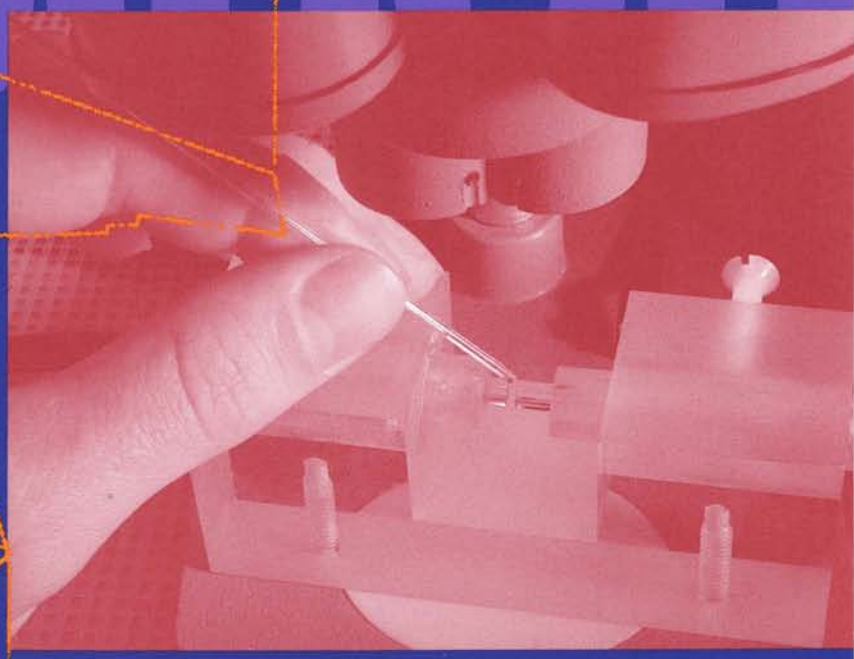
Spinoff 1992



NASA

Spinoff 1992

National Aeronautics and Space Administration
Office of Commercial Programs
Technology Transfer Division

by James J. Haggerty

NASA

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Foreword

On the eve of its 35th anniversary, NASA can look back with pride on a record of solid accomplishment in aeronautics and space.

Our nation has led the way in space. American orbital observatories, peering back in time billions of years, have contributed significantly to our knowledge of the origin and evolution of the universe. American robotic spacecraft have ranged to the far ends of the solar system, returning incalculably valuable closeup views of the planets.

We have probed the depths of our own planet Earth, and we have accumulated a wealth of scientific information in pursuit of space science. NASA's aeronautical research has contributed substantially to safer, more efficient, more environmentally acceptable flight.

These past accomplishments have given us the confidence necessary to meet the challenges ahead: building and operating Space Station *Freedom*, critical for further advances in space; developing the technology for a 21st century extension of the human presence in the solar system; and being a leading partner in the world's effort to understand the nature and causes of global change to permit intelligent decisions for protecting the global environment. To meet these challenges is to invest in tomorrow, to invest in greater scientific knowledge—among the greatest legacies one generation can leave to the next.

NASA needs the support of the American people to make this investment. We in NASA pledge to use wisely the resources entrusted to us. We are reviewing all our programs and our methods of conducting them with an eye toward attaining the goals we have set at the lowest possible cost.

I firmly believe that we can produce for the nation a forward-moving program of aerospace research that is affordable yet bold and aggressive; a program that will enable the United States to maintain a leading role in aerospace progress.

Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

Introduction

Competitiveness in the global marketplace is one of the most critical issues facing American industry today. Technology is the key to successful competition: the nation that boasts the most advanced technology—and the ability to effectively and efficiently apply it to new products—will inevitably be the leader. With this leadership comes a robust economy and an elevated standard of living for the leader-nation's people.

This is why the great storehouse of technology NASA has built over the past three decades of aerospace research is more important than ever. This technology is not perishable; it can be used over and over—and it can be applied in areas far different from those for which it was originally developed.

NASA-developed technology, therefore, represents an immensely valuable bank of know-how on which American companies may draw to bring new products and processes to the world market—at more competitive prices because the technology has already been developed.

Thousands of companies have taken advantage of this national technology resource. Many of them have generated secondary applications. Hundreds of spinoffs have resulted from the application of space-derived technology. In fact, considering the difficulty of tracing the technology source embedded in many of our new products, the actual number may be several times this estimate.

Whatever the number, spinoff products and processes have collectively made an enormous contribution to the U.S. economy, job creation, industrial productivity, and the nation's lifestyle. They represent a substantial dividend on the national investment in aerospace research.

Through its Technology Transfer Program, NASA seeks to broaden and accelerate the spinoff process to expand the economic and social benefits to the nation, and to facilitate the secondary application of NASA technology by those who can make productive use of it. This publication is designed to heighten awareness of the technology available for reapplication and its potential for public benefit.

Spinoff 1992 is organized in three sections:

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

Section 2, the focal point of this volume, contains a representative sampling of new spinoffs that have resulted from secondary application of technology originally developed to meet the goals of the mainline programs.

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

John G. Mannix
Assistant Administrator for Commercial Programs
National Aeronautics and Space Administration

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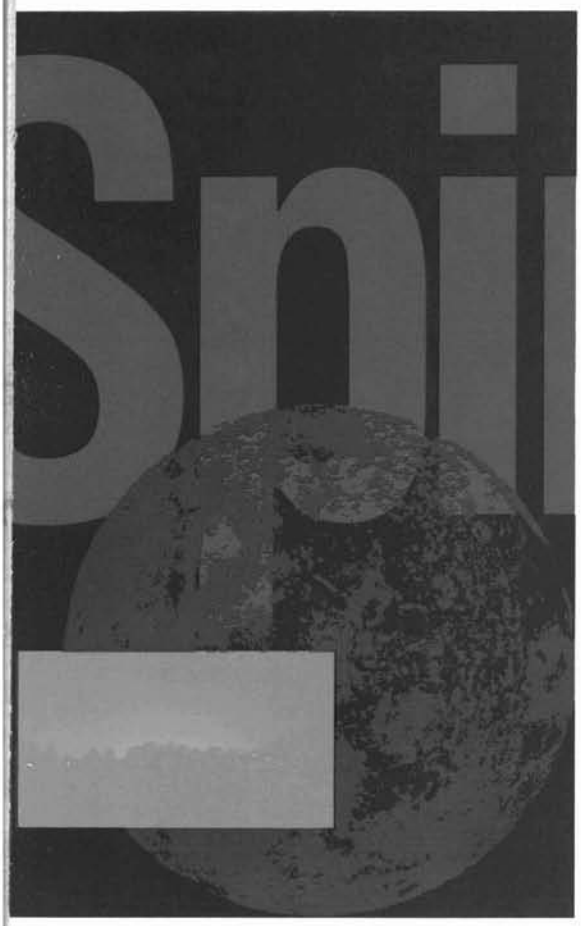


Aerospace Aims

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

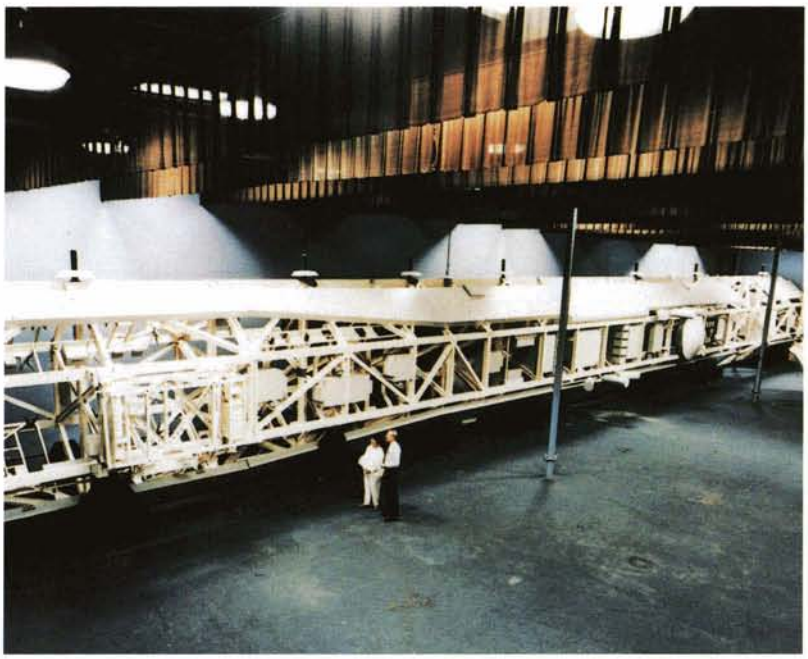
Operations in Space: Today and Tomorrow

PROGRESS ON SPACE STATION FREEDOM HIGHLIGHTS NASA'S THRUST TOWARD EXPANDING HUMAN ACTIVITIES IN SPACE

During 1991-92, the Space Station *Freedom* program scored notable progress in many areas of component design, development and test, setting the stage for a significant milestone: the start of the major manufacturing phase in 1993.

A big step was completion of a series of preliminary design reviews that validated the station's restructured design and enabled progression into the detailed design phase. At midyear 1992, the program was in the final year of the five-year Phase C design effort and was approaching the important Critical Design Review. After that review, planned for early 1993, designs will be frozen and the contractor teams will begin manufacture of the various components of the station.

In addition to progress in engineering design, there have been advances in hardware development. Among the first flight hardware systems, solar cells for the station's first pair of solar array have been built. Among prototype hardware and systems, testing of the Environmental Control and Life Support System demonstrated the ability to reclaim water for reuse as shower and drinking water. An all-



At left, Space Station *Freedom* is shown in its Permanently Manned Capability (PMC) Configuration. Initial PMC is targeted for year 2000. Shown above is a mockup of the central truss assembly, which will be built and launched in sections and joined in orbit to provide the structural framework that stiffens and stabilizes the station.

composite payload rack was developed and approved by the international partners. Tests were completed on a rotary joint that will transfer station power and data while providing stiffness to the structure. These are only a few examples of a broad range of hardware and software developmental activities accomplished by five NASA centers, their 56 major contractors, and the international partners.

Progress is also being made on ground facilities that will support Space Station *Freedom*. Johnson Space Center is outfitting the Space Station Mission Control Center and Space Station Training Facility, which were dedicated in January 1992. Kennedy Space Center's Space Station Processing Facility is well along and planned for activation in 1994. Work continues on outfitting the Payload Operations Integration Center and Payload Training Complex at Marshall Space Flight Center.

NASA and its international partners — Canada, Japan and nine member nations of the European Space Agency (ESA) — completed a series of bilateral and multilateral reviews and resolved a number of technical and programmatic issues. Italy, already a member of the ESA team, took on an expanded responsibility under an agreement with NASA whereby the Italian Space Agency (ASI) will design and develop two Mini-Pressurized Logistics Modules for the station.

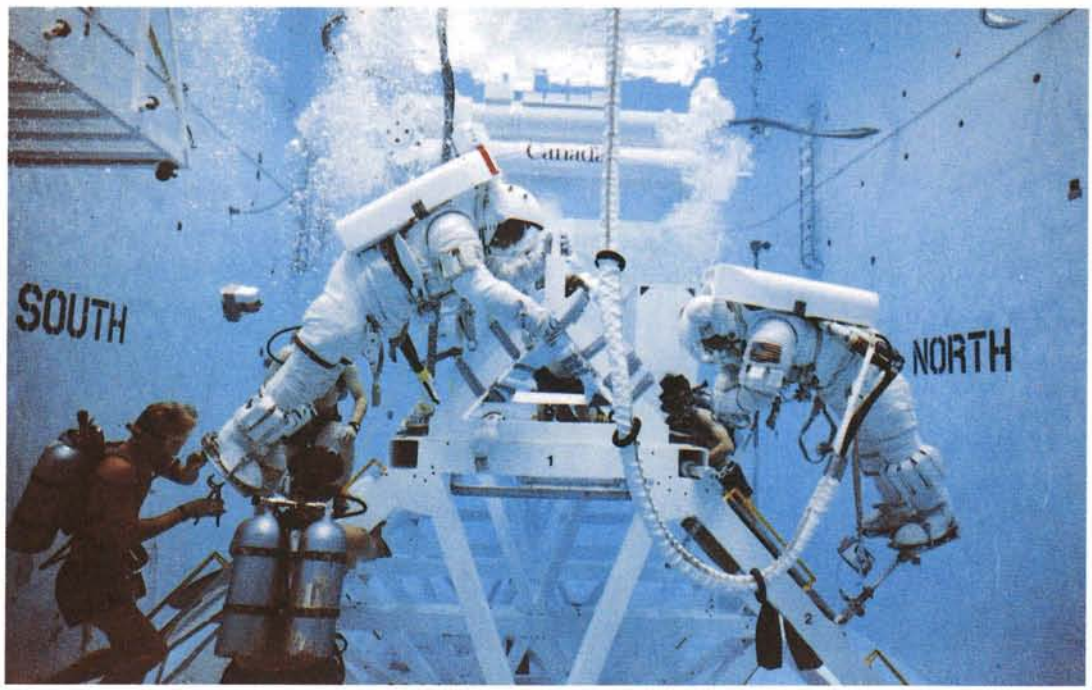
Assembly of the space station will take 18 flights of the Space Shuttle, the first early in 1996. After the components delivered on the first five flights have been assembled and checked out, the sixth flight will deliver the initial pressurized segment, the U.S. Laboratory Module. At that point, targeted for early 1997, the partially assembled station will have all the components and equipment that will make possible an early Man-Tended Capability (MTC), meaning part-time occupancy of the station while the Shuttle Orbiter is docked.

