at top center around the base of a typical filter system.

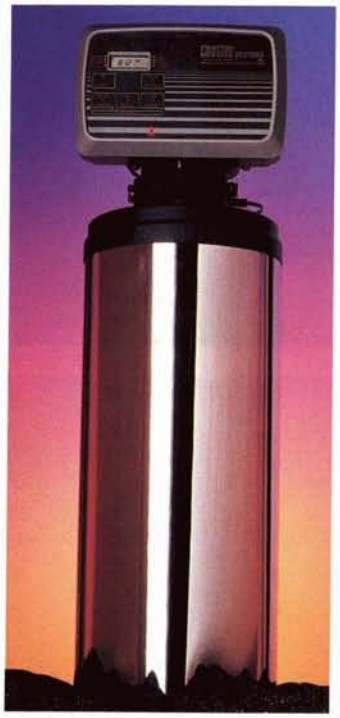
Aquaspace systems remove some substances—chlorine, for example—by



atomic adsorption, other types of organic chemicals by mechanical filtration, and still other substances by catalytic reaction.

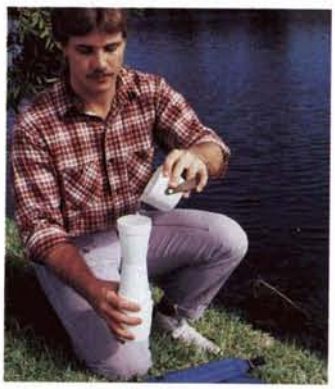
Seeking to find a more effective method of filtering potable water that was highly contaminated, Pedersen learned that NASA had conducted extensive research in methods of purifying water on board manned spacecraft. He obtained a number of NASA technical reports concerning that research. NASA information that contributed importantly to the development of Aquaspace Compound, Pedersen states, included technology related to the use of ions as filtering agents and methods dealing with the absorption and adsorption of organic compounds.

Aquaspace filters are finding wide acceptance in industrial, commercial, residential and recreational applications in the U.S. and abroad. WWI produces a wide range of systems to meet these various needs, from a simple Apollo Pocket Filter that works like a



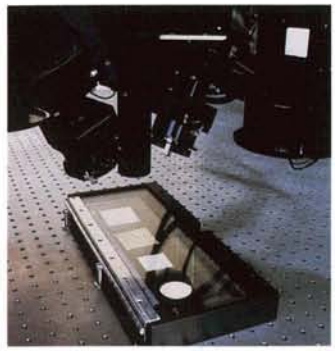
drinking straw to high capacity units for communities in developing nations where the water is highly contaminated.

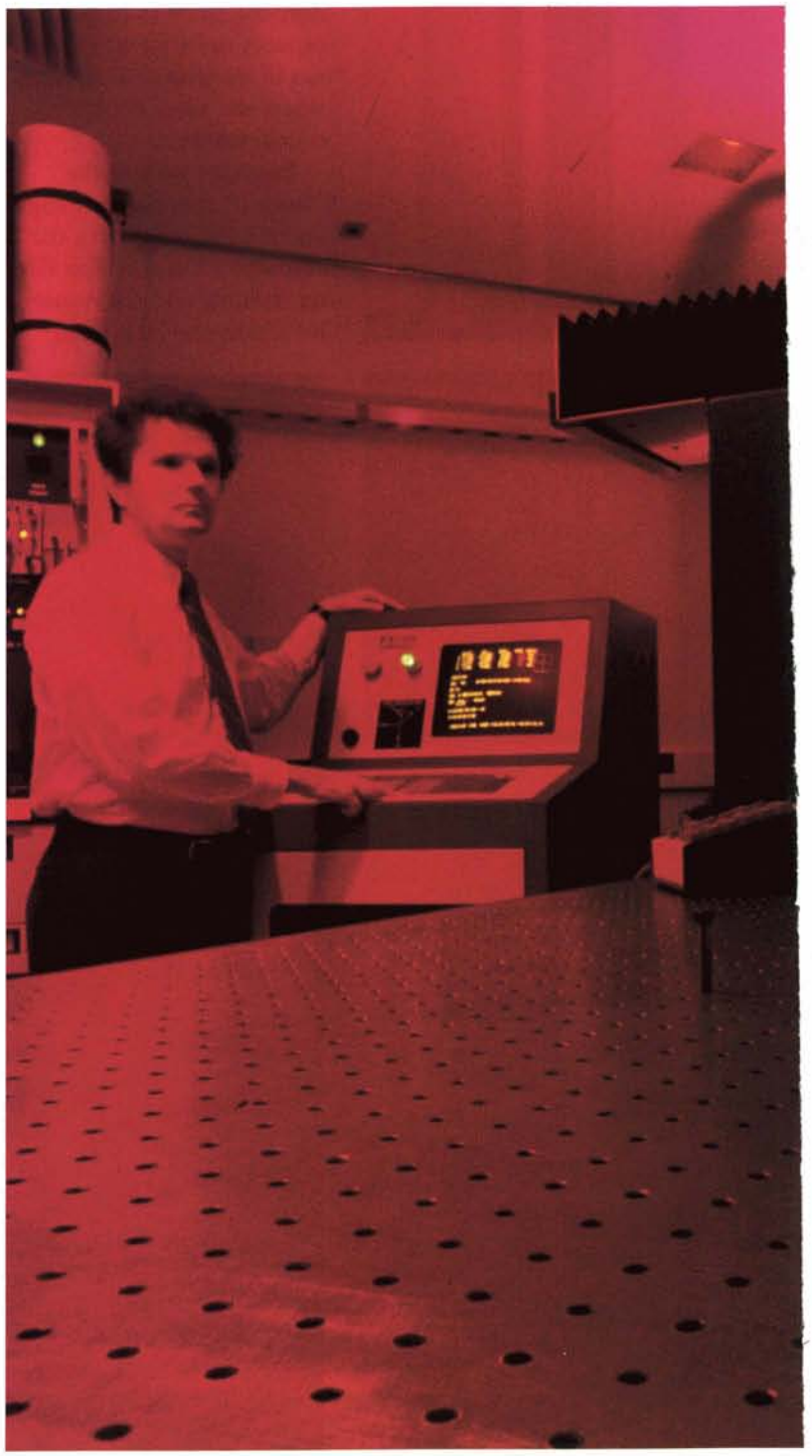
Examples include the Voyager® filter for camping and traveling use (left); the Aquaspace Counter Top Filter (below); and the Aquarius Under-the-Sink Filter (right). At right below is a whole-house unit installed in a laundry room. A special advantage of whole-house filtration in contaminated water areas is protection from diseases that occur through topical absorption of contaminants through the skin and through inhalation. ▲



®Aquaspace and Voyager are registered trademarks of Western Water International Inc.

Document Monitor





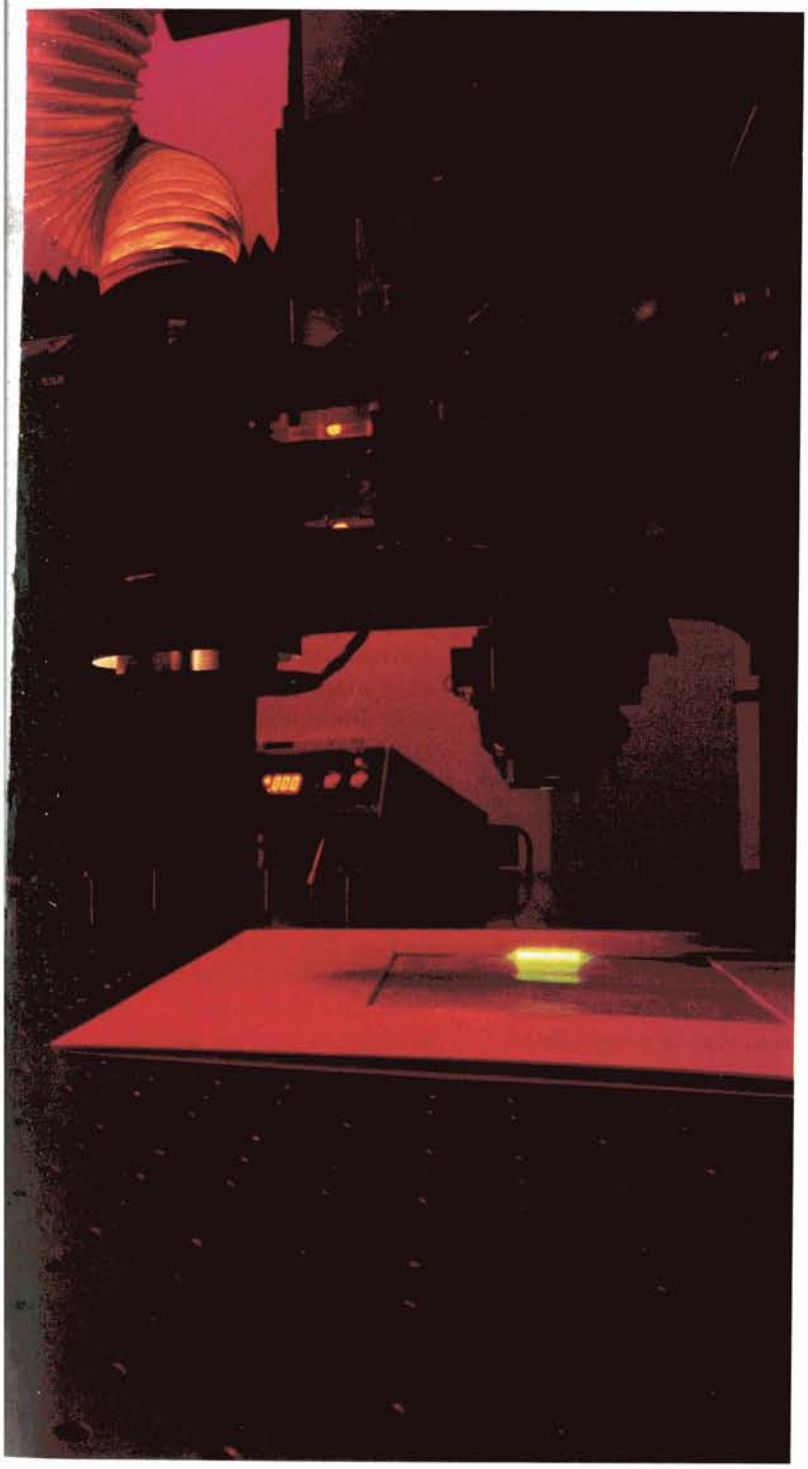
Originally developed to create pictures of solar system planets and moons, NASA imaging technology has found employment in such diverse areas as medical diagnosis and monitoring, Earth resources survey by remote sensing and quality control in industrial operations. Its further utility is being investigated in a variety of other applications and image processing technology shows promise of becoming one of the most prolific sources of spinoff.

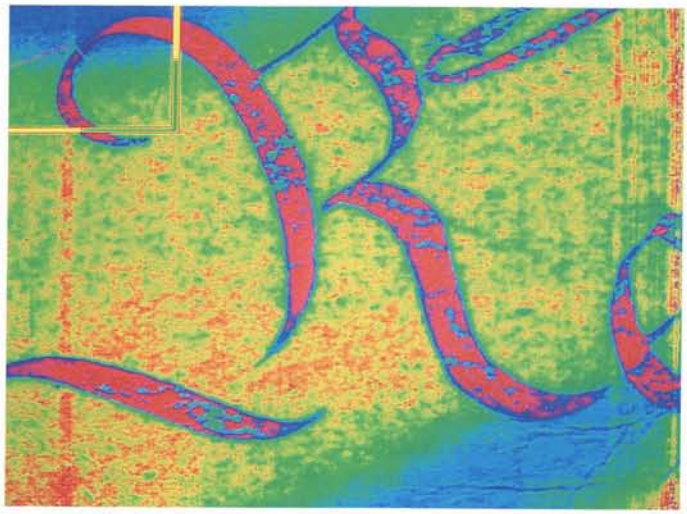
A unique application is a combined hardware/software system called the Charters of Freedom Monitoring System, which will periodically assess the physical condition of the U.S. Constitution, the Declaration of Independence and the Bill of Rights. Although protected in helium-filled glass casings, the documents are subject to damage from light, vibration and humidity, their parchment pages may stretch or split, and ink may fade, flake or wear off.

The job of the monitoring system is to image the documents precisely at selected times, then compare each new image to detect as early as possible any change in the characteristics of the ink or parchment. That will allow National Archives conservators to plan action to halt the deterioration.

The project began in 1982 when the National Archives retained NASA's Jet Propulsion Laboratory (JPL) to develop a systematic method of determining the condition of national archives. JPL conducted studies of concepts based on space imaging technology, in particular a charge-coupled device (CCD) that had been employed in a number of imaging spacecraft, including the new Galileo Jupiter explorer and the Hubble Space Telescope. JPL asked The Perkin-Elmer Corporation, Norwalk, Connecticut, optical systems prime contractor for the Hubble Space Telescope, to apply its optical expertise to development of a precise photometer and to integrate it into a complete document monitoring system. Perkin-Elmer began work in 1984 and delivered the system to the National Archives in 1987.

The photometer is a CCD detector used as the electronic "film" for the system's scanning camera, which mechanically scans the document line by line and acquires a series of images, each representing a one square inch portion of the document. The photometer





is capable of detecting changes in contrast, shape or other indicators of degradation with five to 10 times the sensitivity of the human eye. A Vicom image processing computer receives the data from the photometer, stores and manipulates it, allowing comparison of electronic images over time to detect changes.

The complete monitoring system is shown at upper left. Next to it is a closeup of the camera and a radiometeric reflectance target, used to calibrate the photometer's illumination, a green light that provides the essential contrast and does not damage the parchment. The exact intensity of the light is carefully established so that it can be precisely duplicated in every future scanning.

In the center is the system in operation in a darkroom environment. Above is a false color image, a segment of the Constitution that shows (in the red areas) signs of ink flaking that possibly occurred before the document was encased in its protective shield. Below are two supporting units: the taller one is the electronics rack that converts analog data to digital and controls the light sources, shutter and CCD; the other is an Anorad Automatic III system for positioning the photometer over the document.

The latter, along with the Vicom computer, is among several commercially available components integrated into the system to minimize cost and maintainability.

Perkin-Elmer also developed user friendly software in accordance with JPL's requirement that people without image processing training be able to operate the system. The Charters of Freedom Monitoring System was designed to be maintainable for at least 50 years. Precise control of illumination, positioning, vibration and temperature ensure the repeatability of each image, so that conservators can assume with confidence that changes detected are actually changes in the document and not in the system. ▲

Farmland Survey

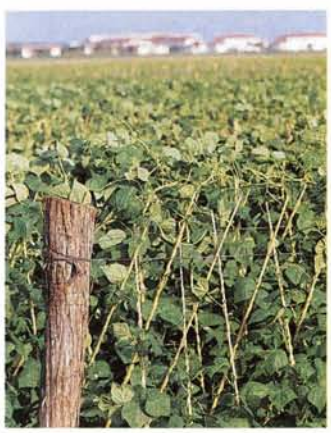
Below is a Florida scene representative of a national situation: visible in the background is a fair-sized community on what was recently highly productive farmland. A 1981 U.S. Department of Agriculture (USDA) study estimated that the nation is converting farmland to non-agricultural uses at the rate of 3 million acres a year.

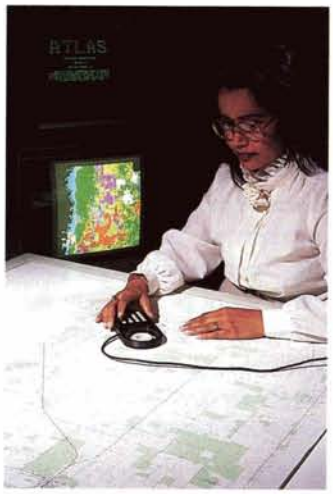
Seeking reliable information on farmland loss in Florida, the state legislature—in 1984—directed establishment of a program for development of accurate data to enable intelligent legislation of state growth management. Thus was born Florida's massive Mapping and Monitoring of Agricultural Lands Project (MMALP), which was to employ data from the NASA-developed Landsat Earth resources survey satellite system as a quicker, less expensive alternative to ground surveying.

The three year project involved inventory of Florida's 36 million acres and county-by-county tabulation of the acreage in each land cover classification, such as cropland, pastureland, citrus, woodland, wetland, water and populated areas. Direction of the project was assigned to the Florida Department of Community Affairs (DCA), with assistance from the Department of Transportation (DOT), which had expertise in satellite remote sensing operations. As MMALP project director, DCA assigned Robert Groce, a resource conservationist on loan from the USDA Soil Conservation Service. At right above, Groce (standing) is comparing notes with Florida DOT remote sensing specialist Jesse Day.

The utility of the Landsat system for land cover survey stems from the fact that each type of land cover emits or reflects a unique type of radiation that can be detected and differentiated by Landsat's sensors. Computer processing of Landsat data at ground facilities enables creation of electronic imagery or tapes from which informative resource maps can be prepared. An example of an MMALP image is shown below; here pastureland is highlighted in red and the other colors represent cropland, woodland and developed areas. At right center, DOT remote sensing specialist Khaleda Hatim is using such Landsat imagery to prepare a land cover classification map of a segment of Florida. Maps like these, covering all of the state's 67 counties, were prepared with 1984 data, and those maps were compared with another set of maps for the same areas developed with 1973 Landsat data, thus providing a graphic comparison of the land cover changes that had occurred over the 11-year span.

Early in the project, Groce decided that combining soil data with the Landsat land cover data would make available to land use planners





a more comprehensive view of a county's land potential. He obtained the cooperation of the USDA Soil Conservation Service, which agreed to digitize—and pay for—soil surveys for two counties, with data for the other counties to come later. At upper right, MMALP soil scientist Susan Ploetz is preparing an overlay that incorporates USDA soil data. Addition of data on soil types and characteristics allows farmers and state officials to determine whether a particular block of land has prime agricultural soil and what types of crops might be grown there; it also gives developers an overview of areas with land characteristics best suited to the needs of a planned development.

To verify the data going into the land cover maps, both USDA soil data and Landsat sensor data, the MMALP group made frequent "ground truth" tests (below). This involved taking actual soil samples at a particular site or visually checking the vegetation to make sure the computer processed information was accurate. The information proved accurate.

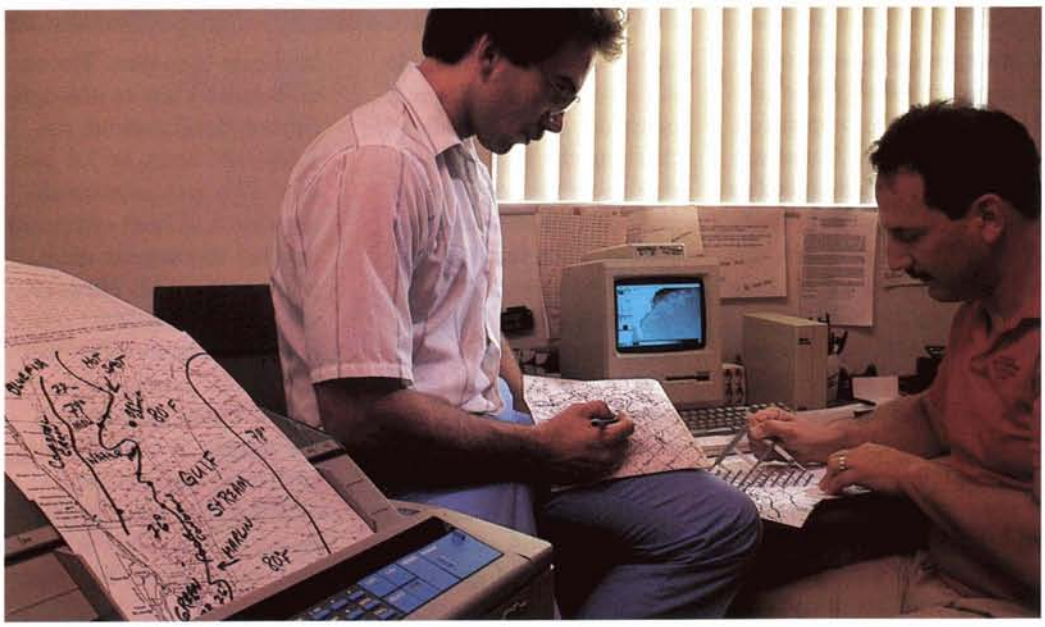
In July 1987, Florida's DCA completed the MMALP project and later in the year submitted a report to the state legislature. It showed the agricultural land acreage for each county as of 1973 and 1984 and the percentage of loss of agricultural land over that span. The total farmland lost to non-agricultural developments was 1,683,986 acres, or 5.6 percent. This was substantially less than had been estimated in other assessments made prior to MMALP. However, some counties showed significant losses and they will have to be monitored.

The report also detailed the acreage in each of 21 land cover classifications as of 1984. The agricultural land and total cover information, eventually to be supplemented by all-state soil data, built a comprehensive computerized data base that provides Florida officials an important planning tool. This was the first effort to use Landsat data for mapping an entire state and, says project director Robert Groce, "Everyone seems to be satisfied with the process and with the results."▲

Fishing Forecasts

At right, Captain Jerry Coleman of the Florida Keys based charter fishing boat *Paradise* is looking over a ROFFS chart that offers advice as to steering clients to where the fish are—and hopefuly sooner than the competition.

ROFFS stands for Roffer's Ocean Fishing Forecasting Service, Inc., Miami, Florida. It is operated by oceanographer Dr. Mitchell Roffer, who describes it as a high technology small business providing fish-location assistance to commercial, recreational and professional tournament fishermen. Roffer combines satellite and computer technology with oceanographic information from several sources to produce frequently updated charts—sometimes as often as 30 times a day—showing clues to the location of marlin, sailfish, tuna, swordfish and a variety of other types. He also provides customized ROFFS forecasts for racing boats and the shipping industry, along with seasonal forecasts that allow the marine industry to formulate fishing strategies based on foreknowledge of the arrival and departure times of different migratory fish.



Fish are somewhat predictable, says Roffer. From research conducted over his 10 years with the University of Miami's Rosenstiel School for Marine and Atmospheric Science, he concluded that specific ocean conditions—such as temperature gradients, the color and biological quality of the water, or movements of ocean currents—influence the whereabouts of fish concentrations. But as ocean conditions change, the fishes' "preferred habitats" change, thus the need for frequently updated forecasts.

ROFFS provides what are essentially customized fisheries oceanographic maps overlaid on nautical charts. The service, says Roffer, offers marine operators greater productivity, decreased operating expenses and larger profits. A lot of people seem to agree; ROFFS customers, serviced by facsimile systems, telephone coded messages, computer-based electronic mail or marine radio, stretch from Canada to the Gulf Coast, from the Caribbean down to South America.

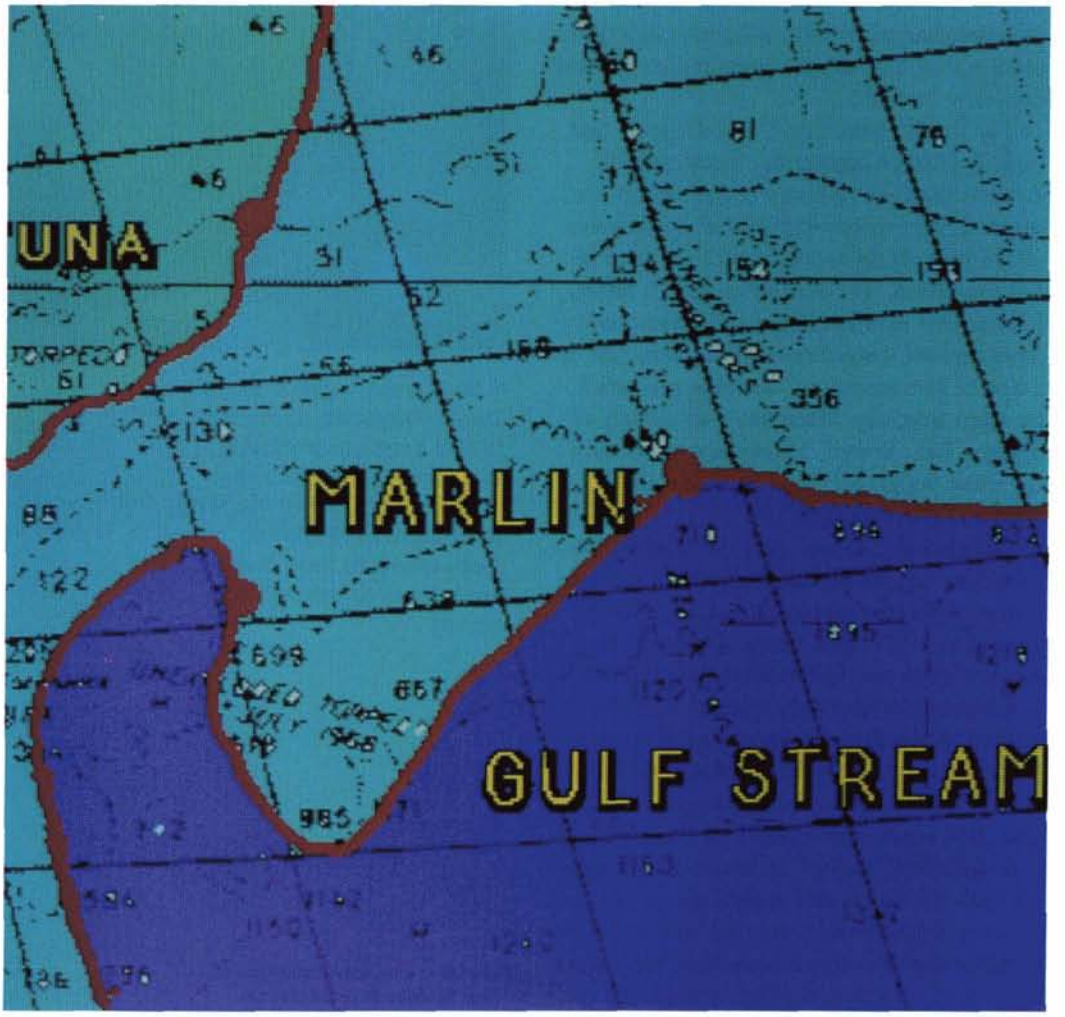
Above, Roffer (in red) and an assistant are incorporating satellite imagery into a ROFFS chart. A portion of the completed chart is shown at right; it shows oceanographic information along with predictions of where

baitfish, tuna and marlin will be during the following 24-36 hours.

The ROFFS service exemplifies the potential for benefit to marine industries from satellite observations of the oceans. NASA is developing technology toward a possible ocean monitoring system of the 1990s that would offer such broad benefits as marine weather and climate prediction, maritime safety, improved ship design and ship routing techniques, and, of course, an information service for directing fishermen to most productive waters.

As a preliminary, NASA conducted a mid-1980s Fisheries Demonstration Program, a research/technology transfer effort by Jet Propulsion Laboratory in cooperation with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Navy and Coast Guard, Scripps Institution of Oceanography, and the Western Fishing Boat Owners Association, San Diego, California.