After MTC is achieved, Shuttle flights for assembly and maintenance will continue at the rate of four a year. There will be, in addition, three MTC "utilization" flights each year, during which the Shuttle will dock at the station for 13 days or more and four of the crew will conduct experiments on Space Station *Freedom*.

On the 17th flight, now targeted for September 1999, the Shuttle will deliver the Assured Crew Rescue Vehicle, which will be permanently docked at the station to allow one or all of the crew to return to Earth in a medical emergency, or if the station experiences a malfunction sufficiently serious to require evacuation. With the delivery of the rescue craft, Space Station Freedom will have Permanently Manned Capability. After that, there will be one last assembly flight, to bring a node containing a centrifuge facility and associated equipment for life sciences research.

(Continued)

Operations in Space: Today and Tomorrow (Continued)



At Johnson Space Center's Weightless Environment Test Facility, a truss segment undergoes tests of new concepts for installing, maintaining and replacing externally mounted space station equipment.

Space Station *Freedom* has a threefold mission:

First, it is to serve as a permanent outpost for learning to live and work productively in space, an orbital research base with essential resources of volume, power, data handling and communications to accommodate long duration studies of human physiology in space, research necessary to pursuit of the nation's long range exploration goals.

Second, the station will provide a laboratory with advanced equipment and the constant presence of a hands-on crew for learning how to use the microgravity environment of space for research and development of new medicines, new materials and new technologies.

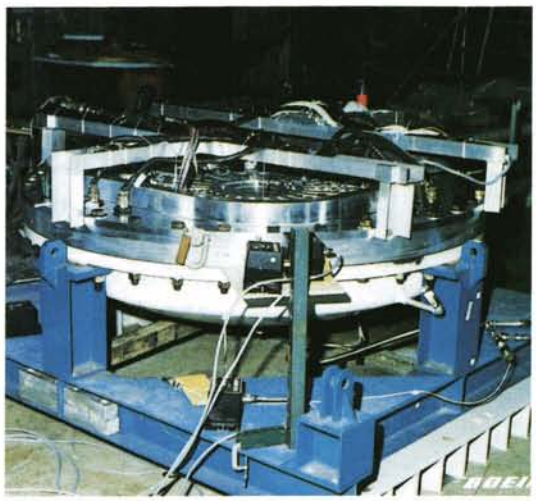
Third, *Freedom* will be an engineering testbed in low Earth orbit, a place for learning how to build, operate and maintain space systems and for developing the equipment, logistics and know-how for further exploration of space.

This is a test article of the International Standardized Payload Rack, an all-composite frame that houses multiple modular experiment packages aboard Space Station Freedom. There are 43 experiment racks in the station's three pressurized laboratories and 12 more housing station equipment; each is 60 pounds lighter than an aluminum counterpart.

Space Station *Freedom* will be roughly the length of a football field (including both end zones), measured along the pre-integrated horizontal truss. Attached to the truss will be four pressurized modules: the U.S. built habitat, home for the crew of four; and three laboratories — the U.S. Laboratory Module, ESA's *Columbus* attached laboratory, and the Japanese Experiment Module. All of the habitat/laboratory modules have Earth-like atmosphere; two nodes with the same environment serve as passageways for astronauts or equipment moving from one module to another.

At Marshall Space Flight Center's water and air recycling testbed, engineers are testing *Freedom's* Environmental Control and Life Support System, which must cleanse water for reuse, revitalize pressurized atmospheres and process waste products.

At far right, a space station hatch mechanism prototype undergoes engineering test at Marshall Space Flight Center.



Also attached to the truss is the Canadian Mobile Servicing System, which will play a major role in assembling *Freedom* and thereafter will be used to support astronaut extravehicular activity and load/unload materials from docked Space Shuttle Orbiters.

Freedom is being developed by three teams of contractors performing as many "work packages" under the supervision of three NASA centers. Marshall Space Flight Center, with prime contractor Boeing Defense & Space Group, has responsibility for the U.S. habitat and laboratory modules, associated systems, logistics elements and payload operations. Johnson Space Center and McDonnell Douglas Space Systems Company are teaming on the truss structure, resource node outfitting, various flight systems, crew training and flight operations. Lewis Research Center, with prime contractor Rocketdyne Division of Rockwell International, is in charge of development of *Freedom's* complete power system and associated software.

Ames Research Center is responsible for the station's centrifuge facility, which will support life sciences research in orbit. Kennedy Space Center will handle payload processing, Shuttle launches and Orbiter off-loading after mission to the space station. Langley Research Center's assignment is to define space station evolution to meet future needs, such as research and development on growth requirements, support of lunar missions and support of a manned expedition to Mars. ●

In short-term weightlessness aboard a KC-135 research aircraft, an astronaut team tests a special type of treadmill designed to allow astronaut exercise aboard Space Station Freedom with minimal disturbance of microgravity experiments.

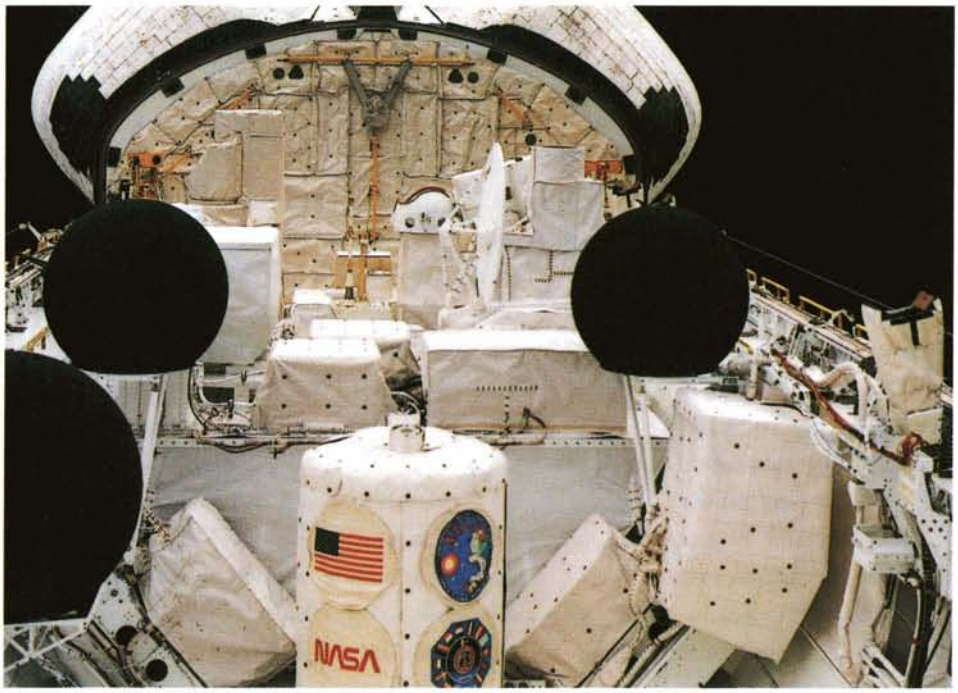
Space Shuttle Operations

The first Space Shuttle mission of 1992 began on January 22 when flight STS-42, Orbiter *Discovery*, was launched into orbit carrying the Spacelab International Microgravity Laboratory (IML). Developed by the European Space Agency (ESA), Spacelab is a multiple-use orbital laboratory, carried in the Shuttle Orbiter's cargo bay, that can include combinations of pressurized modules and unpressurized pallets; for this mission, a "long" module accommodating four astronauts in shirtsleeve environment was employed.

The seven-day mission was devoted largely to life sciences and materials processing experiments developed by more than 200 scientists representing NASA, ESA, the Canadian Space Agency, the French Center for Space Studies, the German Space agency and the Japanese National Space Development Agency. In addition to more than 40 primary experiments, *Discovery* carried 10 secondary payloads, including a Chinese Society of Astronautics experiment involving study of simulated space debris. A major NASA experiment, contained in a Gravitational Plant Physiology Facility, tested the influences of gravity and light on plant growth.

An example of the research performed during the IML flight is shown at **top left**, where mission commander Ronald J. Grabe is operating a computer at a specially designed workstation. The Mental Workload and Performance Experiment involved evaluation of a workstation developed specifically for operating computers under microgravity conditions (on a prior mission, crew members experienced difficulties at a workstation designed along Earth-use lines). Information from the experiment will aid in designing workstations for future Spacelab missions and for Space Station *Freedom*.

At **lower left**, astronaut David C. Hilmers (striped shirt) and ESA payload specialist Ulf Merbold conduct a visual stimulator test. Merbold is staring into a rotating dome with a pattern of colored dots on its interior and at the same time turning a knob indicating his perception of body rotation. The test was an experiment in space adapta-

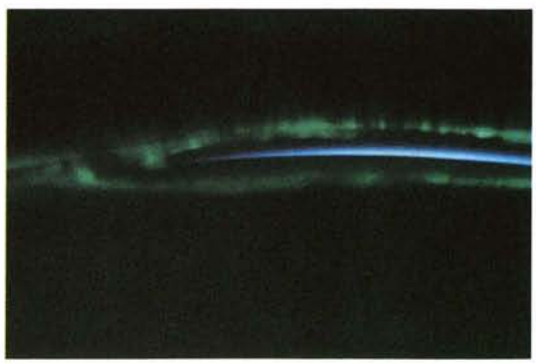


tion, an effort to learn how much subjects rely on visual information instead of inner ear sensing.

Flight STS-45, Orbiter *Atlantis*, launched March 24, carried the first of a series of ATLAS (Atmospheric Laboratory for Applications and Science) payloads; **at left** is an unusual low angle view of the launch. The ATLAS program is intended to develop a broad database of atmospheric information to enable informed decisions on global environmental matters. ATLAS-1 was the first manned flight in the Mission to Planet Earth program.

The ATLAS-1 payload included 14 instruments, most of them mounted on two pallets in *Atlantis'* cargo bay and operated by astronauts on the Orbiter's aft deck. Shown **above** is a cargo bay scene showing the ATLAS-1 payload. The cylindrical package in the foreground, with the U.S. and foreign emblems, is the "igloo," which contains avionic equipment for command, control and data handling support for the experiments. The three dark spheres are part of Japan's SEPAC (Space Experiments with Particle Accelerators) package. SEPAC's electron beam gun generated streams of electrons to create artificial aurorae for study of the interaction of solar energy and Earth's magnetic field. The crew also photographed natural aurorae. Shown **below** is a view of the Aurora Australis, or Southern Lights; the green auroral activity engulfs the thin blue line that marks Earth's limb (edge). The payload packages were developed by a multinational team representing NASA, ESA, Belgium, France, Germany and Switzerland.

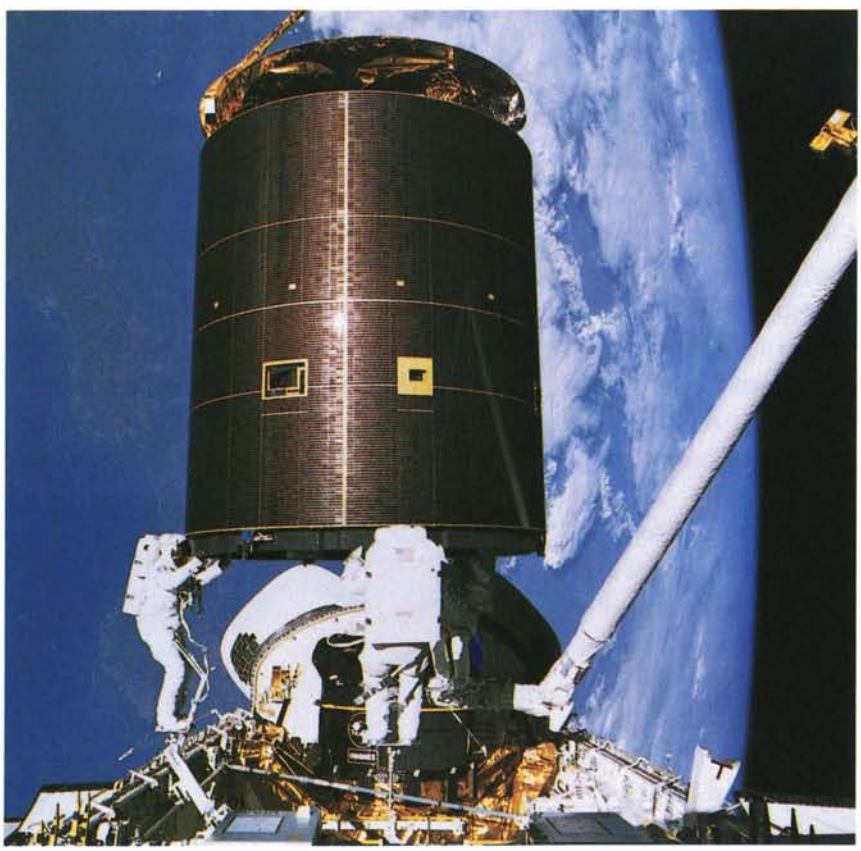
The ATLAS instruments studied the chemical composition of the atmosphere, the transfer of energy from the Sun to Earth's atmosphere, and the effects of pollutants on Earth's environment. The ATLAS program seeks to develop a general information base on how Earth's atmosphere and climate are affected over the length of a solar cycle (11 years). A second ATLAS flight is planned for 1993 and the long range plan contemplates as many as eight additional flights at the rate of about one a year. (Continued)



Space Shuttle Operations (Continued)

The Space Shuttle Orbiter *Endeavour* lifted off the launch pad on its first flight in the evening of May 7, bound for a dramatic rescue of the 4 1/2-ton commercial communications satellite INTELSAT VI. Mission STS-49 subsequently set a record as the first U.S. orbital flight with four EVA (extravehicular activity) forays and another as the first flight of any nation wherein three astronauts conducted EVA at the same time.

The dynamics of the big INTELSAT VI in microgravity conditions foiled two attempts to capture the satellite with a specially designed capture bar. This resulted in an intense effort by the Shuttle crew and scores of technicians on the ground to invent a technique whereby three astronauts would simultaneously grapple the satellite.

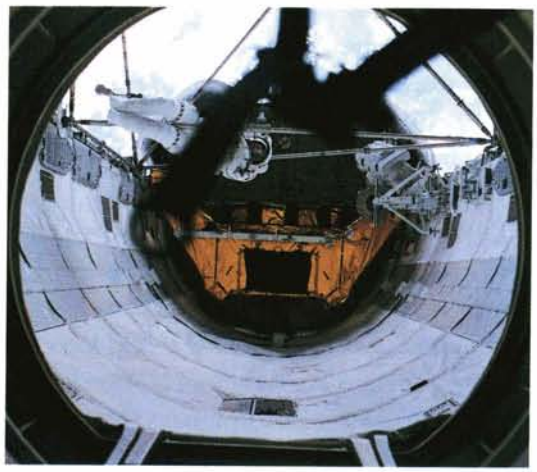


That was successfully accomplished in an 8 1/2-hour EVA on May 13 by astronauts Thomas D. Akers, Richard J. Hieb and Pierre J. Thuot. It was the longest EVA in space history.

The photo at **lower left** shows the moment of capture as *Endeavour* orbited above Mexico; Hieb is at left, Akers in center photo and Thuot, on the far side of the satellite is visible only at the lower limbs. The astronauts maneuvered the satellite onto a replacement rocket motor mounted in the cargo bay which, on the following day, boosted the satellite into a transfer trajectory that would eventually allow INTELSAT VI to begin communications relay from geosynchronous orbit (the satellite commenced operations in mid-July).

The rescue was not the only important activity of STS-49. The crew also conducted an evaluation of hardware concepts and assembly techniques that may be employed in assembling Space Station *Freedom*. The EVA participants in the Assembly of Station by EVA Methods exercise were astronauts Akers and Kathryn C. Thornton. At **top right,** Akers is positioning a strut. At **top center,** Akers and Thornton are seen in a view of the cargo bay taken from the airlock. They were assisted in their assembly tests by astronaut Bruce Melnick, who operated the shuttle manipulator arm from the Orbiter's cabin.

Akers and Thornton built a 15 by 15 by 15-foot truss structure segment in the cargo bay, then simulated attachment of modular nodes to the truss; this was a preview of an actual task planned for assembly of Space Station *Freedom*. On STS-49, the simulation involved attachment of a Mission Peculiar Experiment Support Structure to the truss segment.



Endeavour made its first landing (**below**) on May 16 at Edwards Air Force Base, California after a highly successful nine-day mission. The landing itself was one final test, an evaluation of a new drag chute system.

The fourth Shuttle mission of the year, STS-50, launched June 25, was the longest ever flown — 14 days. It marked the first flight tests of modifications made under NASA's Extended Duration Orbiter program, which contemplates eventual 60-day capability. The mission was flown by the Orbiter *Columbia*, which was equipped with extra fuel tanks for the Orbiter's electricity-generating fuel cells, together with other duration-extending modifications.

STS-50 marked the first flight of the U.S. Microgravity Laboratory (USML), a facility contained within a Spacelab pressurized long module. USML-1 involved 31 major experiments in four broad areas: materials science, fluid physics, combustion science and biotechnology. ●

Technology Development

NASA's Integrated Technology Plan contemplates a broad program of technology development in two main areas: the research and technology base (R&T) and the Civil Space Technology Initiative (CSTI).

The R&T base effort involves generic research in such key disciplines as propulsion, materials and structures, thermal management, automation and robotics, human support, aerothermodynamics, information sciences and communications.

The CSTI program embraces focused technology projects to demonstrate new capabilities needed for advanced missions. CSTI research delves into five areas of technology advancement: space science, planetary surfaces, space transportation, space platforms and operations. Technology development projects range from small low-budget experiments to full-scale development of prototype systems.

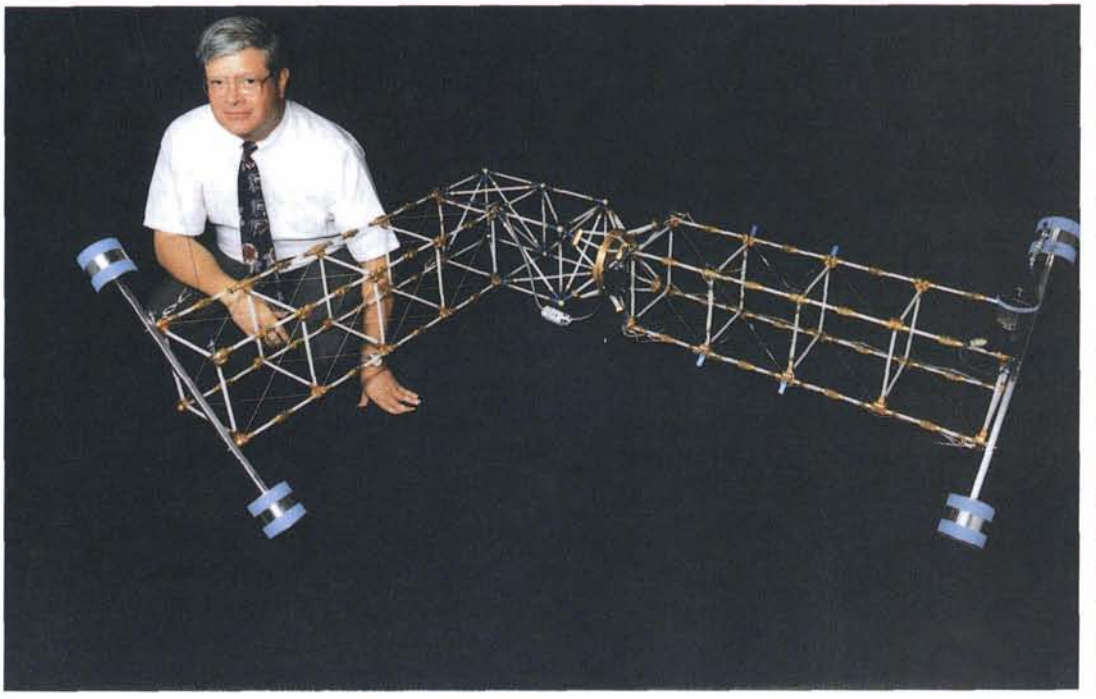
Representative of projects with potentially large payoff that can be accomplished for relatively small financial outlays is the In-Space Technology Experiments Program (IN-STEP), in which flight experiments are conducted as secondary payloads aboard the Space Shuttle or on expendable launch vehicles. Established in 1987, IN-STEP sponsors technology experiments from NASA, industry and universities for evaluation or validation in the space environment. More than 40 experiments have been approved and more are to be selected.

An example of an IN-STEP project is the Middeck O-gravity Dynamics Experiment (MODE) flown aboard Shuttle flight STS-48 in September 1991. Designed by Massachusetts Institute of Technology, MODE was an in-orbit study of the mechanical and fluid behavior of components for future space structures, such as Space Station *Freedom.* Langley Research Center is MODE program manager and McDonnell Douglas Space Systems Company, prime contractor for *Freedom's* central truss, is a cost-sharing program participant.

Testing space structures under Earth-gravity (1G) conditions poses problems because gravity significantly influences their dynamic responses. Additionally, the suspension systems needed for tests at 1G further complicate gravity effects. Models of space structures intended to operate in zero gravity, or microgravity, can be tested more realistically in the weightless conditions of orbit.

MODE consisted of electronically instrumented hardware and test articles tended by astronauts in the Shuttle Orbiter's pressurized middeck. The experiment studied the sloshing of fluids in partially-filled containers and the vibration characteristics of jointed truss structures. MODE occupied 3 1/2 middeck lockers; one contained the Experiment Support Module (ESM) that controlled the experiment, the others held the fluid test articles and the structural test article, a six-foot model of a large space structure tested in four different truss configurations (**at left** is the ESM with a fluid behavior experiment attached; **above,** Langley MODE manager Robert W. Buchan poses with an L-shaped truss configuration).

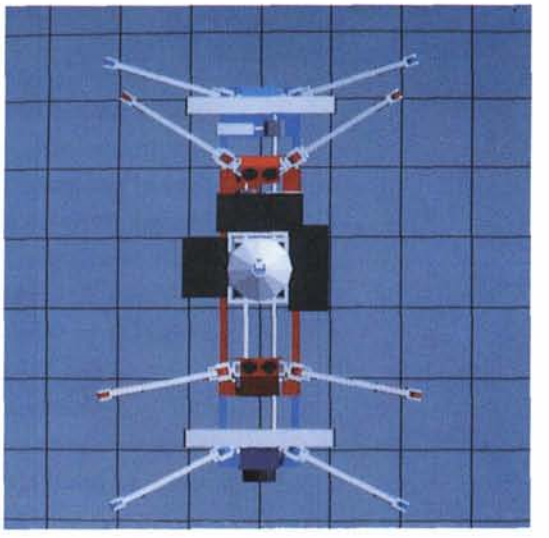
Another example of a technology



development is one that will simultaneously accomplish an Earth exploration objective and preview important planetary exploration technologies. At year end 1992, a pair of robotic vehicles will explore an active volcano, Mount Erebus in Antarctica, part of a NASA/National Science Foundation program designed to use the Antarctic environment as a surrogate planetary environment.

Developed by Carnegie Mellon University, the two mobile robots will work as a team, one a transporter, the other a rappeller. The transporter, a crawling robot, will carry the rappeller to the volcano crater, navigating with a combination of stored maps and local terrain sensing. The rappeller (**right**), a legged robot with a payload of scientific instruments, will descend into the volcano, gather data, collect samples, analyze gases, take photos and return to the transporter. Human interaction with the robots will be accomplished from a base camp on the mountainside equipped with robot controls, displays and computers to process commands and robot data.

Project Erebus is expected to provide fundamental insights into the construction and control of environmentally survivable, capable robotic systems. The perception component of the research will advance the state of the art in mapping rugged terrain. The approaches used for modeling the sparsely featured terrain and objects to be encountered in the Mount Erebus mission are applicable to a wide range of navigation and manipulation tasks. The program is developing core robotics technologies applicable to both expanded operations in Earth polar regions and planetary exploration. ●



Space Exploration

The Space Exploration Initiative (SEI), as defined by NASA Associate Administrator for Exploration Dr. Michael D. Griffin in 1992 Congressional testimony, is "an integrated set of activities leading to the establishment of a permanent lunar base and culminating in the human exploration of Mars."