The program employed ocean surface data from ships and buoys, plus data from satellites—including NASA's specially instrumented Nimbus 7—and meteorological satellites operated by NOAA and the Department of Defense—to create "fisheries aid" charts. The charts incorporated a broad set of ocean observations, including data provided by Nimbus 7 on "color breaks," areas of sharp changes in ocean color usually associated with fish concentrations. The charts were broadcast daily to 35 participating fishermen whose boats were equipped with radio-facsimile recorders such as the one shown above.



The program successfully demonstrated that satellite data, in particular ocean color delineation, combined with surface acquired data, can help commercial fishermen select strategies for more efficient and more economical operations. Among participating fishermen, the most notable results reported were reduced search time and substantial fuel savings. ▲

Spinoff From Mooncraft Technology

Among a selection of spinoffs that enhance public safety is a fire protection material derived from Apollo's heat shield

Descending from orbit after a mission to the moon, the Apollo Command Module carrying three astronauts plunged into Earth's atmosphere at something close to 25,000 miles per hour. At that tremendous velocity, air friction built up temperatures on the spacecraft's exterior surfaces as high as 5,000 degrees Fahrenheit—yet the interior remained comfortable.

The reason was Apollo's heat shield, which was coated with an "ablative" material. The material was literally allowed to burn off, dissipating heat energy and thereby delaying temperature buildup on the spacecraft's structure. In addition, the burned material charred to form a second protective coating that blocked heat penetration beyond the outer surface.

The Apollo heat shield was designed and built by Avco Corporation. Subsequently, Avco entered into a contract with Ames Research Center to develop spinoff applications of the heat shield technology in the field of fire protection. The successful NASA effort, followed by further company research and development toward new applications, led to a line of fire protection materials produced by Avco Specialty Materials, a subsidiary of Textron Inc., Lowell, Massachusetts. One of the most widely accepted of the family is Chartek® Fireproofing.

Developed a decade ago, the original formulation was known as Chartek 59. Its protective properties were dramatically demonstrated in 1985, in a spectacular fire test when NASA and the Federal Aviation Administration deliberately crashed a jetliner in a safety evaluation of a new type of aircraft fuel. The airplane's fuselage was almost entirely destroyed by a fire that raged for more than two hours. But interior cameras and tape recorders, encased in boxes coated with Chartek 59 and sealed with a special silicone foam, emerged intact, the film still usable.

Since then the formulation has been made even more effective, through a mesh re-

In Saudi Arabia, a worker sprays Chartek Fireproofing on structural parts of a crude oil processing plant. The long life fireproofing material is a spinoff from the heat shield that brought returning Apollo astronauts safely through temperatures as high as 5,000 degrees.

®Chartek is a registered trademark of Avco Specialty Materials Textron.

Freshly coated with Chartek Fireproofing, a segment of an offshore oil platform awaits delivery to its working site. The fireproofing material is in wide use in the oil industry and in other industries where there is high fire risk.

inforcement improvement, introduced in 1986, that offers longer-term fire endurance. The improved product is known as Chartek III Fireproofing.

Chartek III Fireproofing provides long-term fire protection for structural steel in high risk industrial applications, such as the structure, conduits, pipes and valves of offshore platforms and storage tanks used in the hydrocarbon processing industry. As was the case in the Apollo heat shield, the spray-on epoxy coating delays temperature buildup on the surfaces to which it is applied; it is, in other words, a means of buying time in a fire environment, allowing time to extinguish the fire, to redirect threatened fuel supplies, or to evacuate people.

In the presence of fire, Chartek III Fireproofing provides two kinds of protection. One of them is ablation, the technique used on Apollo involving dissipation of heat by burnoff. The other is called "intumescence," or swelling. Heat causes the Chartek coating to swell to a thickness six times greater than when it was applied, forming a protective blanket of char that retards transfer of heat to the steel structure. The mesh reinforcement keeps the char intact and reduces metal fatigue.

Chartek Fireproofing provides fire protection for as much as two or three hours, depending on the type of fire and the thickness of the coating applied. And because the material is non-porous, it offers bonus value as a superior coating for long-term protection against corrosion when there is no fire. ▲

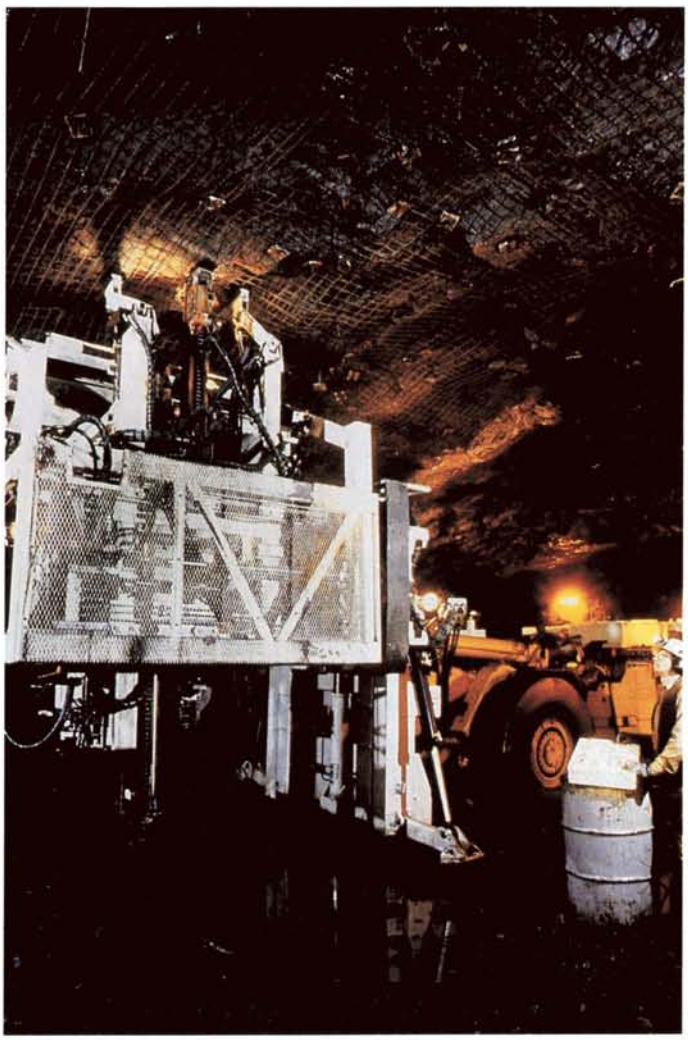
The Space Shuttle's Remote Manipulator System—known to its builders as Canadarm—is a 50-foot robot arm used to deploy, retrieve or repair satellites in orbit. It made its debut in 1981 and operated successfully on 18 missions prior to the Shuttle standdown that began in 1986.

Canadarm was designed and built by Spar Aerospace Limited, Toronto, Ontario under contract to the National Research Council of Canada as Canada's contribution to the Space Shuttle program. The project was funded by the Canadian government in the conviction that the technology would generate important Earth-use spinoffs. It has. In fact, Spar Aerospace has formed a Remote Manipulator Systems Division specifically dedicated to development and construction of robotic systems.

The initial spinoff version, shown above, is designed to remove, inspect and replace large components of Ontario Hydro's CANDU nuclear reactors, which supply some 50 percent of Ontario Hydro's total power reduction. All work is controlled from an operations

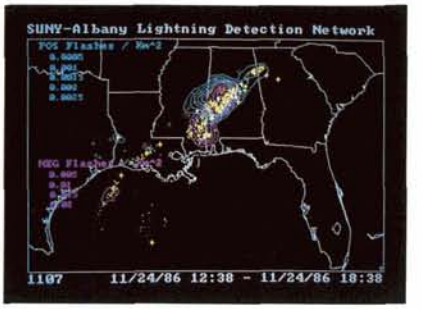
center remote from the reactor. Cameras on the robot arm provide the operators views of each stage of the operation, while the job is monitored over a communications network. The CANDU robot is the first of Spar's Remote Manipulator Systems intended for remote material handling operations in nuclear servicing, chemical processing, smelting and manufacturing.

A second spinoff program began in 1985 with the signing of an agreement with Inco Limited for development of remote controlled mining equipment to enhance the safety and productivity of Inco's hardrock mining operations. The first such system, now in service, is a machine for installing wire mesh screening and rock bolts to shore up the roofs of mine corridors, as pictured at right above. An operator controls the machine from a position under an already-screened area, where he is protected from rockfall; he positions the mesh, drills in a predetermined pattern, then inserts and tightens the rock bolts, handling 35 feet of screening and 18 bolts in a three-hour sequence. The system not only improves safety in a hazardous operation that costs more than a score of lives annually, it also increases productivity fourfold.



The Remote Manipulator System Division is also manufacturing a line of industrial robots and developing additional systems for nuclear servicing, mining, defense and space operations. ▲

Lightning Detection



Lightning causes an estimated $50 million a year in damage to power lines, transformers and other electric utility equipment. Much of the damage could be prevented or more quickly repaired if utility companies had a better understanding of lightning's characteristics and where it may strike.

Lightning strikes are not yet predictable, but a U.S. East Coast Lightning Detection Network (LDN) operated by the State University of New York (SUNY) at Albany is providing utilities and other clients data on lightning characteristics, flash frequency and location, and the general direction in which lightning-associated storms are heading. The system, which began as a purely scientific endeavor and evolved into a practical application, has grown into a network that covers virtually the whole East Coast and extends beyond the Mississippi River. It includes 30 lightning monitoring stations, each with a strike coverage of about 250 miles.

The network is jointly funded by NASA, the National Science Foundation, the State of New York and the Electric Power Research Institute. There are two similar networks in the west and midwest, but NASA has no involvement with them.

The monitoring stations are equipped with direction finding antennas that detect lightning strikes reaching the ground by measuring fluctuations in the magnetic field. The stations relay strike information to the SUNY-Albany LDN operations center (above), which is manned round the clock. The center's computers process the data, count the strikes and spots their locations, and note other characteristics of the lightning, such as flash density. LDN's processed data is then beamed to a satellite for broadcast to clients' receiving stations. At top right is a representative computer graphics display showing the location and flash density contours of 1,107 ground strikes recorded during a six-hour period in the southeastern United States.

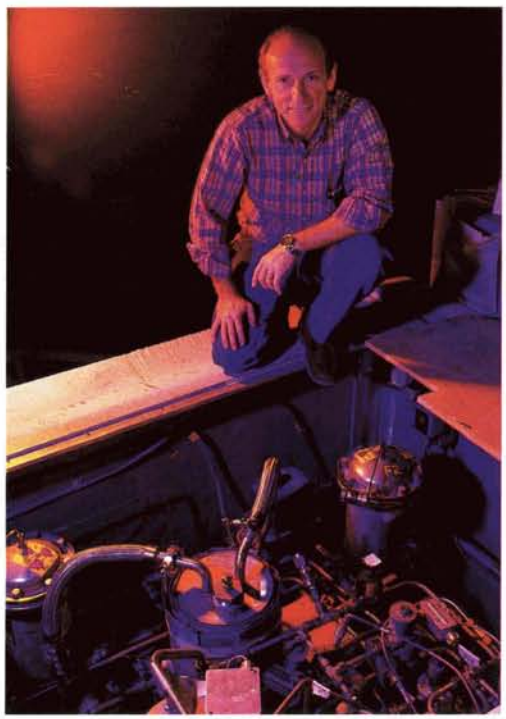
The National Weather Service uses SUNY-LDN data to determine the intensity of thunderstorms. But the major users are 25 utilities, including the big North Carolina Duke Power Company, which uses the information as a management tool. Duke scientist Nick Keener explains how the data is employed:

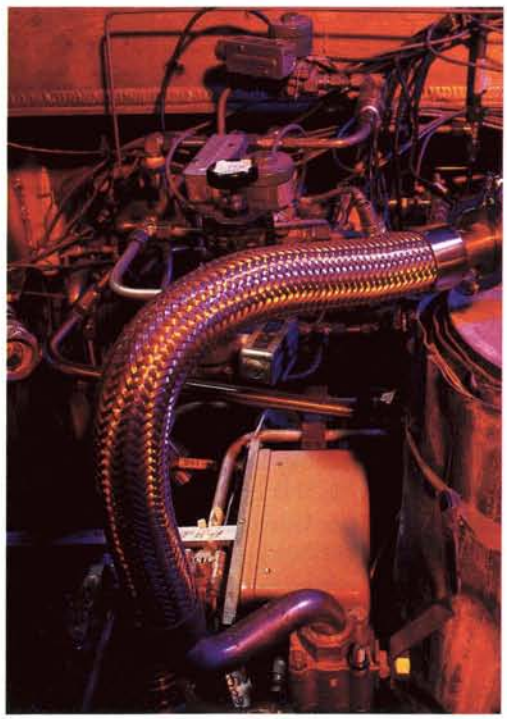
"Since lightning is one of the major causes of electricity interruption to both residential and industrial customers during the summer months, advance knowledge of approaching thunderstorm activity is extremely useful in scheduling field crews in anticipation of power outages. By utilizing real-time lighting strike information, managers are now more able to effectively manage their resources. This reduces outage time for customers."

The information is also valuable to a special Duke Power working group that is looking for methods and technology to improve transmission system reliability. It allows matching customer problems with specific strikes to determine cause and effect; it enables study of the operating records of each transmission facility with detailed knowledge of lightning activity; line maintenance can be directed at actual problem areas; and the design of new transmission lines can be better tailored to the actual lightning activity of a geographical area. ▲

Argonne (Illinois) National Laboratory is a multidisciplinary research center with primary focus on engineering research, particularly in nuclear power; basic science; and biological and environmental science and technology. It is among the world's most advanced scientific/technological facilities, but even so sophisticated a center can benefit on occasion from spinoff technology.