Those goals are for 21st century accomplishment. For the remainder of the 20th century, NASA's Exploration Program Plan contemplates a series of affordable,

unmanned "precursor" missions; initial efforts toward developing hardware for the first human missions of SEI; and investigation of the many technologies involved in the longer term human missions — for example, lightweight materials, nuclear propulsion, nuclear power, life sciences, radiation protection and life support systems. In Dr. Griffin's words:

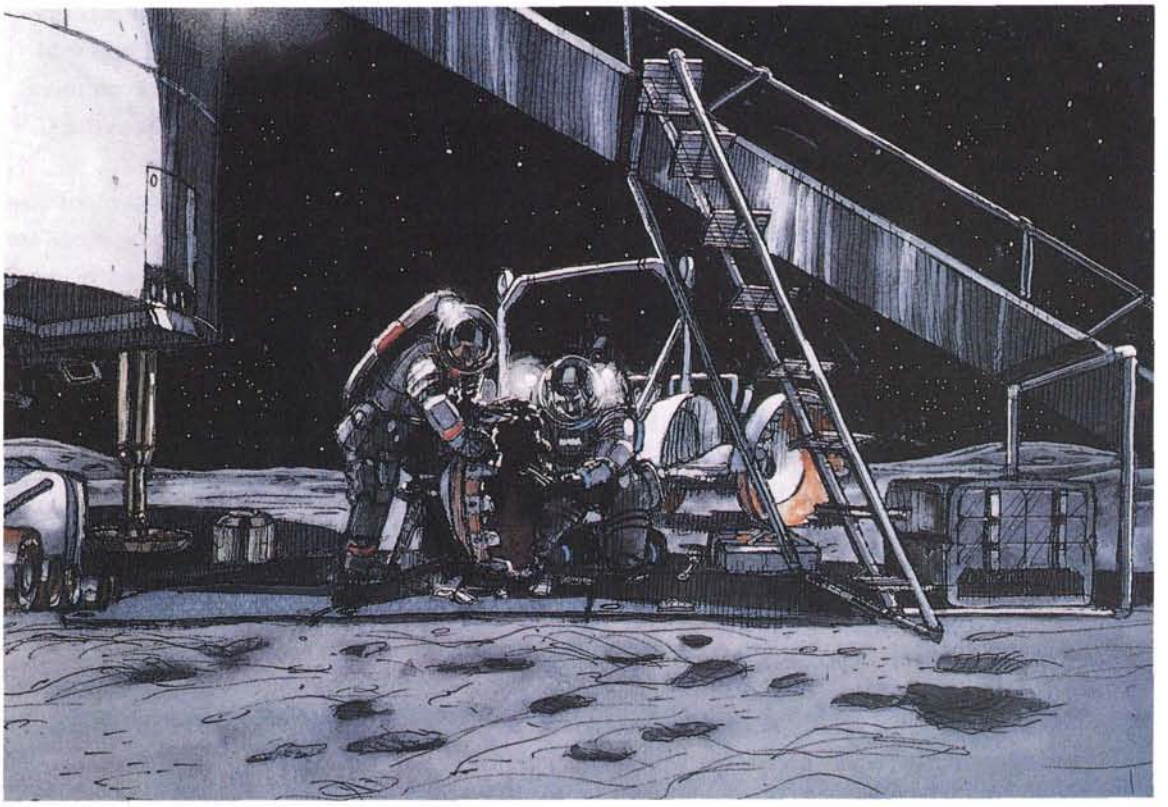
"Our near-term strategy is twofold. First, we need to start small, to develop and conduct small-scale, robotic/automated precursor missions designed to fill the gaps in our scientific and technical knowledge. Second, we need to do it with a management culture that can be relied upon to 'do it right,' on budget and on time. Only then will precursors give way to piloted missions."

The first candidate precursor missions will be lunar resource and terrain mappers, both targeted for launch in 1996. Using the Moon as the initial target for precursor missions makes sense, SEI planners believe, in terms of leveraging existing knowledge and ease of access, as well as preparing for an eventual permanent base on the Moon.

The resource mapper will concentrate on analyzing and mapping the chemical composition of the Moon; the terrain mapper will chart the lunar topography and gravity field.

These and later precursors will collect data for three types of maps that would constitute a knowledge base for advanced exploration:

- Resource maps containing information about the nature and distribution of lunar and Martian resources. Such maps will have a major impact on subsequent decisions. For example, resolving the question about whether there is water ice at the lunar poles would be a principle factor in locating a lunar base.
- High resolution terrain maps, needed to assist in determination of suitable landing sites, planning lunar/Martian traverses, and conducting other surface activities.
- Gravity maps, an important need identified by the Apollo lunar landing program, wherein navigational difficulties were experienced in low lunar orbit on some missions, due to insufficient understanding of the Moon's gravitational field; further characterization of both the lunar and Martian gravitational environments is essential to full-scale human exploration.



AFFORDABLE, UNMANNED PRECURSOR MISSIONS WILL PRECEDE ADVANCED HUMAN EXPLORATION

Other robotic missions are planned to advance capabilities in navigation, communications and surface exploration.

Where earlier human missions relied on ground tracking stations and spacecraft on-board systems for navigation, a more effective approach now contemplated involves emplacement of a constellation of radio beacons in lunar and Martian orbit to enable precise, real-time position determination with greater accuracy at lower cost.

Communications between the lunar and Martian surfaces and Earth would be accomplished by an orbiting communications satellite, or by a network of such satellites; such a system would allow lighter, less expensive exploration vehicles and reduced dependence on Earth-based communications facilities.

While most of the robotic preliminaries to human exploration can be accomplished by orbiting spacecraft, filling all the data gaps requires landing spacecraft on the Moon or Mars. This demands developing a capability for landing payloads of roughly 400-500 pounds to deploy roving vehicles, acquire surface and sub-surface samples, and perhaps return samples to Earth.

The relatively small precursor spacecraft will be launched by Delta-class vehicles and mission costs will be significantly lower than earlier-planned exploration flights to meet the requirements of a "go as you pay" budgetary environment. Conducting several small missions, as opposed to one large mission, minimizes both technical and programmatic risk. The engineering complexity of a mission increases sharply with the number of payloads involved. Since cost increases with complexity, keeping the number of payloads to a minimum keeps costs down and improves the chances of a problem-free mission. The multiple smaller mission philosophy also bars the possibility of a major failure derailing the entire program, and it provides more opportunities to build effective management discipline. ●

Trailblazing Future Flight

INVESTIGATION OF TECHNOLOGY NEEDS FOR TOMORROW'S SUPERSONIC PASSENGER TRANSPORTS HIGHLIGHTS SELECTED EXAMPLES OF AERONAUTICAL RESEARCH

In 1991, U.S. manufacturers produced $27 billion worth of airline transport aircraft and sold $20 billion worth of them to foreign customers, according to Aerospace Industries Association. That underlines the great benefit to the U.S. economy and international trade balance of high value, high technology jetliners.

U.S. plane builders claim 60-65 percent of the world jetliner market but competition from abroad continues to intensify. Aircraft and engine manufacturers of several nations are developing advanced subsonic jetliners and conducting studies toward getting an early jump on the next plateau of international aviation competition: the long range, economical, environmentally acceptable second generation supersonic passenger transport, which could be flying by 2005.

Committed to continuing a leadership role in developing the knowledge base for emerging new technologies, NASA is conducting research to support American manufacturers' own technology development efforts. Along with a variety of programs designed to enhance the safety, productivity and efficiency of subsonic jetliners, NASA is cooperating with U.S. engine and airframe manufacturers on a High Speed Research program that focuses on the environmental concerns that might preclude full scale U.S. industry development of a supersonic transport: the effects of engine emissions on the stratosphere, airport noise and the sonic boom.

The most critical technology need is an advanced combustion concept to reduce nitrogen oxide (NOx) emissions, which are expelled in jetliner exhaust to react with the atmosphere and deplete ozone. NASA is collecting data from research aircraft and satellites and using it to develop, test and evolve computer models that estimate the impact on the atmosphere of NOx emissions. Initial results suggest that there are potential operating areas in the lower stratosphere where the ozone layer would be minimally damaged by a high speed transport fleet if NOx emissions could be significantly reduced below current levels.

NASA's work in this area includes laboratory experiments employing sophisticated instruments to study and develop engine burning processes that will control combustion byproducts. The goal is to cut NOx emissions by 90 percent. The key is to burn the fuel in a way that avoids excessive flame temperatures, which generate NOx at a high rate. NASA is testing two especially promising low emissions concepts.

NASA RESEARCH FOCUSES ON IMPROVING THE ENVIRONMENTAL CHARACTERISTICS OF THE SUPERSONIC TRANSPORT

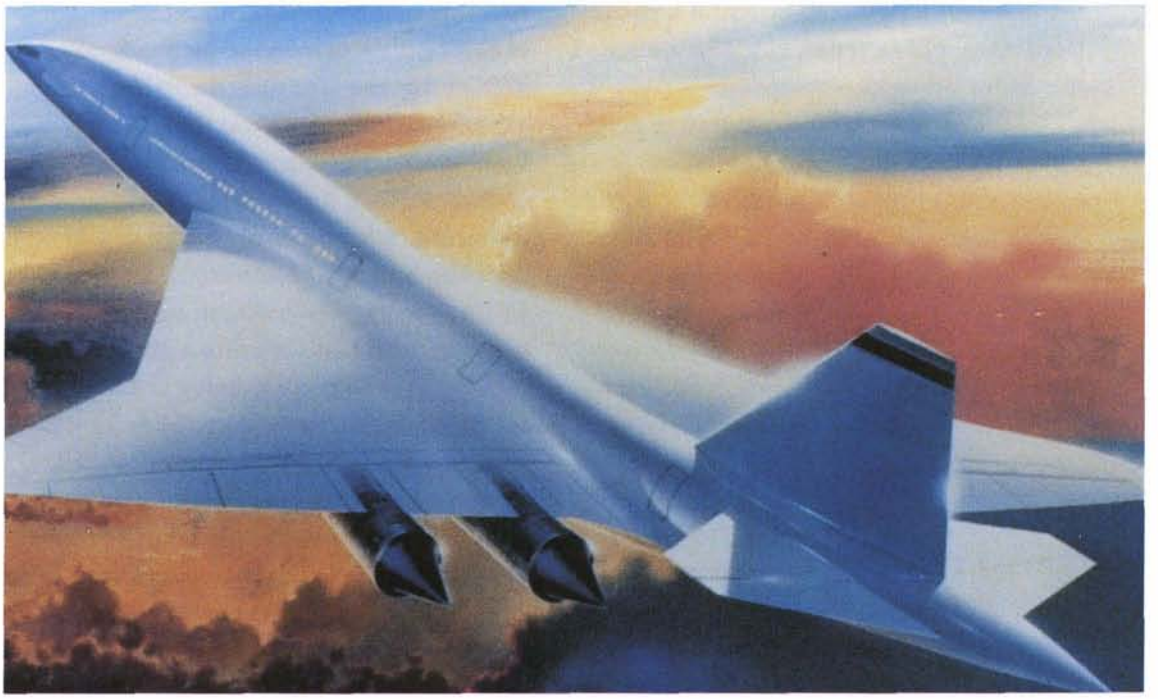
Development of advanced high temperature materials is critical to these concepts. This area of research is being addressed in a new Enabling Propulsion Materials program initiated in 1992, a NASA/industry effort that brings together the nation's three foremost engine materials research groups: Lewis Research Center, General Electric Aircraft Engines and Pratt & Whitney Division of United Technologies.

NASA awarded the two manufacturers five-year contracts to develop, process and evaluate ceramic, intermetallic and metal matrix composite materials for high temperature turbine engine applications. Early work focuses on developing small diameter composite fibers that can withstand temperatures from 2375 to 3000 degrees Fahrenheit.

Existing supersonic transports generate high airport noise levels but they are

exempted from noise regulations. However, the next generation supersonic transport will have to meet the same community noise standards as subsonic jetliners.

One approach to achieving acceptable airport noise levels is an engine configuration that has lower jet exhaust velocity at takeoff — like the high bypass turbofans that power today's subsonic transports — and a separate high velocity turbojet cycle for best supersonic cruise performance. This "variable cycle" engine would switch to the turbojet cycle after accelerating through the sound barrier at high altitude.



A NASA program addresses the technology needs of future supersonic airliners, such as the concept pictured, a Boeing Commercial Airplane Company design.

A second approach is use of noise-suppressing exhaust nozzles that reduce sound levels without sacrificing aerodynamic performance. The mixer-reactor concept — a nozzle that mixes low energy outside air with high energy engine exhaust — appears to be the most promising design. GE Aircraft Engines and Pratt & Whitney are working with NASA on this phase of the effort; Langley Research Center is also playing a major role, testing a series of different nozzle configurations in its Jet Noise Laboratory.

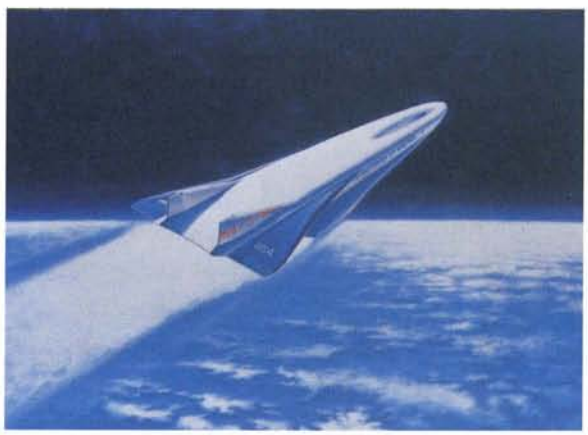
The third major area of environmental concern — the boom created by shock waves generated during supersonic flight — is being addressed by Langley and Ames Research Centers. They are conducting "boom shaping" research, which involves aerodynamic shaping of wing and fuselage sections to reduce the apparent boom at ground level. Since 1990, the two centers have been wind tunnel-testing scale models of low boom configurations. Langley is conducting complementary tests with volunteer subjects in a sonic boom simulator to determine the boom level that is generally considered not objectionable to the public. This research has economic as well as environmental implications: the ability to operate overland, perhaps in specially designated corridors, is vital to airline acceptance of the supersonic transport.

The engine research also influences operating economics, as does another aspect of the High Speed Research program, which seeks to increase the supersonic transport's fuel efficiency by smoothing the airflow over the wing and dramatically reducing the drag generated by air friction on the airplane's skin (see page 25). ●

Hypersonic Research

Shown **below** is an artist's conception of the X-30, an experimental research vehicle intended to explore flight within and beyond the atmosphere at speeds up to 25 times the speed of sound. It is the planned centerpiece of the National Aero-Space Plane program being jointly conducted by NASA and the Department of Defense, aided by a team of five major aerospace companies.

The program is structured to develop the technology for a revolutionary class of spaceplanes capable of taking off and landing horizontally like an airplane and flying directly into Earth orbit. Such craft would offer access to space with airplane-like flexibility and high responsiveness and, because they would not need the extensive facilities and support personnel currently required for vertical space launches, they promise substantial reduction in operating costs.



The X-30 is a "lifting body" type of vehicle whose fuselage produces aerodynamic lift. The airframe structure will be made of strong, heat-resistant titanium alloys with the hottest spots protected by carbon-carbon panels or active cooling. The X-30 will be powered through most of its flight regime by several "scramjet" (supersonic combustion ramjet) engines burning a mix of liquid hydrogen carried aboard and oxygen scooped up from the atmosphere. The vehicle will also have a low-speed propulsion module for takeoff and landing. Several small rocket motors will provide the final boost into orbit and the slow-down for re-entry.

The X-30's carefully-shaped fuselage will also act as part of the propulsion system. The bottom of the forward fuselage will compress and feed air to the engines. The bottom rear of the fuselage will act as an exhaust nozzle to increase thrust. Studies predict that the area near the exhaust will experience low pressure as the X-30 flies at lower altitudes at speeds below Mach 3; to counteract that, the NASP team will employ a concept called "external burning" — injecting hydrogen fuel into the airstream behind the engines and igniting it — to increase nozzle and net thrust pressure.

This concept is being considered for flight testing to validate the technology aboard a Mach 3-plus Lockheed SR-71A research plane (**below**), one of three on loan to NASA from the Air Force. For the experiment, a 10-foot half-scale model of an X-30 type aft engine cowling and exhaust nozzle would be mounted atop the SR-71A's fuselage.

A decision as to whether to proceed with the construction of the X-30 is scheduled for September 1993. ●

Rotorcraft Research

Below is an Army UH-60A Black Hawk helicopter, extensively modified for its new job of serving as the primary research tool of a NASA/Army five year program aimed at expanding the ability of pilots to fly close to the ground, around

obstacles and in bad weather. Known as RASCAL (Rotorcraft/Aircrew Systems Concepts Airborne Laboratory), the helicopter will in fact be a comprehensive flying laboratory when fully outfitted.

A prime objective of the effort, being conducted at Ames Research Center, is improving the maneuverability and agility of helicopters (maneuverability refers to total helicopter performance, agility to the helicopter's speed in executing maneuvers in response to pilot commands). RASCAL will provide a realistic evaluation of such experiments as innovative computer software that determines a helicopter's response to commands; displays that provide pilots information; new guidance and navigation systems; and ways to improve helicopter weapon systems.

RASCAL will be used in three separate research programs: one to investigate maneuverability/agility with advanced flight controls; another to develop low altitude guidance algorithms and displays that will allow helicopters to automatically follow terrain and avoid obstacles; and a third that will develop ways to measure and rate helicopter agility and produce a system to help pilots fly with improved stability and control.

In another helicopter technology advancement effort, Ames Research Center is conducting wind tunnel tests of a new bearingless rotor system that offers promise for developing faster, safer helicopters that would be more cost effective due to improved maintainability and lower fuel consumption.

Developed by McDonnell Douglas Helicopter Company, the rotor system eliminates the conventional hinges and bearings connecting the rotor blades to the rotor shaft. These hinges and bearings are complex, hard to maintain and the cause of aerodynamic drag that increases fuel use. The new rotor system mimics the hinges with an elastic flexible attachment that needs no bearings. It has fewer moving parts yet allows all the necessary blade motions.

Under a NASA/McDonnell Douglas agreement, Ames is evaluating the system for an initial 10-week tunnel run in 1992 and is planning a second series of tests for 1993. Test data will remain proprietary to McDonnell Douglas for one year after completion of the tests, but NASA will have access to the data for advanced rotorcraft research. ●

High Performance Aircraft

NASA's High Performance Aircraft research program probes advanced technologies intended primarily for military aircraft but which also have potential civil aircraft applications. These activities are cooperative projects with aerospace firms, with the Department of Defense, including the Air Force, Navy, Army and the Defense Advanced Research Projects Agency (DARPA), and sometimes with international developmental teams.

An example of the latter is the X-31 Enhanced Fighter Maneuverability demonstrator (**below**) undergoing flight test at Ames-Dryden Flight Research Facility, a key effort of the NATO Cooperative Research and Development Program. An International Test Organization (ITO) under DARPA management is conducting the flight tests to collect data that may be applicable to highly maneuverable fighter aircraft. In addition to NASA and DARPA, the ITO includes representation from the Federal Republic of Germany, the U.S. Air Force and Navy, and the X-31's industrial builders, Rockwell International and Germany's Messerschmitt-Boelkow-Blohm.

Two X-31s are being flown to demonstrate the value of thrust vectoring (maneuvering by directing the exhaust engine flow) together with an advanced flight control system for close-in air combat at very high angles of attack.

The angle of attack is the angle between an airplane's wing chord and the local undisturbed air flow. Significant advantages can be gained by a pilot whose airplane is capable of stable and controlled maneuvers at high angles of attack. In such conditions, forces produced by the aircraft control surfaces are reduced, resulting in decreased control effectiveness and possible loss of control. In addition, vortices that develop at high angles of attack can produce excessive loads and vibrations leading to component failure.

Thrust vectoring "paddles" on the X-31's exhaust nozzle direct the exhaust flow to provide control in pitch (up and down) and yaw (left and right) that improves maneuverability at high angles of attack. Military officials believe that this technique can give fighter pilots a tactical advantage over planes without enhanced controls.

The X-31 was first flown in October 1990 and during 1990-92 it made 108 test flights at Rockwell's Palmdale (California) facility. After a period of maintenance, it started a second phase of flight testing at Ames-Dryden in April 1992. International pilots are making about 20 flights a month with each X-31, extending the plane's flight envelope to prepare for military utility evaluations in 1993.

Another example of high performance flight testing at Ames-Dryden involves evaluation at supersonic speeds of a new electronic control system designed to improve the performance, reliability and safety of military aircraft, future commercial supersonic transports and the hypersonic X-30 National Aero-Space Plane (see page 22).

In April 1992, a NASA F-15 research plane (**above right**) began supersonic tests of

the Performance Seeking Control (PSC), an advanced phase of a program of subsonic testing initiated in 1990. The PSC monitors the plane's computerized control systems in flight and automatically adjusts the combination of factors — such as fuel flow and air flow into the engines — to get the most thrust for the lowest possible revolutions per minute. Researchers expect the PSC-controlled F-15 to generate about nine percent greater thrust and 10 percent lower fuel consumption at supersonic cruise.

Among improvements expected are prolonged engine life due to lower operating temperatures; in the F-15, for example, every reduction of 70 degrees Fahrenheit reduces the rate of engine wear by 50 percent. In combat applications, the higher thrust shortens takeoff distance and time to climb, permitting the fighter to intercept an adversary more quickly. The F-15's airframe builder — McDonnell Aircraft Company — and engine builder — Pratt & Whitney Division of United Technologies — are participating in the PSC research program with NASA.

In support of NASA's High Speed Research program for supersonic transport technology development (see page 20), Ames-Dryden is flying a supersonic F-16XL (**below**), an experimental derivative of the General Dynamics-built F-16 fighter in service with the U.S. Air Force and allied nations, in an investigation of laminar flow control at high speeds.

The supersonic transport, flying at Mach 2 or better, is extremely sensitive to aerodynamic drag generated by air friction on the airplane's skin, which can sharply reduce the plane's fuel efficiency and range. One way to curb the drag is to siphon off the turbulent airflow to produce a smooth, or laminar, airflow over the wing.

The single seat Number One F-16XL has a "glove" test surface fitted to its left wing. A suction system draws turbulent air through millions of tiny laser-cut holes in the test section to get improved laminar flow over that part of the wing. The two-seat Number Two F-16XL will be tested with a slightly different laminar flow control system that more closely resembles the apparatus that could be installed on a high speed civil transport. ●

Windshear Prediction

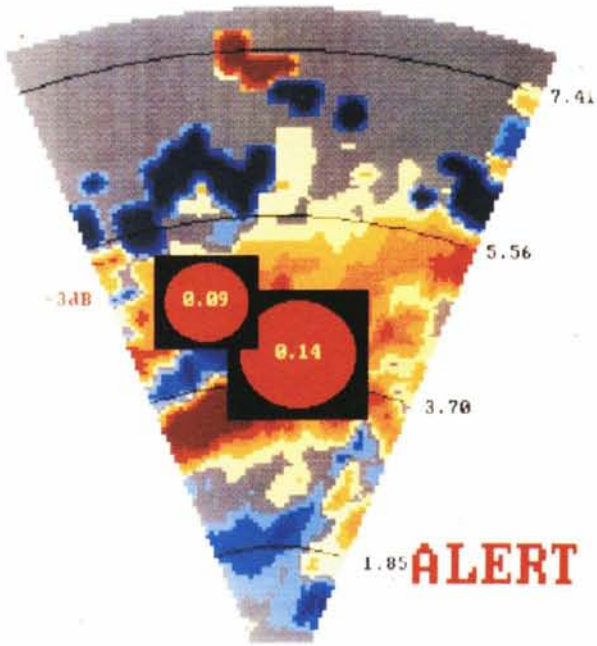
Windshear is a sudden shift in wind velocity and direction. Its most violent characteristic is the microburst, an intense downdraft that produces strong divergent winds near the ground, typically for a short duration over a relatively small area. When an airliner is taking off or landing, a microburst can force the plane into the ground before the flight crew can take corrective action.

NASA and the Federal Aviation Administration (FAA) are jointly developing technologies for avoiding the consequences of hazardous windshear. Since 1986, they have been investigating the physics of windshear, developing models for assessing the requirements and performance of windshear sensors, and conducting flight tests of sensors.

The FAA has mandated that commercial jetliners must have an approved microburst system by the end of 1995. Some carriers may opt for using "reactive" systems that employ modified versions of instruments already in operational service; such systems can advise the start of a "windshear event" as the plane enters the turbulent air of a microburst. NASA and the FAA are focusing on technologies that will provide 20-40 seconds of advance warning of an upcoming microburst.

In the final phase of the windshear research program, NASA and the FAA are testing three types of sensors aboard Langley Research Center's Boeing 737 Transport Systems Research Vehicle (TSRV). One is a LIDAR (light detection and ranging) system that uses an optical laser telescope developed by United Technologies Optical Systems Inc., West Palm Beach, Florida and Lockheed Missiles and Space Company, Sunnyvale, California. The system sends light beams ahead of the aircraft to "bounce" off atmospheric particles and return to the optical unit. Measurement of the Doppler shift of the light beam (the difference in wavelength frequency of the outbound beam and the return) provides an indicator of windshear velocity.

Another system being tested is a Doppler radar system using an antenna dish manufactured by Collins Commercial Avionics, Cedar Rapids, Iowa; the installation in the nose of the TSRV is shown **at left.** The radar, a modified aircraft weather radar, detects sudden large changes in raindrop velocities in a storm well ahead of the airplane. NASA's modifications filter out false indicators — such as cars moving in opposite directions near the air-



NASA AND THE FAA ARE EXPLORING TECHNOLOGIES TO PROVIDE ADVANCE WINDSHEAR WARNING

port — and allow windshear readings near ground level.

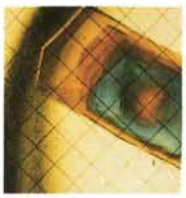
The third system, developed by Turbulence Prediction Systems, Boulder, Colorado, employs a passive infrared sensor. Because the microburst is cooler than the surrounding air, it can be detected by infrared sensing; an infrared instrument using various wavelengths senses the temperature differential one to two miles ahead of the aircraft. This sensor is also mounted in the nose of the TSRV; an external mirror reflects light through a small window to the infrared optics.

Tests in 1991 and 1992 were conducted in the Orlando (Florida) and Denver (Colorado) areas. Orlando often has moisture-filled microbursts and Denver experiences relatively dry microbursts, making the two areas excellent candidates for studying the full range of microburst conditions. Both airports have experimental ground-based Doppler radars designed to spot windshear. Information from these systems enabled flying the TSRV directly into microbursts.