Donald E. Bohringer, Argonne engineering specialist, employed NASA information in two projects associated with the laboratory's Intense Pulsed Neutron Source (IPNS) facility. The IPNS is a powerful source of pulsed neutron beams for studies of the atomic and molecular structure of solids and liquids. It produces neutrons by firing accelerated protons at a uranium target. The NASA technology Bohringer employed involved improved vibration protection for a gamma ray detector in one project and, in the other, new leak detection technology. The IPNS and other Argonne facilities have many vacuum and pressure vessels and early detection of leaks is highly important; the NASA information supplemented Argonne's own leak detection technology. Bohringer learned of both items in *Tech Briefs*, a NASA publication that informs potential users of technology available for transfer.





Bohringer read in *Tech Briefs* that NASA's Jet Propulsion Laboratory (JPL) had developed a package for gamma ray detectors that protects the detector's semiconductor crystal and isolates it from shock and vibration. He was interested in this development because the IPNS has two gamma ray detectors, located in the uranium target cooling system, subject to vibration effects. He requested and received a Technical Support Package that provided detailed information, including a complete construction design, about the JPL development. It helped him develop a modified mounting system for the detector that combined the JPL design with Argonne innovation.

At left above, Bohringer perches on the thick wall of the uranium target cooling system housing; in front of him is the gamma ray detector, exposed to view during a maintenance period when the huge concrete/lead shielding blocks that cover the cooling box during operation were removed. The detector (tan box) is shown in closeup above.

Bohringer used another *Tech Brief* lead relative to soap-solution leak testing, a technique widely employed in aerospace and other industrial operations. It involves brushing a soap solution on the joint to be tested while the vessel contains helium under pressure; if no bubbles appear, it is assumed that the leakage, if

any, is acceptably low. But exactly how low had never been quantified until Marshall Space Flight Center conducted an extensive research study and produced a document describing the minimum leak rate to which soap solution detection is sensitive. The minimum turned out to be less than one-tenth the previously assumed minimum rate.

At left, Argonne chief technician David Leach is demonstrating a soap solution leak detection test in a system pressurized with helium; in the closeup above the bubbles identify leak areas that need attention. ▲

A Universal Antidote

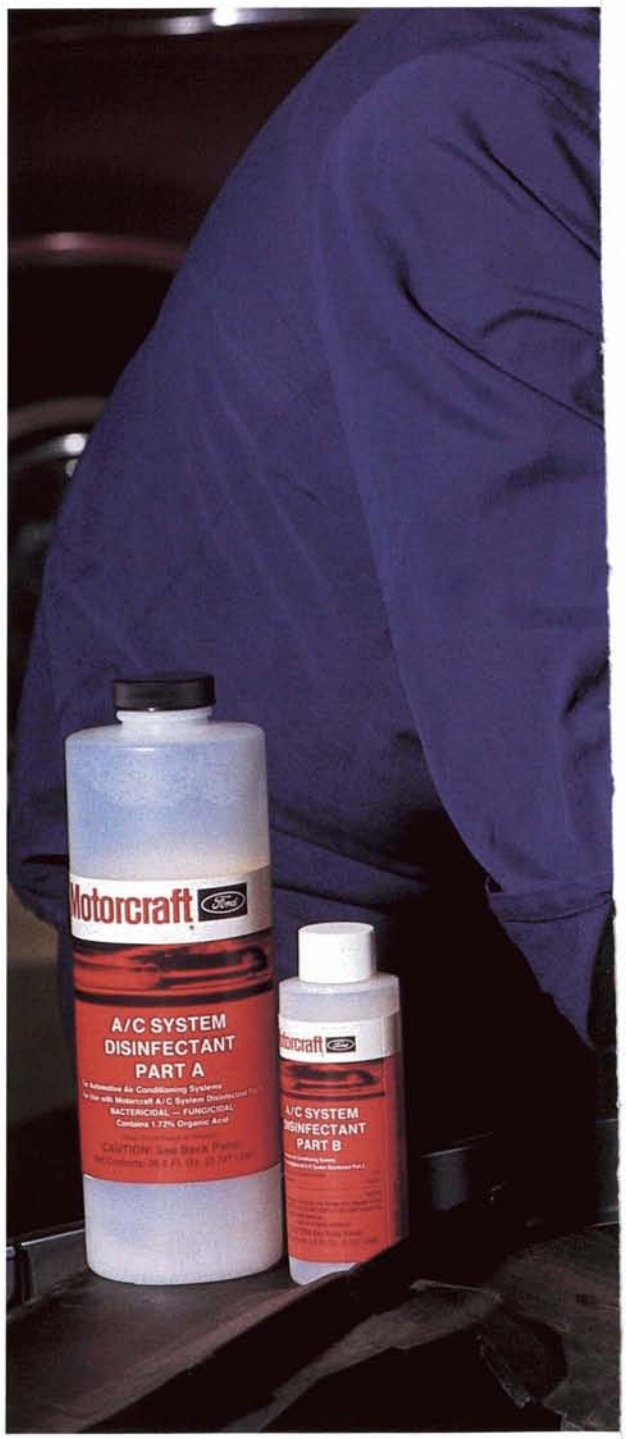
Among technology transfer examples in the field of transportation is an exceptionally versatile disinfecting compound for automotive and many other uses

For years, auto manufacturers have had a problem: customers, especially those in hot, humid climates, complained about the mold that forms in car air conditioners or, more specifically, about the obnoxious musty odor the mold causes. It was a problem because potential mold-killing substances could also leave lingering toxicity, and the alternative—removing the air conditioner from the vehicle for cleaning and disinfecting—was costly.

Last fall, two of the Big Three U.S. automakers concluded arrangements with Alcide Corporation, Norwalk, Connecticut for distribution of Alcide's patented Ren New Air Conditioning Disinfectant. The special properties of the Alcide® formulation, which has been approved by U.S. regulatory authorities, enable it to destroy mold and fungus, as well as bacteria and viruses, with minimal harm to humans, animals or plants. This allows use of the product to disinfect and deodorize auto air conditioners without removing them and without any lingering toxicity.

The disinfectant/deodorizer is one of a wide range of Alcide formulations engineered for a variety of purposes, spanning automotive, medical, agricultural, pharmaceutical and consumer markets. Alcide is not, strictly speaking, a spinoff from aerospace technology. But the products themselves and the company that makes them are beneficiaries of assistance provided by NERAC, Inc., Tolland, Connecticut, one of NASA's nine

An Alcide Corporation chemist performs a quality control check on a sample of Alcide, a multipurpose compound that destroys mold, fungus, bacteria and viruses without harming human, animals or plants.



A technician is spraying Alcide disinfectant into the evaporator case of an auto air conditioning system; the product eliminates musty odor by killing the odor causing molds and bacteria that grow in the warm humid environment of many car air conditioners.

Courtesy Crest Lincoln Mercury, New Haven, Connecticut

A Universal Antidote *(Continued)*

After several years of development and test, Alcide Corporation has brought to the commercial marketplace a product of important potential for dairy farmers—a germicidal barrier teat dip that contributes to reduced mastitis in dairy herds by destroying the organisms that cause the infection, thus aiding increased production of higher quality milk.

Industrial Applications Centers, which provide information retrieval services and technical help to industry and government clients. The story of Alcide Corporation's genesis and product development offers an example of the type of assistance centers like NERAC provide.

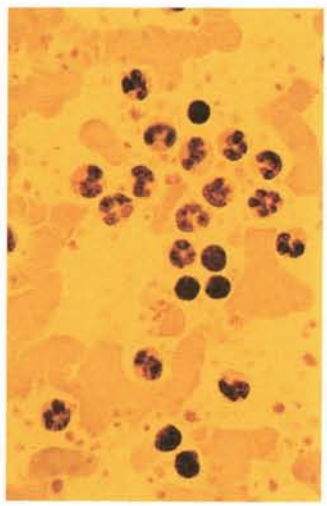
The exceptional properties of the Alcide compound were discovered by Howard Alliger in 1977 and further developed by Robert D. Kross, Alcide Corporation's vice president of research and development. While he was developing a compound for sterilizing ultrasonic cleaning tanks, Alliger found that the compound killed bacteria, viruses and fungi on or shortly after contact, yet was nontoxic to humans, animals and plants, whose tissues lack the chemical environment to which Alcide reacts.

Alliger recognized that he had found something with potential for many uses other than tank sterilization. He teamed with fellow inventor Elliott J. Siff and, in 1980, formed a company to develop, market and license the compound. Today, Siff is president and chief executive officer of Alcide Corporation; Alliger is no longer active in the company.

After an additional series of tests established the broad potential of Alcide compound, the company requested NERAC's aid in identifying possible applications and the types of businesses that might have a need for such a product. NERAC conducted a computer search of more than a dozen databases and uncovered scores of applications, among them treatment of viral, fungal and bacterial infections in animals; treatment of human skin diseases; disinfection and sterilization of medical facilities; as a sterilant for food production machinery and food preservation; as a preservative for cutting oils and paints; and as a deodorant/disinfectant for carpets, chemical toilets, public conveyances and meeting places.

Alcide Corporation developed and tested specific compounds for some of these applications and some of them are now commercially available, but regulatory approvals slowed the commercialization process for several years. However, Alcide is now beginning to make major advances in the U.S. and abroad. The year 1987 was a big one for the company. In addition to the auto company arrangements, Alcide also made agreements with Bausch & Lomb for disinfecting contact lenses; with Procter & Gamble for mouthwash, toothpaste and other oral care applications; with W.R. Grace's American Breeders Service Division and the French firm O.H.F. Santé Animale for distribution of a barrier teat dip designed to help prevent mastitis in cows.

Among major research in progress, Alcide Corporation is teaming with Koor Foods in Israel to develop an antimicrobial food wash; with Cobe Laboratories, Denver, Colorado, in testing a new formulation for cleansing kidney dialysis machines; and with the University of Connecticut Medical School to study the effect of the Alcide compound on human wound healing and scar tissue suppression. At Israel's Hebrew University Dental School, trials are in progress on a plaque reducing mouthwash and in England researchers are meeting success in human clinical trials of treating herpes and other sexually transmitted diseases with appropriate Alcide formulations. ▲



At left center, researchers are conducting one of a series of tests to determine whether Alcide formulations can alter the course of lung disease. This is one of a number of research projects, in the U.S. and abroad, investigating the potential of Alcide technology in such diverse medical applications as wound healing, treatment of acne, herpes and cystic fibrosis. In the top photo, researchers are checking the results of tests relative to the anti-inflammatory and anti-scar properties of Alcide. The photo above is a representation of what the Alcide compound looks like in microscopic view.

®Alcide is a registered trademark of Alcide Corporation.

Business Jets

Shown at top is the new Learjet 31 business jet and below it its larger and heavier companion, the Learjet 55C. Both are built by Learjet Corporation, Tucson, Arizona and both feature NASA-developed "winglets," nearly vertical extensions of the wing (closeup at lower right) designed to reduce fuel consumption and generally improve airplane performance.

Powered by twin turbofans, the aircraft carry up to 10 passengers. The Model 55C, which takes off at 21,000 pounds, is the largest of the Learjet family. The Model 31 (15,500 pounds) is the lowest priced Learjet, an "entry level" airplane intended for the business aircraft operator who wants to move up from propeller-driven aircraft to jet performance. Both feature Delta Fins, innovative company-designed tail surfaces that provide high directional stability at all speeds and improved handling in the traffic pattern and at lower takeoff, approach and landing speeds. Both airplanes are expected to receive Federal Aviation Administration certification in mid-1988.

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

Winglets are particularly effective on the two new Learjets, which can routinely operate above 45,000 feet and are capable of flying at altitudes up to 51,000 feet. At such altitudes, where the air is thinner, the drag reduction afforded by the winglets is more pronounced.

Learjet was the first manufacturer to use the winglet design in production aircraft, initially on the Models 28/29 introduced to service in 1979. Several other plane builders are taking advantage of the NASA technology, notably McDonnell Douglas in its new MD-11 jetliner. ▲

The accompanying photos show exterior and interior views of the 1987 Honda Acura Legend Coupe, which was designed with the aid of the NASA-developed NASTRAN® computer program. The Legend is among the latest cars designed by Honda R&D Company, Ltd., Japan, a longtime user of the NASTRAN program.

The program is an offshoot of the computer design technique that originated in aircraft/spacecraft development. Engineers create a mathematical model of the vehicle and "fly" it on the ground by computer simulation. This allows study of the performance and structural behavior of a number of different designs before settling on a final configuration.

From that base of experience, Goddard Space Flight Center developed the NASA Structural Analysis Program (NASTRAN), a general purpose predictive tool applicable to structural analysis of automotive vehicles, railroad cars, ships, nuclear power reactors, steam turbines, bridges, office buildings—and that's just the beginning of a lengthy list.

The NASTRAN program takes an electronic look at a computerized design and predicts how the structure will react under a great many different conditions. Quick and inexpensive, it minimizes trial-and-error in the design process and makes possible better, lighter, safer structures while affording significant savings in development time. One of the most widely used of all aerospace spinoff technologies, the NASTRAN program is available through NASA's Computer Software Management and Information Center (COSMIC)® at The University of Georgia (see page 140).