The photo at **left above** shows a NASA test crew in the research cockpit of the TSRV, a second cockpit aft of the standard pilots' compartment in which pilots fly "blind," using their advanced systems and informational displays. In center cockpit are a forward-looking nose video camera monitor and a radar display that is flashing the location and intensity of microbursts. At **right above** is a closeup of a radial hazard factor display showing potentially hazardous microbursts 2-3 miles ahead of the aircraft. The plane's position is at the bottom of the cone; dark red areas indicate greatest shear intensity.

The flight tests also demonstrated a Langley-developed data link between the ground weather and the TSRV, and suggested the feasibility of deriving a windshear alert from that data and displaying it in the aircraft (warnings from ground radar are typically relayed by voice). ●

Commercial Use of Space



NASA SEEKS TO STIMULATE PRIVATE SECTOR INVESTMENT IN SPACE VENTURES TO ASSURE U.S. COMPETITIVENESS IN COMMERCIAL SPACE ACTIVITY

In October 1991, NASA announced the selection of two additional Centers for the Commercial Development of Space (CCDS) and deactivation of one earlier-established center.

The two new centers are the Space Communications Technology Center, Florida Atlantic University Research Corporation (Boca Raton) and the Center for the Commercial Development of Space in Satellite and Hybrid Communication Networks, University of Maryland Systems Research Center (College Park). These facilities were selected from 10 proposals received in response to a NASA solicitation.

The Center for Space Processing of Engineering Materials was discontinued by agreement between NASA and Vanderbilt University, Nashville, Tennessee because the center was unable to generate the requisite level of corporate support.

The CCDS are NASA-sponsored not-for-profit research consortia composed of industrial firms, academic institutions and government organizations. They were established to expand the technology base on which to build new commercial space industries and to help move emerging technologies from the laboratory to the marketplace with speed and efficiency.

Since the program was established in 1984, the number of centers has grown to 17 and the number of industrial participants to almost 200. Each of the centers focuses on a particular area of space endeavor that offers potential for commercial development and therefore attracts industry interest and participation. The 17 CCDS specialize in eight research disciplines: four are engaged in space materials processing, three in life sciences,

Astronaut John Blaha, assisted by mission specialist Shannon Lucid, is monitoring a Shuttle-based experiment in forming polymer membranes in microgravity, part of a program aimed at expanding the technology base for commercial processing of membranes, typically used in such applications as kidney dialysis and desalination of water. Polymer membrane processing and protein crystal growth are two major areas of research conducted by NASA's Centers for the Commercial Development of Space.

two in remote sensing, two in automation and robotics, two in space power, two in advanced communications, one in space propulsion and one in space structures and materials.

A new area of space-based processing is the U.S. Commercial Electrophoresis Program in Space (USCEPS), introduced in 1991 by Pennsylvania State University's Center for Cell Research (State College). USCEPS is a program designed to enable American industry to enhance the purification and processing of cells, subcellular particles, proteins, growth factors and other biological products.

The new program is the first to couple industry access to space with ground-based services. The ground-based service will allow preflight evaluation of how much improvement over ground-based methods can be expected by processing in the microgravity environment of space.

A NETWORK OF DEVELOPMENT CENTERS HELPS MOVE TECHNOLOGIES FROM THE LAB TO THE MARKETPLACE

Electrophoresis is a processing technique widely used on Earth. It separates desired biological material from a mixture by means of electrical stimulation. In several years of Space Shuttle flights that concluded in 1985, McDonnell Douglas Corporation demonstrated that an electrophoresis system in a microgravity environment could separate more than 700 times the material that could be extracted from Earth-based processing, with a fourfold increase in purity.

USCEPS builds on Penn State's expertise and on a decade of process development and flight experimentation by McDonnell Douglas, a subcontractor on the USCEPS team. The team is developing a new engineering concept and expects to have a flight-qualified electrophoresis unit ready for service aboard a SPACEHAB facility (see page 34) beginning in 1994.

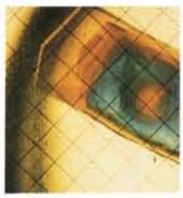
Much of the CCDS research is accomplished by secondary payloads carried in middeck lockers aboard Space Shuttle flights. Experimentation over the past year has included investigations in materials research and biotechnology. Two frequently flown experiments are polymer membrane processing and growing high quality protein crystals in microgravity.

Polymer membranes are used by industry in material separation processes. Typical applications include kidney dialysis, desalination of water and separating oxygen from air. In a program known as IPMP (for Investigation of Polymer Membrane Processing), Battelle Advanced Materials Center, Columbus, Ohio is studying the physical and chemical processes that occur during the formation of polymer membranes in microgravity in an effort to expand the technology base for commercial membrane processing techniques.

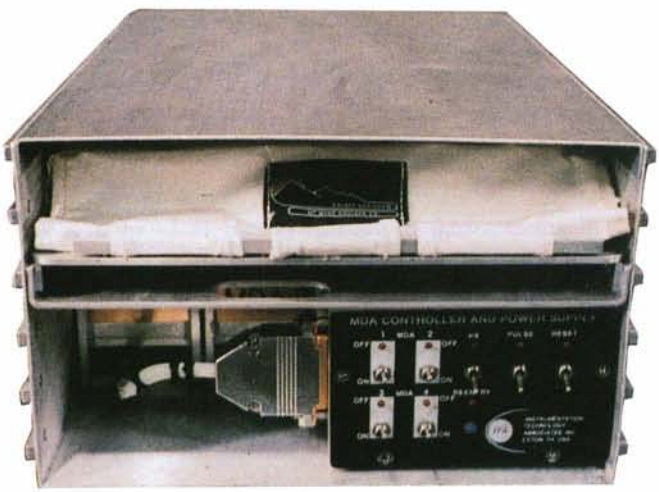
On several Shuttle flights, the Battelle CCDS has investigated an evaporation/quench process for preparing polymer membranes. The process begins by applying a sample mixture of polymer and solvents to a casting surface. The solvents are separated from the solvent mixture, then water liquid or vapor is introduced to provide a slow precipitation process and to set each membrane's structure. After each flight experiment, the samples are returned to Battelle for analysis and quantitative evaluation, in which the membranes are compared with membranes produced in Earth-based laboratories.

Battelle expects to obtain IPMP samples that are significantly different from their ground-based counterparts. Preliminary results from several IPMP missions indicate that the space process provides membranes with substantially different characteristics. (Continued)

Commercial Use of Space (Continued)



Over the past decade, there has been tremendous growth in the use of protein pharmaceuticals, such as insulin, interferons, human growth hormones and TPA (tissue plasminogen activator). As a result, there is increased demand for pure protein crystals, because high purity can facilitate Food and Drug Administration approval of new protein-based drugs that promise dramatic advances in combating many human health problems, for example, diabetes, cancer, immune system disorders, rheumatoid arthritis and emphysema.



At right is the BIMDA payload carried in a middeck locker aboard the Space Shuttle Orbiter. BIMDA is a compact system designed to accommodate a large number of materials processing experiments; its principal hardware is a set of four MDA Minilabs. Below, astronaut Jay Apt is holding bioprocessing modules in a BIMDA-based experiment to determine the reaction of live cells to hormones and other stimulating agents under microgravity conditions. Another BIMDA experiment involved growth of protein crystals (such as those pictured at far right) that are larger, purer and more uniform than typical Earth-grown crystals.

A related need of pharmaceutical researchers is large, uniform crystals, which aid in determining a protein's molecular shape, an essential step in several areas of medical research. Once the three-dimensional structure of a protein is known, it may be possible to design drugs that will either block or enhance the protein's normal function within the human body or other organism.

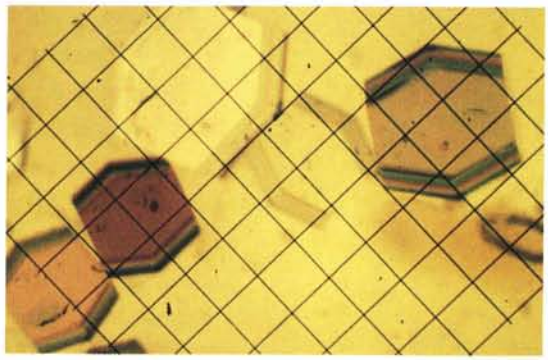
Research has shown that larger, more uniform crystals of greater purity can be grown in the microgravity environment of Earth orbit than can be made in Earth facilities. Protein crystal growth (PCG) experiments, therefore, have become a major area of flight research activity in a program jointly sponsored by NASA's Office of Commercial Programs and Office of Space Science and Applications.

PCG experiments were conducted aboard 13 Space Shuttle flights from 1985 through mid-1992. After initial investigations with prototype equipment aboard the first eight flights, an advanced Protein Crystallization Facility (PCF) was introduced on two Shuttle flights in 1991. Developed by the Center for Macromolecular Crystallography, a NASA CCDS based at the University of Alabama at Birmingham, the PCF successfully demonstrated its ability to produce crystals that are larger and better ordered than their ground-based counterparts, and also to produce a much larger quantity of crystals than had been grown on earlier Shuttle flights.

STS-49, the maiden flight of the new Shuttle Orbiter *Endeavour* in May 1992, marked the introduction of a still more advanced PCF as part of a Commercial Protein Crystal Growth (CPCG) payload. The reconfigured PCF incorporated changes needed to reduce the cost and the amount of protein sample required, and at the same time to increase the quantity and quality of the crystals. Also on STS-49 as part of the CPCG payload was a new Commercial Refrigerator Incubator Module, developed for the Center for Macromolecular Crystallography by Space Industries, Inc., Webster, Texas, to

provide a preprogrammed temperature profile for more effective crystal growing.

Another materials processing system — BIMDA, for BioServe ITA Materials Dispersion Apparatus — was introduced to commercial space experimentation on two 1991 Shuttle flights, STS-37 in April and STS-43 in August. The BIMDA payload was developed jointly by BioServe Space Technologies, University of Colorado (Boulder), and Instrumentation Technology Associates, Inc. (ITA), Exton, Pennsylvania, an industrial affiliate of the BioServe CCDS. BIMDA includes four ITA-developed Materials Dispersion Apparatus (MDA) Minilab units; an MDA controller and power supply, and a refrigerator/incubator module; a BioServe-developed Bioprocessing Testbed; and a Bioprocessing Module developed by Johnson Space Center (JSC).



PROTEIN CRYSTAL GROWTH, A MAJOR AREA OF RESEARCH, HOLDS PROMISE OF PRACTICAL BENEFIT

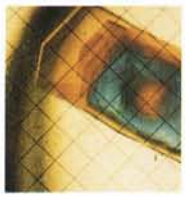
The MDA is a privately-financed facility designed to allow a large number of simultaneous experiments at low cost. Each MDA Minilab can accommodate as many as 150 samples for growing protein crystals, casting thin film membranes, and conducting biomedical and fluid science experiments.

A major experiment conducted by the MDA Minilab units of the BIMDA payload on STS-43 was the growth of a urokinase crystal in a cooperative experiment between Dr. Dennis Morrison of JSC and Abbott Laboratories, Abbott Park, Illinois. Urokinase is an enzyme used to dissolve blood clots, one of the key enzymes that cancer cells secrete as part of their mechanism of invasion and metastasis (spreading through the body system).

Growing urokinase crystals to study their structures is very difficult. Only a few small, fragile crystals have been grown on Earth and the growth took six months or more. On STS-43, a series of 20 experiments involving three different growth methods produced one small, rod-shaped urokinase crystal in less than seven days. The crystal was too small for analysis, but the experiment identified a viable technique toward eventual determination of the three-dimensional structure of urokinase, which could lead to the design of inhibiting agents and possible development of a treatment to curb cancer spread.

Starting in 1992, ITA's Minilab hardware will be offered to private industry, university and government agency researchers on a commercial basis as a low-cost, generic, orbital materials processing payload known as CMIX (Commercial MDA ITA Experiments). ●

Electronic Still Camera



Below is a photograph of the volcano Tolbachinsky in the northern Pacific area of Asian Russia, one of a series of images taken from low Earth orbit by the crew of Space Shuttle flight STS-42 in January 1992. The photo, which brings out the dramatic relief of the volcano's summit crater area, is novel because it was acquired without film. It was taken by the Electronic Still Camera (ESC) shown **at right**, which is being used in Shuttle-based tests to evaluate future space applications and the commercial potential of the new technology.

The ESC was developed by Johnson Space Center. The development evolved from a need for a more efficient method of returning high resolution imagery during long duration space missions.

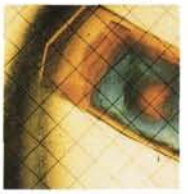
Electronic still photography provides the means by which a hand-held camera electronically captures and produces a digital image with resolution approaching film quality. Stored on removable hard discs or small optical discs, the digital images can

be converted to a format suitable for downlink transmission to Earth, or they can be enhanced on orbit using image processing software, capabilities that will significantly improve Space Shuttle and Space Station Earth observation activities.

The ESC has the basic photographic platform of a 35 millimeter Nikon F4 camera. It is converted to digital capability by placing a Charge Coupled Device at the film plane of the F4. ESC accessories include flash, zoom and wide angle lenses; removable filters can be added to provide low light capability and a modest spectral capability. Shuttle crews can view, enhance and process the images in orbit using a modified laptop computer.

STS-42 marked the second flight test of the ESC. On STS-48 in September 1991 the downlink capability was successfully demonstrated. Additional Shuttle evaluations are planned to complete a series of detailed test objectives. It is expected that successful development of the ESC will lead to advances in space photographic systems such as higher resolution monochrome cameras, high resolution full color cameras, spectral cameras and low light cameras. ●

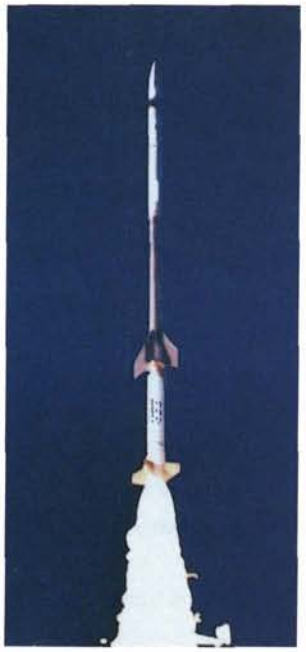
Sounding Rocket Research



In addition to making available orbital research facilities aboard the Space Shuttle Orbiters, NASA provides commercial space investigators opportunities to fly experiment packages at relatively low cost on suborbital launch vehicles (sounding rockets) that expose experiments to the microgravity environment for periods in the range of five to 14 minutes.

On November 16, 1991, a commercial launch service provider — EER Systems Corporation, Vienna, Virginia — launched its Starfire 1 sounding rocket (**below**) on a mission designated Consort 4 by its sponsor, the University of Alabama in Huntsville's Consortium for Materials Development in Space (UAH CMDS), a NASA Center for the Commercial Development of Space.

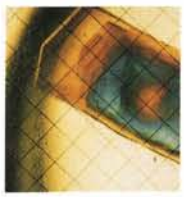
The 1,000-pound payload (shown **at right** being weighed prior to launch at White Sands Missile Range, New Mexico) included nine materials science and biotechnology payloads, which were carried to an altitude of 185 miles and exposed to microgravity for seven minutes. Integration of the experiment hardware into the Starfire 1 was handled by McDonnell Douglas Space Systems Company. Starfire 1's recovery system, which includes a heat shield to protect the payload during re-entry and a parachute to provide a soft landing, enabled successful recovery of the payload.



The payload included experiments in polymeric foam formation for space structural applications; polymer curing; polymer membrane processing (see page 29); deployment of inflatable space beams; a biomodule for study of microgravity effect on cells, plant tissues and protein crystals; liquid phase sintering of selected metallic products; powdered materials processing; fluid mixing by Materials Dispersion Apparatus Minilabs (see page 31); and an electrodeposition process for producing thin-deposited films. The latter process is commercially and medically important because it has potential for advancing the technology of human implants; electrodeposition, or coating, of certain materials could significantly lengthen the lifetimes of surgical implants such as hip joints and dental posts.

Following the successful flight of Consort 4, UAH CMDS contracted with EER Systems for three additional Starfire launches, the first — Consort 5 — projected for 1992. Another UAH CMDS sounding rocket program also employs a larger Prospector launch vehicle, which can provide up to 16 minutes of microgravity exposure; the vehicle was developed by Orbital Sciences Corporation, Fairfax, Virginia. A structural failure on its initial flight caused loss of the vehicle and payload; a second Prospector flight was planned for 1993. •

Commercial Space Developments



On April 3, 1992, SPACEHAB, Inc., Washington, D.C. unveiled its first commercial module for space experimentation (**left**). Scheduled for flight aboard the Space Shuttle in the spring of 1993, the pressurized module was developed to meet a need for additional experiment space in the Shuttle Orbiter. Carried in the Orbiter's payload bay and accessed through an airlock (**below**), it adds the equivalent of about 50 middeck experiment lockers.

Under a NASA/SPACEHAB agreement, SPACEHAB modules will be carried on eight Shuttle flights. SPACEHAB will pay NASA for launch services and will lease its module to commercial and government customers. NASA has contracted for lease and integration services for some 100 experiments to be conducted on the first six SPACEHAB flights in 1993-96; this volume will provide flight opportunities for NASA's Centers for the Commercial Development of Space and NASA/industry Joint Endeavor projects.

The module was developed entirely with private capital. McDonnell Douglas Space Systems Company, a partner in the program, conducted the design, development and production of the modules under contract to SPACEHAB, and will handle ground integration for all experiments.

Being readied for service debut is another innovative system that will significantly enhance the CCDS capability for experimentation in space: the COMET (Commercial Experiment Transporter) unmanned spacecraft that will make possible recovery of some experiment payloads for analysis on Earth, and will permit long duration orbital operation of other payloads that do not have to be recovered.

COMET is a dual spacecraft, as shown in the model at **top right**. The base section and its solar panels make up the non-recoverable service module, which has 15 cubic feet of payload volume and provides power, attitude and thermal controls; it can support experiments in orbit for a year or more after the recovery system is ejected. The service module is shown undergoing test at **right center**.

The upper module is the recoverable re-entry vehicle, which has more than nine cubic feet of payload volume, plus a recovery system that includes a parachute and an air bag to cushion final impact. Launched from NASA's Wallops (Virginia) Flight Facility by a Conestoga 1620 launch vehicle, the spacecraft is sent into orbit at an altitude of 300 nautical miles. After about a month in orbit, the re-entry vehicle is separated from the service module and returns to Earth, to be retrieved from Utah's Great Salt Lake Desert.

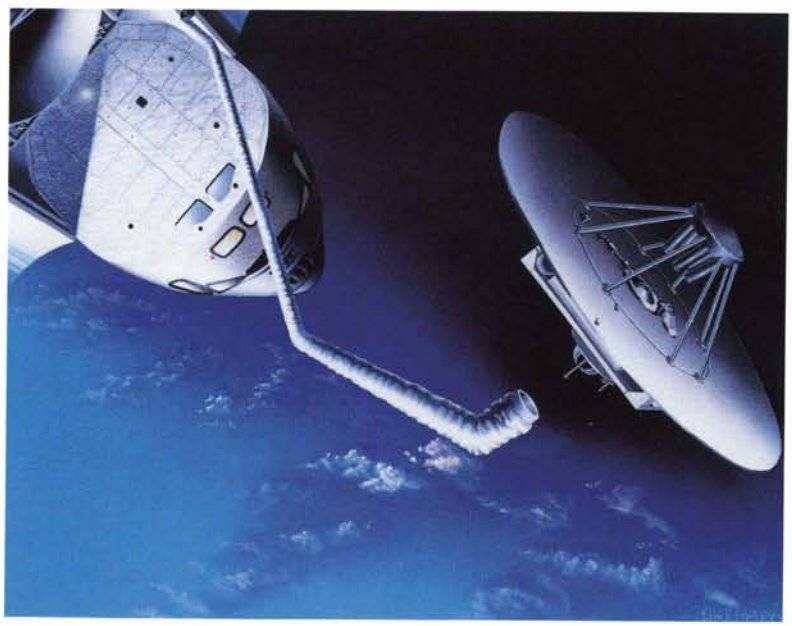
The COMET system is being provided by a three-company team composed of

Westinghouse Electric Corporation, Baltimore, Maryland (service module and systems engineering); EER Systems Corporation, Vienna, Virginia (launch vehicle and launch services); and Space Industries, Inc. (SII), Houston, Texas (recovery system, payload integration, orbital operations and recovery services). The program is managed by a group of NASA CCDS, led by the Center for Space Transportation and Applied Research at the University of Tennessee, Tullahoma.

During a flight, orbital operations are controlled from SII's Commercial Payload Operations Control Center in Houston. Data from COMET experiments is transmitted to investigators throughout the nation via a personal computer-based communications network. This system makes it possible for payload sponsors to monitor the status of their experiments and make adjustments when necessary.

In late 1993, one of the NASA CCDS — Space Vacuum Epitaxy Center, University of Houston, Texas — will begin a new type of orbital research with a novel space system called the Wake Shield Facility (WSF). Epitaxy is a term for growing crystals in a special atom-by-atom, layer-by-layer manner to produce varying crystalline structures. Epitaxial growth under high vacuum conditions can produce crystalline thin films of higher quality and purity than can be grown on Earth. Such films offer promise of important advances in superspeed computers, lasers, communications and infrared devices, and other microelectronic applications.

Developed by Space Industries, Inc., the WSF is a device that makes orbital epitaxial research possible. A 12-foot diameter disc (**below**) with its own power, command and control units, it sweeps an orbital "wake", creating an ultravacuum region behind the disc where epitaxial thin films can be grown. Carried to orbit in the payload bay of the Shuttle Orbiter, the WSF can be operated as a Shuttle system, extended from the payload bay by the Orbiter's remote manipulator arm, or it can be released to operate as a free flying spacecraft and later recovered. ●



Probing the Universe

THE EXCITING DISCOVERIES OF NASA'S ORBITING OBSERVATORIES HIGHLIGHT A RESUMÉ OF THE AGENCY'S BROAD SPACE SCIENCE PROGRAM

Earth's atmosphere absorbs or blocks out almost all of the invisible radiation emanating from the stars. Earth-based telescopes, therefore, can never view the total universe, only the small portion of it that radiates in visible light and very small bands in the infrared and radio regions.

The advent of orbital observatories has contributed enormously to astronomical advancement because it has put the telescopes above the atmosphere and enabled them to "see" in all bands of the electromagnetic spectrum, including the full ultraviolet, infrared, x-ray and gamma ray ranges. This capability is particularly important to astronomical science; it makes possible observations in a broad spectrum of once invisible radiations, and each band of the spectrum offers a different set of clues to the origin and evolution of the universe.

During the first three decades of the space age, NASA operated a number of orbiting observatories that opened a new window on the universe, but generally they were restricted by limited spectral coverage.

Today, astronomical science is taking a giant step forward with a series of highly advanced, extrasensitive orbiting observatories dedicated to covering specialized segments of the electromagnetic spectrum. These spacecraft and others to follow will collectively be able to examine the full range of radiation in the universe and produce a comprehensive picture of the cosmos that no single observatory could provide.

The centerpiece of the advanced observatories group is the Hubble Space Telescope (HST), a cooperative program of NASA and the

Acquired by the Hubble Space Telescope, this true color image of the giant elliptical galaxy NGC 1275 reveals about 50 massive globular clusters (blue dots), each containing as many as 10 million densely packed stars. Images like this are regularly providing astronomers important new data.

The Compton Gamma Ray Observatory took these images, and others like them, that enabled scientists to study the "growth" of a 1991 solar flare. Over the eight-hour span covered by the two images, the flare progressed from 100 million to 500 million electron volts. The Compton Observatory, the Hubble Space Telescope and several other observatories are contributing to a scientifically invaluable "new look" at the universe.

European Space Agency. Launched April 24, 1990, the 12 1/2-ton HST views in the visible, ultraviolet and near-infrared ranges.

HST regularly provides astronomers exciting new information about the distant cosmos. It continues to probe the chemistry of the early universe, acquiring imagery from celestial bodies billions of light years away, and it is conducting "close" observations within our own solar system, such as its examination of aurorae on the giant planet Jupiter. Searching for massive black holes in the cores of the galaxies, the space telescope found evidence of a black hole with a mass 2.6 billion times that of the Sun in a galaxy known as M87, 52 million light years distant, and another, 100 million light years away, in the galaxy M51.

In the galaxy NGC 1275, some 200 million light years from Earth, HST detected about 50 bright objects at the center of the galaxy that appear to be young massive globular star clusters — a surprising discovery because globular clusters, dense spherical collections of 100,000 to 10 million stars, are normally considered among the oldest objects in the universe.

These are just a few examples of a lengthy succession of discoveries provided by HST despite a flawed mirror detected after its arrival in orbit; innovative techniques for enhancing and reconstructing HST images have alleviated some of the effects of the optical problem and additional improvements will be made during a Space Shuttle servicing mission planned for late 1993 or early 1994. Goddard Space Flight Center has responsibility for controlling the telescope and processing its data. The center for collection and distribution of the data is the Space Telescope Science Institute in Baltimore, Maryland, operated for NASA by the 17-member Association of Universities for Research in Astronomy.

Goddard also manages and operates the HST's companion, the Compton Gamma Ray Observatory, second of NASA's Great Observatories. Launched April 5, 1991, the Compton Observatory is investigating gamma radiation, the most energetic of all forms of radiation, and its violent sources — pulsars, quasars and black holes.