Virtually all U.S. automakers now employ the aerospace-derived computer design technique and most employ the NASTRAN program or other NASA-developed programs in the design process. Honda R&D Computer Ltd. has been using NASTRAN for more than a decade for structural analysis of auto bodies, motorcycles and such components as tires, wheels, engine blocks, pistons, connecting rods and crankshafts. All of the Honda auto products designed in the 1980s have been analyzed by the NASTRAN program. ▲

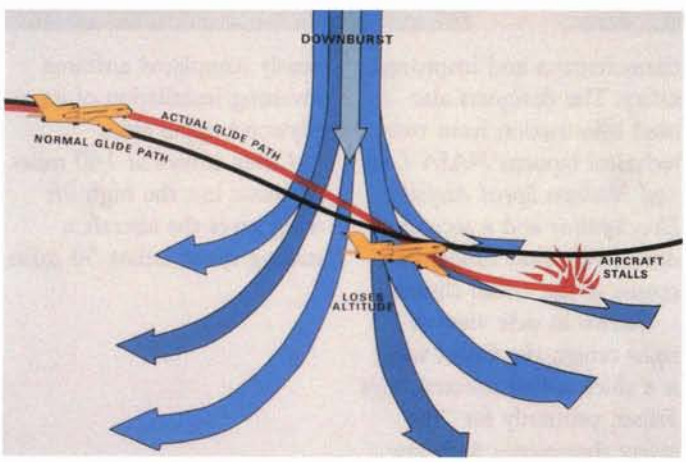
®NASTRAN and COSMIC are registered trademarks of the National Aeronautics and Space Administration.

Windshear Prediction

Windshear, microbursts and extreme air turbulence—caused by sudden, intense changes in wind direction or speed—are difficult to detect and thus dangerous to air traffic. They have been positively identified as the cause of 28 aviation accidents that claimed 491 lives.

The downburst, one of several forms of windshear, is illustrated below. A pilot first encounters unexpected lift and he reacts by dropping the nose of the plane. When, a moment later, the full force of the downburst strikes, the downward push is amplified by the fact that the airplane is already descending. The pilot must then react quickly to restore the plane to its proper glide path. At right, a DC-9 airliner is landing shortly after a thunderstorm at Hartsfield International Airport, Atlanta, Georgia. The vapor streaming from the wingtips is the result of high humidity, a factor in windshear.

Many groups are investigating ways to detect and predict windshear. Since windshear episodes are transient, lasting only five to 10 minutes, the goal is an alert system that would enable holding the plane for the brief period it takes for these intense wind abnormalities to pass. Most researchers are looking to electronic sensors as the answer. But Federal Aviation Consulting Services, Ltd. (FACS), Fresh Meadow, New York is going a different route—applying artificial intelligence techniques to windshear prediction. FACS has been working since 1985 to develop a computer program that will automate the airline dispatch process and include windshear information. FACS' artificial intelligence based Airline Dispatcher program is intended as a backup, not a replacement for the human dispatcher. It would incorporate the same data that a human would request to make a decision, and then draw a conclusion using the same rules of logic as the human expert.



In directing the FACS development, company senior vice president Jerry Eichelbaum initially used an artificial intelligence program called AESOP, originally developed by Langley Research Center. As the design evolved, FACS was able to compact its database and replace the AESOP shell with a new artificial intelligence program called CLIPS. Both AESOP and CLIPS were supplied by NASA's Computer Software Management and Information Center. (See page 140).

FACS has signed an agreement with Genesis Imaging Technologies, Inc., Valley Forge, Pennsylvania. They have put together a prototype flight dispatcher based on FACS software and a hardware package that includes a powerful workstation connected to an optical disc information storage device. The computer program puts emphasis on the factors found in every case where windshear was positively identified as the cause of an accident. The data is overlaid on a cartographic mapping program.

Using all information available, the artificial intelligence module sets up a 20-mile sphere of influence around forecasted areas of windshear. As flight plans are filed, the routes are checked against "no fly" areas indicated. The total FACS/Genesis system presents the user with pictorial displays of navigational maps overlaid with flight planning options. Two major airlines are considering test and/or purchase of the system. ▲

In utility operations that involve flight over difficult terrain, such as forest or jungle, a twin-engine airplane capable of flying on one engine is much preferred for safety reasons. But a twin not only costs more to buy, it is generally more expensive to operate and maintain.

Michael E. Fisher, president of Aero Visions International (AVI), South Webster, Ohio has introduced a compromise—the Culex light twin-engine aircraft which, he says, offers the economy of operation of a single-engine plane, the ability to fly well on one engine, plus the capability of flying from short, unimproved fields in takeoff and landing distances of less than 350 feet. At right above, one of two Culex prototypes is flying a simulated transmission line inspection. At right is a ground view of Fisher and the Culex.

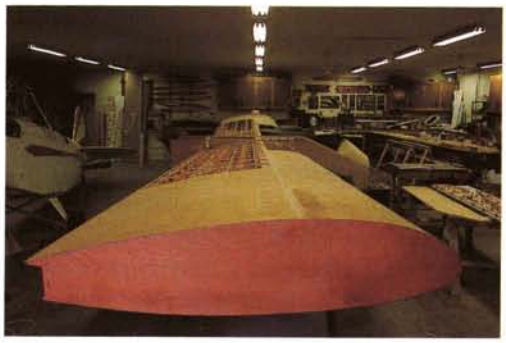
Culex was originally intended to be a factory built aircraft for special utility markets where aircraft are required to fly low over "hostile" terrain—terrain where loss of power would be dangerous—for example, pipeline patrol, bush operations or aerial surveillance. However, it is now offered as a build-it-yourself kit plane. AVI will provide a basic construction kit or a more detailed kit package with many prefabricated subassemblies to maximize the factory-built components.

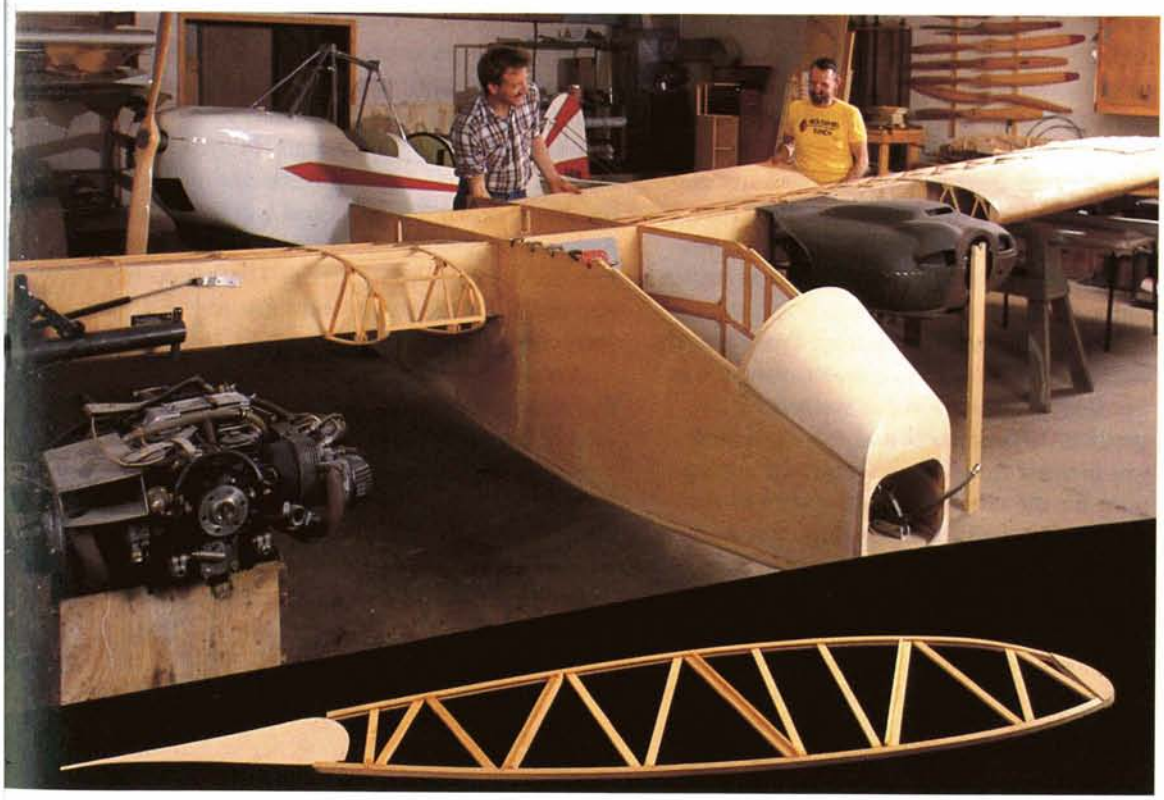
Culex was designed by AVI president Fisher with Wayne Ison and Walter J. Collie of Manchester, Tennessee. A key element of the design is an airfoil developed by Langley Research Center, which has long been engaged in designing a series of high efficiency wings for civil aircraft. Chief Engineer Collie states that the designers selected an airfoil known technically as NASA LS(1)-0417 Mod, one of a family of GAW (General Aviation Wing) airfoils for light aircraft featuring high lift characteristics and improved safety. The designers also used information from two technical reports: *NASA Low and Medium Speed Airfoil Development* and a second describing wind tunnel test results of the airfoil chosen.

Shown in side view at right center, the Culex wing is a thick airfoil selected, says Fisher, primarily for "the safety that comes with low speed stability." It offers high lift at low speed and relatively low drag at cruising speed. Its thickness permits use of a big wing spar for greater structural strength and provides greater internal volume for fuel shortage.

The wing "skin" is aircraft plywood, as is the whole airframe. "Wood is nature's composite," says Fisher. "We prefer wood for airframe structures because it absorbs the bending moments associated with flight loads without developing fatigue and it doesn't corrode." At upper right is a nearly completed airframe awaiting installation of its plywood upper skin.

Culex cruises at 140 miles per hour but the high lift wing gives the aircraft a stalling speed below 50 miles





per hour. The company has flight tested two prototypes, one a 1,200 pound version with two 80 horsepower engines, the other a 650 pound version with two 48 horsepower engines. During the test program, Culex demonstrated its ability to climb at 350 feet per minute with one engine shut down.

At left, AVI employees are installing flaps on a third prototype, which has one engine in place and the other awaiting installation.

Below, a worker is producing wing ribs with the aid of a construction jig; the wooden parts are bonded together by polyester resins for superior strength characteristics. ▲

A New Tool for Quality Control

Highlighting spinoffs in industrial productivity and manufacturing technology is a new product inspection system capable of finding tiny flaws previously undetectable

Industry has long employed machine vision systems for quality control inspections and generally they work fine. If there is a problem it is that such systems cannot detect all of the imperfections their users would like to observe and correct.

Diffracto Ltd., Windsor, Ontario is now offering an inspection system that allows detection of minute flaws previously difficult or impossible to observe. Called D-Sight, it represents a revolutionary technique for inspection of flat or curved surfaces to find such imperfections as dings, dents and waviness. The system amplifies these defects, making them highly visible to simplify decision making as to corrective measures or to identify areas that need further study.

According to Diffracto, D-Sight can identify 94 percent of the defects when inspecting stamped sheet metal; that compares with 50 percent for conventional flaw-detection methods. D-Sight is also used to detect imperfections in glass or plastics, such as surface sinks, waviness or paint finish irregularities.

The system is a spinoff from Space Shuttle research. Diffracto Ltd., a major company in the field of machine vision systems for inspection, measurement and robot guidance, was licensed to develop commercial applications for the vision guidance system of the Shuttle Orbiter's remote manipulator arm, known to its Canadian developers—Spar Aerospace Ltd., Weston, Ontario—as Canadarm (see page 132). In the course of experimenting with the vision system, Diffracto engineers noted the phenomenon of reflected light from the target material. This led to a company R&D program that produced an initial CVA 3000 Development System.

The CVA 3000 employs a camera, high intensity lamps and a special reflective screen to produce a D-Sight image of light reflected from a surface. The image is captured and stored in a computerized vision system, then analyzed by a computer program. A live image of the surface is projected onto a video display and compared with a stored master image to identify imperfections. Localized defects measuring less than one thousandth of an inch are readily detected.

Surfaces to be inspected must be reflective. Since some—such as unpainted sheet metal—are not sufficiently reflective, Diffracto has developed a reflectivity enhancing technique that involves wiping or spraying a wetting compound on the surface.

D-Sight is offered in two versions with different levels of capability to allow the most cost-effective selection for a given type of job. The CVA 3000 is the top of the line and there is a lower priced TVA 2000.

Major users so far are auto manufacturers —including Ford, General Motors and Chrysler—who employ D-Sight to inspect external body panels, both metal and plastic, for dings, dents, low spots and waviness. D-Sight's sensitivity allows corrective action before the defects become severe. The system is also useful for die tryout and "first article" inspection.

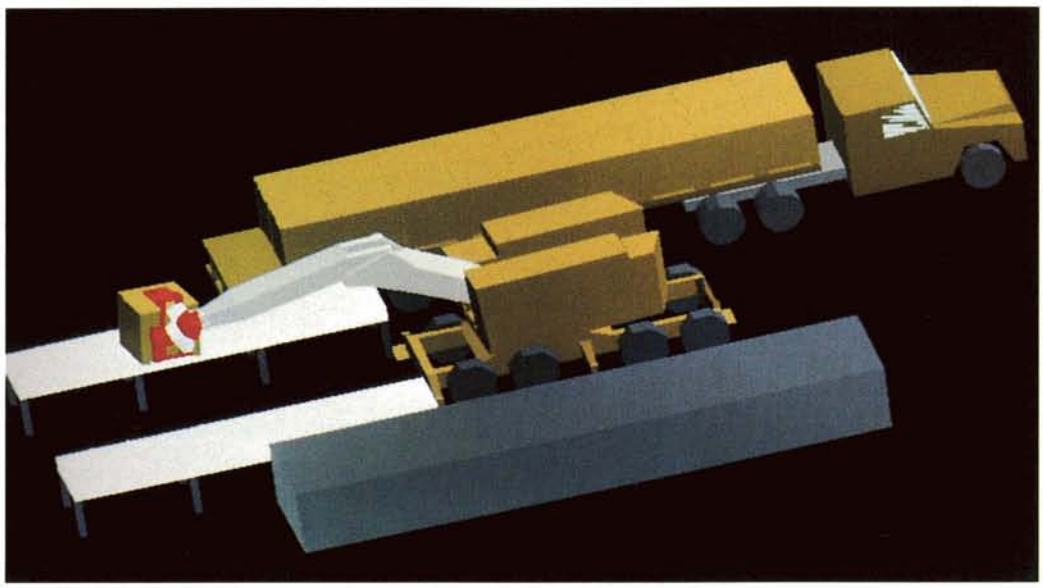
Aircraft manufacturers are evaluating D-Sight for inspection of external aircraft surfaces, especially those made of composite materials. A variant of D-Sight has been developed for inspection of transmissive objects, such as windshields or canopies. The company is also exploring the system's potential application to wind tunnel and thermal imaging research.

The Diffracto D-Sight pictured is a quality control inspection workstation capable of detecting surface imperfections measuring less than one thousandth of an inch. In this test, the target surface is an auto fender (center). The fender is photographed by the camera (right) while the reflective screen (white background) bounces light off the fender to highlight defects. The resulting image is computer analyzed and the discovered defects projected onto the video displays.

D-Sight imagery points out various imperfections, for example, the scratch in this auto door that would not be visible in the showroom.

Computer Aided Design (CAD) of products, such as buildings, aircraft, ships and autos, has long been established practice in industry. An advanced step in the CAD process is use of computers not only to create mathematical models of the design but also to predict how the design will perform in actual service. This is much more difficult than it sounds, because all the situations and problems that the product will face in service life must be reduced to mathematics so the computer can "visualize" what would happen under a variety of circumstances.

Martin Marietta Aero & Naval Systems, Baltimore, Maryland has advanced the CAD art to a very high level at its Robotics Laboratory, which designs, analyzes and simulates robot manipulators. One of the company's major projects is construction of a huge Field Material Handling Robot, or FMR (model shown), for the Army's Human Engineering Laboratory.



Design of the FMR, intended to move heavy and dangerous material such as ammunition, was a triumph of CAD engineering. Separate computer problems modeled the robot's kinematics and dynamics, yielding such parameters as the strength of materials required for each component, the length of the arms and their degree of freedom, and the power of the hydraulic system needed. The Robotics Laboratory went a step further and added data enabling computer simulation and animation of the robot's total operational capability under various unloading and loading conditions.

All these different programs had to be patched together into one integrated program. Rather than develop new integrating software from scratch, the Robotics Laboratory opted to use a NASA computer program known as IAC, for Integrated Analysis Capability Engineering Database. Originally developed by Goddard Space Flight Center, IAC is a modular software package containing a series of technical modules that can stand alone or be integrated with data from sensors or other software tools. The user can define groups of data and the relationships among them.

In the case of the FMR project, the Robotics Laboratory was able to take data from 15 major software packages and reformat that data for viewing in different ways to make the program "transparent" to the user. This flexibility greatly facilitated construction of the FMR prototype and contributed substantially to reducing the cost of the project.

IAC was supplied to Martin Marietta Aero & Naval Systems by NASA's Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC makes available to industrial and other organizations government-developed computer programs that have secondary applicability (see page 140). ▲

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

Machine Tool Software

For almost 20 years, a NASA-developed software package has played a part in the technical education of students who major in Mechanical Engineering Technology at William Rainey Harper College, Palatine, Illinois. Associate Professor William F. Hack has been using the APT (Automatically Programmed Tool) software since 1969 in his CAD/CAM (Computer Aided Design and Manufacturing) curriculum.

At right, Professor Hack (suited) is explaining to students how the APT software works in guiding machine tools. At lower right students are learning how to program computer guided machine tools that use APT software.

APT was designed specifically for computer aided manufacturing. The term APT denotes both the programming language and the computer software that processes the language.

Professor Hack teaches the use of APT programming languages for control of metal cutting machines. Machine tool instructions are geometry definitions written in the APT language to constitute a "part program." The part program is processed by the machine tool. CAD/CAM students go from writing a program to cutting steel in the course of a semester. Harper College leases its APT package (150,000 source statements) from COSMIC, NASA's Computer Software Management and Information Center located at the University of Georgia (see page 140). ▲

Composite Materials

Composite materials, such as those used in a widening range of aerospace and other industrial applications, are made up of two key components: fibers to reinforce the strength of the material, and matrix resins (polymers) to hold the fibers together and provide protection. At right is a photo study of a representative group of fibers used in composites and a beaker of a binding material.

At Langley Research Center, researchers invented an advanced type of polymer, a chemical compound formed by uniting many small molecules to create a complex molecule with different chemical properties. The material is a thermoplastic polyimide that resists solvents; other polymers of this generic type are soluble in solvents, thus cannot be used in applications where solvents are present because the solvents could damage components fabricated from such materials. Generally, the Langley development of the solvent-resistant material created a new polymer with the desirable properties of two major classes of polymers, thus broadening its industrial applications, which include molding resins, adhesives and matrix resins for fiber-reinforced composites.

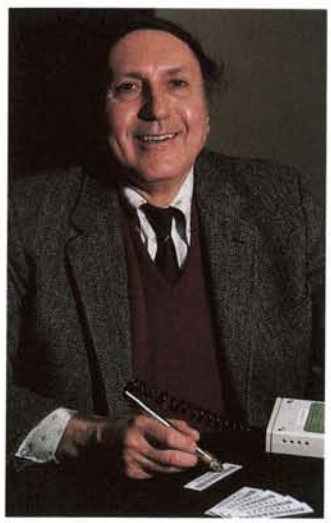
The technology is being commercialized through NASA licenses to several companies, one of which is High Technology Services, Inc. (HTS), Techimer Materials Division, Troy, New York. HTS was founded in 1983 by Milton L. Evans, who had spent 20 years with General Electric Company in scientific, marketing and general management posts; Evans, president of HTS, is shown below next to the processing facility for preparing production batches of thermoplastic polyimides.

HTS is engaged in development and manufacture of high performance plastics, resins and composite materials. Techimer Materials Division sells composite matrix resins that offer heat resistance and protection from radiation, electrical and chemical degradation. The division's core product line utilizes thermoplastic polyimides based on the technology developed at Langley Research Center; HTS has licenses for five NASA patents and has introduced several products based on that technology. The company is actively marketing matrix resins for composites used in aircraft and laminating resins for composites used in printed board circuitry. Techimer is also offering resins as adhesives for flexible circuitry and aerospace structural uses. ▲

Bar Code Labels

Bar codes on supermarket products and other consumer goods have relatively short shelf lives in a benign environment, hence require little special design. But code labels affixed to systems that operate in orbit must maintain high readability for long periods despite exposure to the heat and vibration of launch and the harsh environment of space.

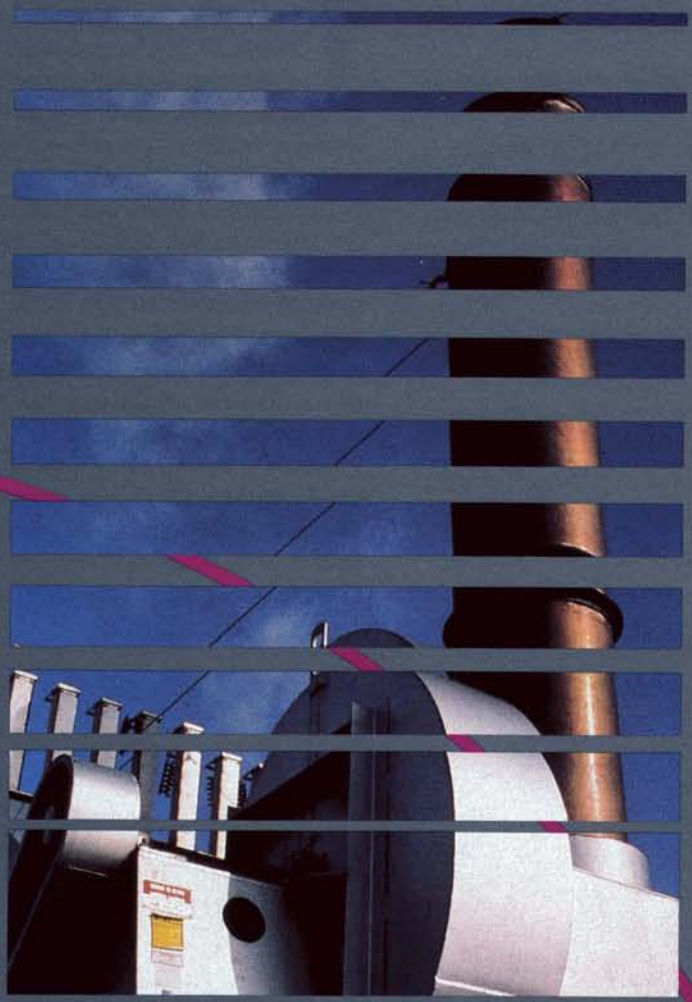
American Bar Codes, Inc. (ABC), Brooklyn, New York, developed special bar code labels, under NASA contract, for inventory control of Space Shuttle parts and other space system components. They combine extreme durability with excellent print contrast ratio, which allows first time accurate reading over a 10-year inventory lifetime of the product. ABC is now producing these bar code labels commercially, for industrial customers who also need labels able to resist harsh environments.



ABC labels are made in a company-developed anodized aluminum process and consecutively marked with bar code symbology and human-readable numbers. They offer extreme abrasion resistance and indefinite resistance to ultraviolet radiation; are capable of withstanding 700 degree Fahrenheit temperatures without deterioration and up to 1400 degrees in special designs; and they offer high resistance to salt spray, cleaning fluids and mild acids. At top, labels exposed to high temperature are still readable although the aluminum base has melted. At lower left, ABC president Nate Moss is using an infrared scanner to check label readability. In the center photo, labels remain readable after an acid immersion test. ▲

Technology Utilization

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



Recycling Technology

A nationwide technology utilization network seeks to broaden and accelerate secondary application of NASA technology in the public interest

The wealth of aerospace technology generated by NASA programs is a valuable resource, a foundation for development of new products and processes with resultant benefit to the nation's economy in expanded productivity.

In a dormant state, however, the technology represents only a *potential* benefit, like oil in the ground. One of NASA's jobs is to translate the potential into reality through an organized effort to put the technology to work in secondary applications and thereby reap a dividend on the national investment in aerospace research.

NASA's instrument of that objective is the Technology Utilization Program, which employs several types of mechanisms intended to broaden and accelerate the transfer of aerospace technology to other sectors of the economy. The program is managed by the Technology Utilization Division, a component of NASA's Office of Commercial Programs. Headquartered in Washington, D.C., the division coordinates the activities of technology transfer specialists located throughout the United States.

Bill Breadheft, NERAC

The Tolland, Connecticut home of NERAC, Inc., one of 10 NASA-sponsored industry assistance centers that offer access to a vast databank, information retrieval services and help in applying the information.

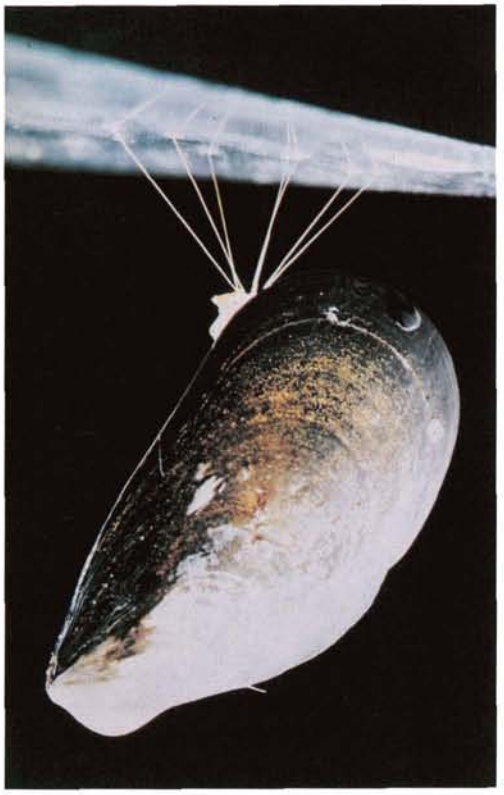
A key element of the program is a network of 10 Industrial Applications Centers (IACs) affiliated with universities across the country. The IACs offer clients access to a great national data bank that includes some 100 million documents of accumulated technical knowledge, along with their expertise in retrieving information and applying it in support of clients' needs. The IACs are backed by a score of Industrial Applications Center Affiliates, state-sponsored business or technical centers that provide access to the technology transfer network.

A representative IAC is NERAC, Inc., Tolland, Connecticut. NERAC was founded in 1966 under the co-sponsorship of the University of Connecticut and NASA. By 1985, NERAC had attained such size and success that the company elected to sever its university ties and become a nonprofit, independent firm operating under continued NASA sponsorship.

NERAC's purpose is to provide U.S. industry and individual entrepreneurs access to existing and evolving technologies, with the aim of enhancing their innovation and productivity and helping them secure a competitive edge in the global market place. The center has helped literally thousands of companies to find new applications; stay abreast of scientific, technical and business developments; gain competitive intelligence; identify qualified technical experts; and monitor patent activity.

Among NERAC's technology assistance programs are document retrieval; a problem-solving service; and a current awareness/update service that alerts a participant, throughout the year, to new developments

This electronic system chassis is representative of a range of ITT Gilfillan parts and products now bonded by structural adhesives rather than more expensive dip brazing. Gilfillan credits NERAC's two year supporting research effort with a major assist in the company's realization of large scale savings.



This ocean blue mussel attaches itself to rocks, piers and other surfaces by secreting a threadlike superglue with extraordinary adhesive properties. Bio-Polymers, Inc., Farmington, Connecticut developed a synthetic mussel glue for the commercial market. NERAC helped the company secure research grants and identify commercial applications.

in a particular topic or research area.

An example of how NERAC helps industry is found in an experience of ITT Gilfillan, Van Nuys, California, manufacturer of advanced radar and command/control systems. In one of several areas where NERAC has assisted Gilfillan, NERAC helped the company investigate structural adhesives over a two-year period. Gilfillan engineers reported that "NERAC was instrumental in supporting ITT Gilfillan's technology program to replace more costly dip brazing of manufactured parts with a process which employs structural adhesives technology. This new process can provide cost savings of up to $1 million per year for production volumes currently being experienced."

In addition to the IACs, other mechanisms include Technology Utilization Officers, located at NASA field centers, who serve as regional managers for the Technology Utilization Program; a software center that provides, to industry and government clients, computer programs applicable to secondary use; applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology; and publications that inform potential users of technologies available for transfer. These mechanisms are amplified in the following pages. ▲

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 and one specialized facility who serve as regional managers for the Technology Utilization Program.

Representative of the group is Tom Hammond, TUO at Kennedy Space Center, shown at right conferring with technology utilization information assistant Helen LaCroix. The top photo shows a portion of sprawling Kennedy Space Center, dominated by the massive Vehicle Assembly Building.

The TUO's basic responsibility is to maintain continuing awareness of research and development activities 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's 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 application.

To advise potential users of the technology's availability, the TUO evaluates and processes selected new tech-

nology 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.

The TUO also serves as a point of liaison among industry representatives and personnel of his center, and between center personnel and others involved in applications engineering projects, which are 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 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

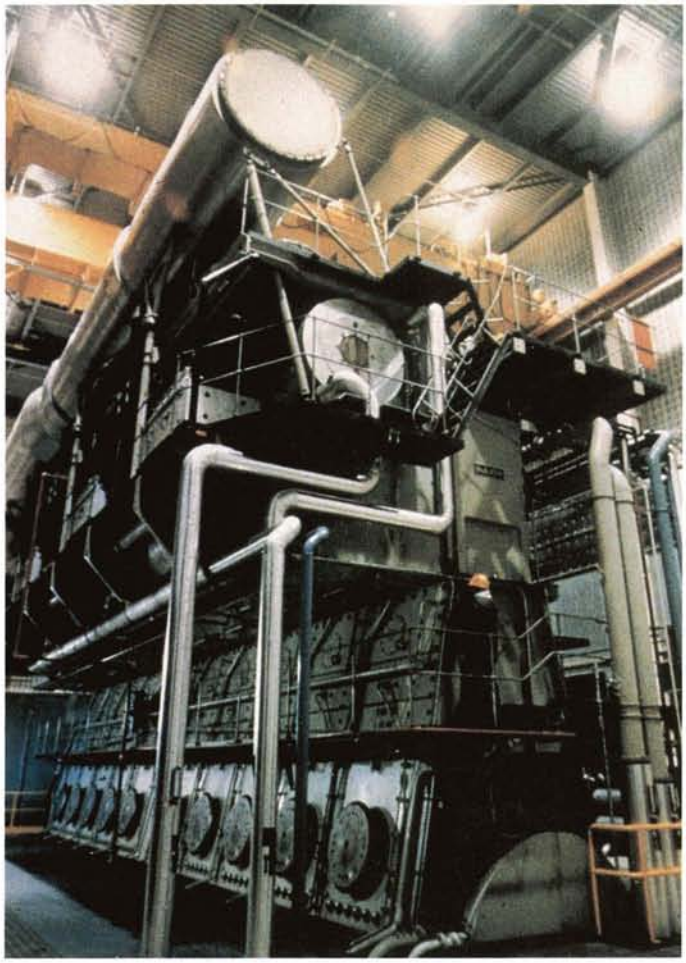
visits to the center, he serves as the contact point.

Support for the TUOs—and for all other elements of the NASA technology utilization network—is provided by the Technology Utilization Office at the NASA Scientific and Technical Information Facility (STIF). This office executes a wide variety of tasks, among them maintenance of the subscription list for *Tech Briefs* (top), NASA's principal tool for advising potential users of

technologies available for transfer; maintenance and mailout of Technical Support Packages (below), which requires a reproduction effort of more than 1.5 million pages annually; and responding to requests for information, an activity that entails processing of some 80,000 mail and other inquiries and mailout of more than 200,000 documents yearly.

The TUO/STIF is also responsible for distribution of technology utilization publications, for research and other work associated with this annual *Spinoff* volume, for retrieval of technical information and referral of highly technical requests to appropriate offices, for developing reference and bibliographic data, and for public relations activities connected with media interest in technology utilization matters. ▲

Software Center



In the course of its varied activities, NASA makes extensive use of computer programs in such operations as launch control, analyzing data from spacecraft, conducting aeronautical design analyses, operating numerically controlled machinery and performing routine business or project management functions.

To meet such software requirements, NASA and other technology generating agencies of the government have of necessity developed many types of computer programs. They constitute a valuable resource available for reuse. Much of this software is directly applicable to secondary applications with little or no modification; most of it can be adapted to special purposes at far less than the cost of developing a new program.

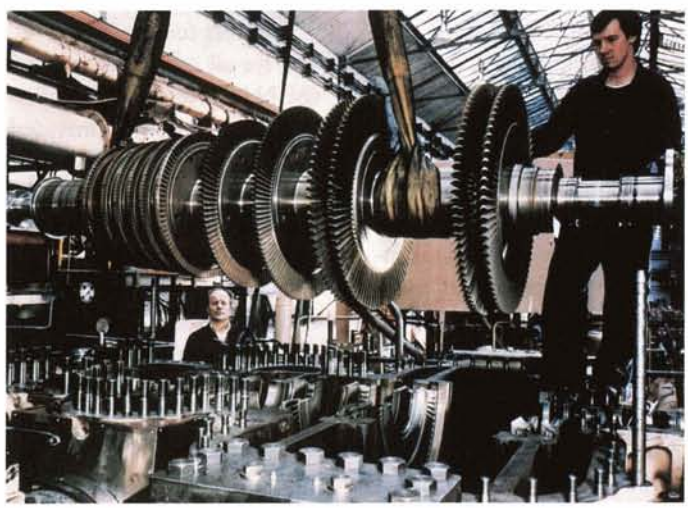
Therefore, American businesses can save a lot of time and money by taking advantage of a special NASA technology utilization service that offers software capable of being adapted to new uses.

NASA's mechanism for making such programs available to the private sector is the Computer Management Software and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC gets a continual flow of government developed software and identifies those programs that can be adapted to secondary usage. The Center's library contains more than 1,400 programs for such tasks as structural analysis, design of fluid systems, electronic circuit design, chemical analyses, determination of building energy requirements, and a variety of other functions. COSMIC customers can purchase a program for a fraction of its original cost and get a return many times the investment, even when the cost of adapting the program to a new use is included.

An example of how this service aids industry is the use of a NASA developed program in design of cogeneration systems.

Cogeneration is the use of one energy source—usually coal, oil or gas—to produce both process energy and electricity. 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—boilers, turbines, valves, generators, piping, pressure regulators, etc. Two such components are pictured: at top left a 22,300 kilowatt diesel prime mover and below it a steam turbine rotor. Thermo Electron engineers analyze the



needs of the customer and the parameters of the components to customize a system of maximum efficiency by means of computer modeling.

One element of Thermo Electron's computer system is a COSMIC-supplied software package called PRESTO, originally developed by Lewis Research Center to analyze the performance of regenerative superheated steam turbine cycles. It is a flexible program that can handle the specifications for most energy systems and provide a realistic prediction of design efficiencies. The company estimates savings of $13,500 a year through use of PRESTO.

Another example is the use of COSMIC's "best seller" NASTRAN computer program by the University of Georgia. Originally developed by Langley Research Center for aerospace design applications, NASTRAN (NASA Structural Analysis System) 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 configurations before settling on a final design.

In the photos above are exterior and interior views of poultry houses whose designs stemmed from research and NASTRAN analysis conducted by the University of Georgia's Agricultural Engineering Department, which is seeking to improve poultry facilities for the benefit of Georgia's billion dollar a year poultry industry. At the University of Georgia, students are being trained to use the NASTRAN system for a variety of new and different applications, including thermal analysis of agribusiness structures, nursery containers and bins used for post-harvest handling of vegetables. The Agricultural Engineering Department reports that use of the NASTRAN program has encouraged student appreciation of numerical problem solving and the department is planning additional applications of NASTRAN in its continuing program for teaching and applying sophisticated computer analyses.

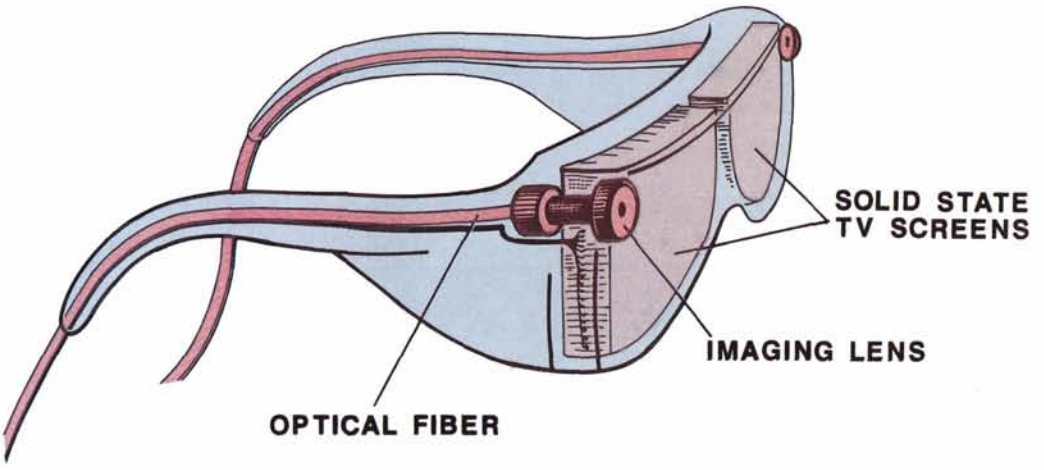
To assist prospective customers in locating potentially useful software, COSMIC publishes an annual indexed catalog of all the programs in the Center's inventory. Available on microfiche, computer magnetic print tape or in hard copy form, the catalog may be purchased directly from COSMIC. The Center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

®COSMIC and NASTRAN are registered trademarks 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.

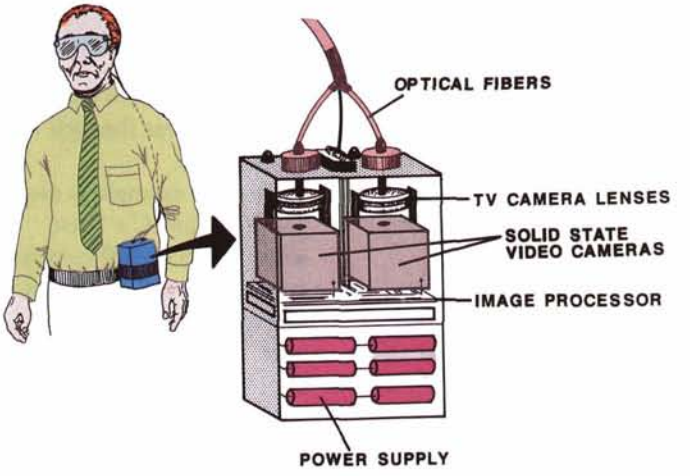
Applications engineering projects originate in various ways. Some stem from requests from assistance from other government agencies, others are generated by NASA technologists who perceive possible solutions to problems by adapting NASA technology to the need. NASA employs an application team composed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

An example of an ongoing applications engineering project is an effort to improve the sight of some 2.5 million people in the U.S. who suffer from "low vision," visual impairment that cannot be corrected medically, surgically or by conventional prescription eyeglasses.



Still in an early stage, this project contemplates employment of space-derived computerized image enhancement technology to alter and enhance images to compensate for the low vision patient's impaired eyesight. The program, expected to take seven to nine years, is a collaborative effort of NASA and the Wilmer Eye Institute of Johns Hopkins Medical Institutions, Baltimore, Maryland. It will be coordinated for NASA by the Earth Resources Laboratory of John C. Stennis Space Center, Mississippi, with technical contributions from the Jet Propulsion Laboratory, Johnson Space Center, and AMES Research Center.

The planned Low Vision Enhancement System, to resemble "wraparound" eyeglasses, above, will custom tailor images of the outside world. The patient will see the world on miniature TV screens where the lenses of eyeglasses are normally located. Lenses and imaging glass fibers will be embedded on each side of the wraparound section, where the front and ear pieces join. The lenses will form images of the scene before the patient on the surfaces of the fibers. The fibers, similar to those used to carry telephone signals, will carry pictures from miniature solid state TV cameras fitted to a belt or shoulder pack as shown above. The images will be processed by a small, battery-powered system in the pack and displayed on the TV screens (top photo).



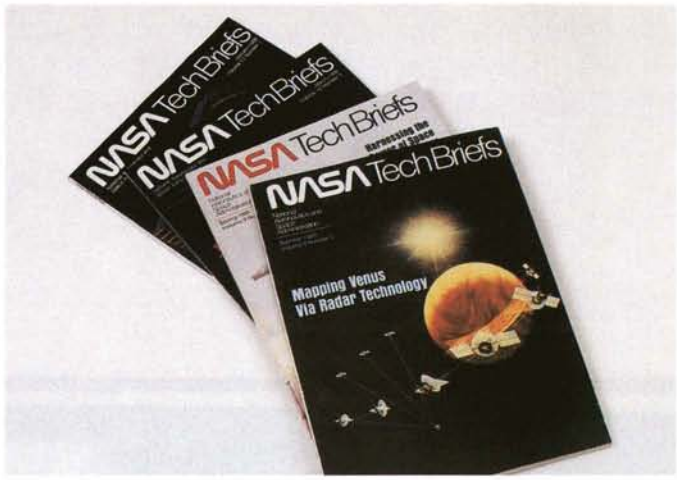
The system is expected to benefit patients who have lost their peripheral or side field of vision, such as those suffering from glaucoma or from retinitis pigmentosa, a progressive degeneration of the retina. It will also benefit patients with central vision loss, the part of vision normally used for reading; such patients may have macular degeneration associated with aging, or diabetic retinopathy, in which diabetes causes swelling and leakage of fluid in the center of the retina.

Another example is a project to develop a stabilized observation instrument platform for public service helicopters, which would enable, for example, police or antidrug agencies to observe ground activity from a remote, undetectable vantage point (left). The observing instruments would be cameras, infrared imagers and low light television cameras.

The problem with existing equipment is that vibration from the helicopter's rotor system makes it difficult to use lenses with long focal lengths because the vibration distorts the imagery from the observing instruments. Fully developed, the cabin-mounted or belly-mounted stabilized platform would negate the effects of vibration and make it possible to observe ground targets with lenses that can focus on two-inch letters (license plate size) from a distance of one to two miles.

This project involves joint effort by RECON Research, Bend, Oregon; Jet Propulsion Laboratory (JPL); and the NASA Application Team, Research Triangle Institute, North Carolina; and NASA's Technology Utilization Division. RECON, with JPL assistance, designed a platform (left) and conducted documented flight tests, using two helicopters and equipment provided by 14 different vendors. The next step is further development to refine the design and produce a moderately priced stabilized platform that could have a broad commercial market—beyond the public service need—in aerial photography and other aviation applications. ▲

Publications



An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed technology is 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 10 times a year in 1988 and once a month beginning in 1989, the publication is a current awareness medium and problem solving tool for more than 100,000 government and industry readers.

First published in 1962 as single-sheet briefs, *Tech Briefs* was converted to a NASA-published magazine format in 1976 and since 1985 it has been a joint publishing venture of NASA and American Business Publications of New York City.

Each issue contains information on newly developed products and processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs, and other innovations originating at NASA field centers or at the facilities of NASA contractors. Firms interested in a particular innovation may get more detailed information by requesting a Technical Support Package; more than 100,000 such requests are generated annually.

Here are some examples of how *Tech Briefs* spreads the word and inspires secondary usage of NASA technology:

The director of engineering of Ball Metal Decorating & Service Division of Ball Corporation, Chicago, Illinois, used NASA heat transfer information contained in *Tech Briefs* as a departure point for the design of an energy saving heat recovery system. The system employs a series of heat exchangers (center) on eight press and coating lines used to decorate metal sheets, along with an economical, highly efficient catalyst that decomposes hydrocarbons flowing out of the ovens used in the metal decorating process. The company estimates that the heat recovery system is providing energy savings of more than $250,000 a year.

Another example: Engineers of Harris Corporation's Semiconductor Sector, Melbourne, Florida read in *Tech Briefs* about Marshall Space Flight Center's development of the Power Factor Controller (PFC), a device for curbing power wastage in alternating current motors. The PFC continually matches voltage with the actual need of motor, rather than the fixed full-load voltage it would normally get, cutting voltage to the minimum required and thus effecting large scale energy savings.

Harris Semiconductor engineers incorporated the PFC technology details in *Tech Briefs* in a related innovation: an integrated circuit that reduces onto one chip most of the circuitry of the PFC for single phase induction motors. The chip is the heart of the Harris HV-1000 Induction Motor Energy Saver (IMES). IMES monitors a motor and provides it with electrical energy computed by the chip to be the precise voltage required to drive the motor at optimum efficiency. Below, a Harris Semiconductor engineer monitors power measurement equipment during operation of a drill equipped with a HV-1000 controller. The IMES-equipped drill uses 79 watts; the same drill without the controller would draw 160 watts.

A third example: At top right, a model is displaying TRX Anti-Fog Composition, an inexpensive preparation that prevents condensation of moisture on plastic and glass without harming the surfaces of such materials. Manufactured by Tracer Chemical Company, Tampa, Florida, it has a variety of applications—for example, fog prevention for eyeglasses, ski goggles, skin diving masks, car windows, bathroom mirrors, camera lenses and helmet shields.

The compound was originally developed by Johnson Space Center to bar fog formation on astronaut helmet visors and spacecraft windows. Tracer Chemical's

president learned of the compound from *Tech Briefs*, subsequently obtained a NASA license for manufacture and marketing of the compound and started production. The company found a strong customer base in the U.S. and additional markets in the United Kingdom, Norway, Japan and Taiwan.

Available to scientists, engineers, business executives and other qualified technology transfer agents in industry or government, *Tech Briefs* is the primary publication of the Technology Utilization Program. Among others are this annual *Spinoff* volume and the *NASA Patent Abstracts Bibliography*, a semiannually updated compendium of NASA patented inventions available for licensing, which now number almost 4,000 (the latter publication can be published from the National Technical Information Service, Springfield, Virginia 22101). ▲

NASA's Technology Transfer System

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

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, Maryland 21240.

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

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

○ *Industrial Applications Center Affiliates:* state-sponsored business or technical assistance centers that provide access to NASA's technology transfer network.

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

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

△ Field Centers

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, California 94035
Technology Utilization Officer:
Laurence A. Milov
Phone: (415) 694-6471

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:
Dean C. Glenn
Phone: (713) 483-3809

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

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia 23665
Technology Utilization 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) 433-5567

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

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Manager:
Norman L. Chalfin
Phone: (818) 354-2240

NASA Resident Office—JPL
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Officer:
Gordon S. Chapman
Phone: (818) 354-4849

John C. Stennis Space Center
Missippi 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) 262-5036

Central Industrial Applications Center
Southeastern Oklahoma State University
Durant, Oklahoma 74701
Dickie Deel, 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
Phone: (412) 648-7000

NASA Industrial Applications Center
Research Annex, Room 200
University of Southern California
3716 South Hope Street
Los Angeles, California 90007
Radford G. King, director
Phone: (213) 743-8988
(800) 642-2872 (CA only)
(800) 872-7477 (toll free, US)

NERAC, Inc.
One Technology Drive
Tolland, Connecticut 06084
Daniel Wilde, Ph.D., president
Phone: (203) 872-7000

North Carolina Science and Technology Research Center
P.O. Box 12235
Research Triangle Park,
North Carolina 27709
H. Lynn Reese, director
Phone: (919) 549-0671

Technology Applications Center
University of New Mexico
Albuquerque, New Mexico 87131
Stanley A. Morain, Ph.D., director
Phone: (505) 277-3622

Southern Technology Applications Center
Progress Center, P.O. Box 24
1 Progress Boulevard
Alachua, Florida 32615
J. Ronald Thornton, director
Phone: (904) 462-3913
(800) 354-4832 (FL only)
(800) 225-0308 (toll free, US)

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

NASA/SU Industrial Applications Center
Southern University
Department of Computer Science
Baton Rouge, Louisiana 70813-2065
John Hubbell, Ph.D., director
Phone: (504) 771-2060

○ Industrial Application Center Affiliates

Alabama
Johnson Research Center
University of Alabama-Huntsville
Huntsville, Alabama 35899
Phone: (205) 895-6257

Alaska
Director, Alaska Economic Development Center
University of Alaska—Juneau
1108 F Street, Juneau, Alaska 99801
Phone: (907) 789-4402

Arizona
Technology Transfer Network
3883 East Thomas Road
Phoenix, Arizona 85018
Phone: (602) 220-0177

Arkansas
SBDC/Technology Center
100 South Main Street, Suite 401
Little Rock, Arkansas 72201
Phone: (501) 371-5382

California
● See Industrial Applications Center, University of Southern California

Colorado
Director, Business Advancement Centers
University of Colorado
1690 38th Street, Suite 101
Boulder, Colorado 80301
Phone: (303) 444-5723

Florida
● See Southern Technology Applications Center, University of Florida

Georgia
Georgia Institute of Technology
O'Keefe Building, Room 222
Atlanta, Georgia 30332
Phone: (404) 894-4299

Hawaii
Director, Pacific Business Center
University of Hawaii
2404 Maile Way, D202A
Honolulu, Hawaii 96822
Phone: (808) 948-6286

Idaho
Director, Idaho Business Development Center
Boise State University
1910 University Drive
Boise, Idaho 83725
Phone: (208) 385-1640

Indiana
● See Aerospace Research Applications Center, Indianapolis Center for Advanced Research

Iowa
Director, CIRAS—Iowa State University
205 Engineering Annex
Ames, Iowa 50011
Phone: (515) 294-3420

Kentucky
● See NASA/UK Technology Applications Program, University of Kentucky

Louisiana
● See NASA/SU Industrial Applications Center, Southern University

Mississippi
Institute of Technology Development
700 North State Street, Suite 500
Jackson, Mississippi 39202
Phone: (601) 960-3634

Montana
Director, University Technical Assistance Program
College of Engineering
402 Roberts Hall
Montana State University
Bozeman, Montana 59717-0007

Nebraska
Director, Nebraska Technical Assistance Center
University of Nebraska
W191 Nebraska Hall
Lincoln, Nebraska 68588

Nevada
Desert Research Institute
P.O. Box 60220
Reno, Nevada 89506
Phone: (702) 673-7388

New England
- See Industrial Applications Center, NERAC, Inc.

New Mexico
- See Industrial Application Center, TAC, University of New Mexico

Director, Business Assistance and Resource Center
University of New Mexico
Albuquerque, New Mexico 87131
Phone: (505) 277-3541

North Carolina
- See Industrial Applications Center

North Carolina Science and Technology Research Center

Director of Small Business
North Carolina Department of Community Colleges
200 West Jones Street
Raleigh, North Carolina 27603-1337
Phone: (919) 733-7051

North Carolina Small Business and Technology Development Center
820 Clay Street
Raleigh, North Carolina 27605
Phone: (919) 733-4643

North Dakota

Director, Center for Innovation and Business Development
University of North Dakota
Box 8103, University Station
Grand Forks, North Dakota 58202
Phone: (701) 777-3796

Oklahoma
- See Central Industrial Applications Center

Southeastern Oklahoma State University

Oregon

Director, Regional Services Institute
Eastern Oregon State College
8th and K
La Grande, Oregon 97850
Phone: (503) 963-2171

Pennsylvania
- See Industrial Applications Center

University of Pittsburgh

South Carolina

State Board for Technical and Comprehensive Education
State of South Carolina
Room 103, 111 Executive Center Drive
Columbia, South Carolina 29210
Phone: (803) 737-9367

Tennessee

Director, Tennessee Technology Foundation
P.O. Box 23184
Knoxville, Tennessee 37933-1184
Phone: (615) 694-6772

Center for Industrial Services
University of Tennessee
Capitol Boulevard Building, Suite 40
Nashville, Tennessee 37219
Phone: (615) 242-2456

Texas

Technology Business Development Division
Texas Engineering Experiment Station
Texas A&M University
310 Engineering Research Center
College Station, Texas 77843-3369
Phone: (409) 845-8717

Vermont

Agency of Development and Community Affairs
State of Vermont
109 State Street
Montpelier, Vermont 05607
Phone: (802) 828-3221

Virginia

Director of Technology Transfer
Center for Innovative Technology
Hallmark Building, Suite 201
13873 Park Center Road
Herndon, Virginia 22071
Phone: (703) 689-3037

Washington

State Director, Small Business Development Center
Washington State University
441 Todd Hall
Pullman, Washington 99164-4740
Phone: (509) 335-7876

West Virginia

Science and Technology Center
West Virginia Board of Regents
950 Kanawha Boulevard East
Charleston, West Virginia 25301
Phone: (304) 348-3607

The Software Valley Corporation
P.O. Box 700
Morgantown, West Virginia 26507
Phone: (304) 296-0110

Department of Statistics and Computer Science
University of West Virginia
311 Knapp Hall
Morgantown, West Virginia 26506
Phone: (304) 293-3607

■ Computer Software Management and Information Center

COSMIC
382 E. Broad Street
University of Georgia
Athens, Georgia 30602
John A. Gibson, director
Phone: (404) 542-3265

▲ Application Team

Research Triangle Institute
Post Office Box 12194
Research Triangle Park,
North Carolina 27709
Doris Rouse, Ph.D., director
Phone: (919) 541-6980

Rural Enterprises, Inc.
10 Waldron Drive
Durant, Oklahoma 74701
Steve Hardy, director
(405) 924-5094

NASA Scientific and Technical Information Facility

Technology Utilization Office
P.O. Box 8757
Baltimore, Maryland 21240
Walter Heiland, manager
Phone (301) 859-3000 extension 241

Spinoff Team:
Project Manager:
Walter Heiland

Technology Associate:
Linda Watts

Technology Associate:
Jane Lynn-Jones

Graphic Services:
The Watermark Design Office

Photography:
Kevin Wilson

Director, Technology Utilization Division
Office of Commercial Programs
NASA Headquarters
Washington, D.C. 20546

NASA
National Aeronautics and
Space Administration