Like HST, the Compton Observatory has regularly provided new discoveries. In early 1992, the observatory made the first detection of high-energy gamma rays from a class of active galaxies similar to quasars. These active galaxies — called BL Lacertae — are a type of "quasar-like" object that emits vast but varying amounts of energy. The Compton findings support the hypothesis that BL Lacertae objects, like quasars, must be powered by supermassive black holes.

The Compton Observatory component that made possible these findings is the Energetic Gamma Ray Experiment Telescope (EGRET), one of four instruments aboard. EGRET is a joint development of Goddard, Germany's Max Planck Institute and Stanford University.

(Continued)

Probing the Universe (Continued)

On June 7, 1992, a Delta II launch vehicle lofted into orbit NASA's 67th Explorer, an astronomical observatory designed to investigate space radiations never before comprehensively explored. The "last frontier of astronomy," project officials termed the target region.

The observatory is the Extreme Ultraviolet Explorer (EUVE), a 3 1/2-ton spacecraft (**below**) developed under the management of Goddard Space Flight Center to explore a wavelength band between the ultraviolet and x-ray ranges. This extreme ultraviolet (EUV) band is difficult to investigate because EUV radiation cannot penetrate the gigantic dust clouds that drift through the universe.

Earlier spacecraft, however, found that there are large areas spanning hundreds of light years that are free of dust, so the EUVE observatory will search for such "tunnels" in its quest for EUV sources. The observatory will also map the locations of the great dust clouds in the Milky Way galaxy.

EUVE carries four telescopes developed by the University of California at Berkeley. Three of them, each about the size of an oil drum, will conduct an all-sky survey to develop a catalog of EUV sources. The fourth is a combination telescope/spectrometer that focuses on specific EUV sources and analyzes the wavelength of the source.

An artist's conception of the Extreme Ultraviolet Explorer, launched in June 1992 to investigate "the last frontier of astronomy," a particular band of the electromagnetic spectrum never before comprehensively charted.

Another observatory, the infrared-viewing Cosmic Background Explorer, shown **at right,** detected variations in the background radiation that courses through the universe from all directions. This background radiation can only be explained as a remnant of the Big Bang, the theoretical monumental explosion some 15 billion years ago that triggered a uniform expansion of the universe, which has continued ever since.

The variations detected showed up as temperature fluctuations revealed by statistical analysis of maps made by COBE's Differential Microwave Radiometer (DMR), one of the observatory's three major instruments. The temperatures and sizes of the fluctuations in the background radiation support a theory that says the structure and behavior of the universe was determined by minute fluctuations that occurred when the universe was younger than one-trillionth of a second. Thus, COBE findings provide evidence to support the Big Bang theory.

To provide the scientifically invaluable maps, COBE's instruments mapped the sky as it would appear if human eyes could see microwaves at wavelengths some 10,000 times longer than visible light. Hundreds of millions of measurements were made by the DMR in the course of a year, then combined by careful computer analysis to make the sky maps.

Launched in November 1989, COBE is rounding out a third year in orbit and still gathering data on fluctuations in the background radiation in the hope of producing even

The Cosmic Background Explorer detected clues that support a theory which holds that the structure and behavior of the universe for the last 15 billion years were determined within the first one-trillionth of a second after the Big Bang.

more precise measurements. COBE is managed by Goddard Space Flight Center.

Another member of the family of advanced observatories now exploring space in different bands of the spectrum is ROSAT, short for Roentgensatellite, a joint NASA/Federal Republic of Germany spacecraft launched in June 1990. Equipped with an x-ray telescope and imaging system and an EUV high resolution imaging system, ROSAT is conducting a multiyear sweeping survey of x-ray sources and making dedicated observations of certain specific sources.

The five observatories — Hubble Space Telescope, Compton Gamma Ray Observatory, EUVE, COBE and ROSAT — are each making new discoveries regularly and, with each observing in a different band of the spectrum, collectively generating incalculably valuable data on the cosmos that may mark the decade of the 1990s as the most productive in the history of astronomy.

Their work exemplifies one of the six main disciplines in NASA's broad space science and applications program. The observatories come under the heading of astronomy and astrophysics, which generally embraces the study of the stars and galaxies toward an understanding of the origin and evolution of the universe.

The other main divisions of the program are:

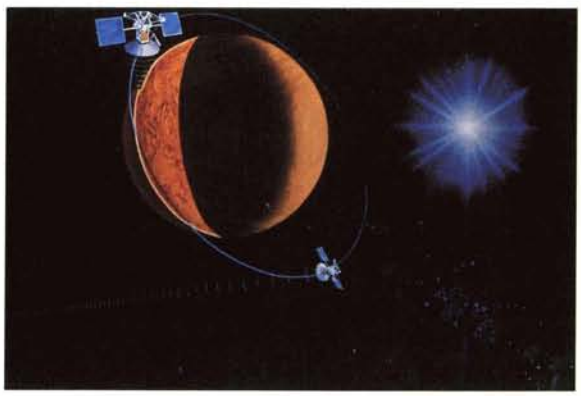
- Space physics, which involves investigation of the origin, evolution and interactions of the Sun/Earth system, including the study of plasma, ionized gases originating in the solar system and beyond.
- Earth science and applications, which seeks understanding of the factors that influence Earth's environment and ways to use that knowledge to benefit humanity.
- Life sciences, aimed at understanding the origin and distribution of life in the universe and at utilizing the space environment to improve knowledge of medicine and biology.
- Solar system exploration, which involves investigation of the planets, moons, comets and other bodies of the solar system.
- Microgravity science and applications, involving investigations directed toward greater understanding of the airless, weightless Earth-orbital environment and its effects on Earth-use materials.

Recent activities in each of these areas are summarized on the following pages; life sciences and microgravity activities are covered in the section on Space Shuttle operations (see pages 12-15). ●

Solar System Exploration

On January 15, 1992, the Magellan spacecraft began its third radar mapping cycle of the surface of Venus.

Launched May 4, 1989, Magellan made a 15-month journey to the cloud-shrouded planet, then went into an elliptical orbit around Venus (**left**) that took it within 186 miles of the surface at its closest point.



In September 1990, the four-ton spacecraft started its mapping mission, using a radar system known as the Synthetic Aperture Radar (SAR). The SAR performs three functions: collecting data for surface imaging; measuring height variations as small as 100 feet to allow construction of a topographic profile of Venus; and measuring natural thermal emissions from the planet to show surface temperature variations. Jet Propulsion Laboratory (JPL) manages the Magellan program for NASA.

Magellan's findings are of prime interest to scientists, who are intrigued by the question of why two very similar planets approximately the same mean distance from the Sun evolved in such dissimilar fashion. The scientific community expects that Magellan's data will contribute immensely to the science of comparative planetology, or relating phenomena on one planet to conditions on another. It is hoped that Earth-Venus comparisons will shed new light on Earth's complex environment.

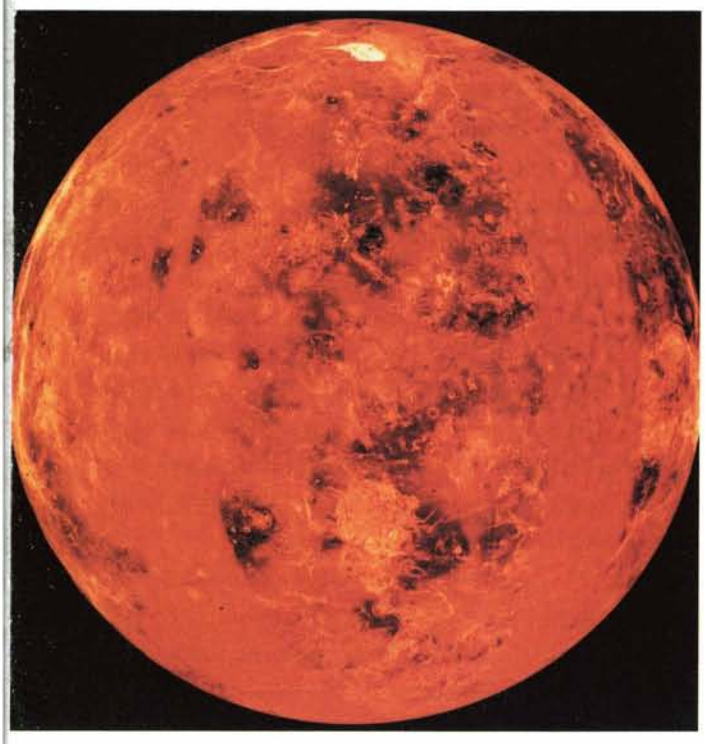
Magellan completed its first mapping cycle on May 15, 1991 (a cycle is one Venus rotation or 243 Earth days, the time it takes for the planet's surface to pass beneath the gaze of the SAR). On the initial cycle, Magellan mapped 89 percent of the planet with 10 times better detail than that of previous Venus imagery. By the end of the second cycle, 94 percent had been mapped, providing a near-global view. **At right** is a global view of the Venus surface in which SAR mosaics are mapped onto a computer simulation of the planetary surface. Where there are data gaps, they were filled by data from a prior NASA spacecraft, Pioneer Venus Orbiter. The simulated colors are based on data from two Soviet Venera spacecraft.

A global survey based on data from Magellan's first two cycles shows that about 85 percent of the planet is covered by volcanic rocks, mostly lava flows that form the great plains, according to project officials. Much of the remaining 15 percent is high-standing "chaotic" material that is faulted and fractured. No Earth-like plate tectonic fractures have been identified.

The third cycle, in progress at *Spinoff* publication time, emphasized stereoscopic imaging. Features can be imaged in stereo by looking at them twice at angles at least 15 degrees apart. Stereo imaging produces a three-dimensional picture and significantly increases scientists' ability to interpret the images.

It was planned to lower Magellan's orbit during the third cycle to 111 miles, just above the planet's dense atmosphere, for maximum sensitivity to variations in the gravity field (gravity is mapped by analysis of slight variations in Magellan's radio signal sent back to Earth). Gravity mapping was planned for a complete 243-day fourth cycle.

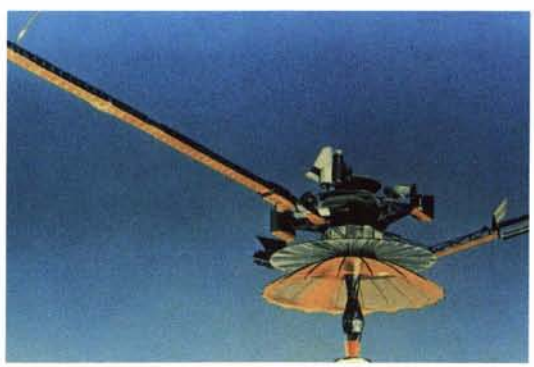
In another solar system exploration project, the Galileo spacecraft (**right**) was once again heading back to Earth on a



roundabout flight path that will eventually take it to Jupiter for an extensive study of the giant planet and its moons. A cooperative U.S./Germany project managed for NASA by JPL, Galileo was launched October 18, 1989 into a complicated trajectory designed to take advantage of multiple planetary gravity assists (using the planet's gravity to gain velocity and change trajectory).

Galileo flew past Venus early in 1990 for its first gravity assist, then made a 10-month trip back to Earth for another assist late in 1990. That assist took the spacecraft into a wide orbit, during which it flew past a 12-mile-long asteroid known as Gaspra and returned the first closeup images of an asteroid (**above right**).

At publication time, Galileo was en route to Earth for a final gravity assist in December 1992 that will send the spacecraft into the final leg of its Jupiter-bound trajectory. The new flight path will provide another opportunity to visit an asteroid — Ida — in 1993. It will also provide several opportunities to free a stuck high gain antenna that threatens to reduce the amount of data that can be sent back to Earth; the antenna is not needed for primary science objectives until



Galileo reaches Jupiter in December 1995. If those efforts fail, JPL plans to use an alternate low gain antenna that would allow accomplishment of 70-80 percent of the highest priority scientific objectives.

Galileo will release an instrumented probe that will descend into the Jovian atmosphere and acquire data on its composition. The main spacecraft will swing into orbit around Jupiter, imaging the planet and its moons with far better resolution than those attained by predecessor planetary spacecraft. JPL designed and built the main spacecraft; Ames Research Center has overall management responsibility for the probe, which was built by Hughes Aircraft. ●

(Continued)

Solar System Exploration (Continued)

Early in 1992, 16 months and 617 million miles after its launch from Earth, the Ulysses spacecraft (**below**) reached Jupiter and used the planet's gravity to make a major change of course in its four-year journey to the Sun. The gravity assist technique — in which a planet's gravity is used as a "slingshot" to accelerate a spacecraft and alter its trajectory — took Ulysses out of the plane of the ecliptic, an imaginary plane that approximates the plane in which all the planets orbit the Sun; thus the spacecraft entered a region of space, the space out of the ecliptic, that has never been explored.

On its new course, Ulysses is headed toward the Sun's south pole, which it will reach in June 1994. Ulysses is a joint project of NASA and the European Space Agency (ESA) managed for NASA by Jet Propulsion Laboratory (JPL).

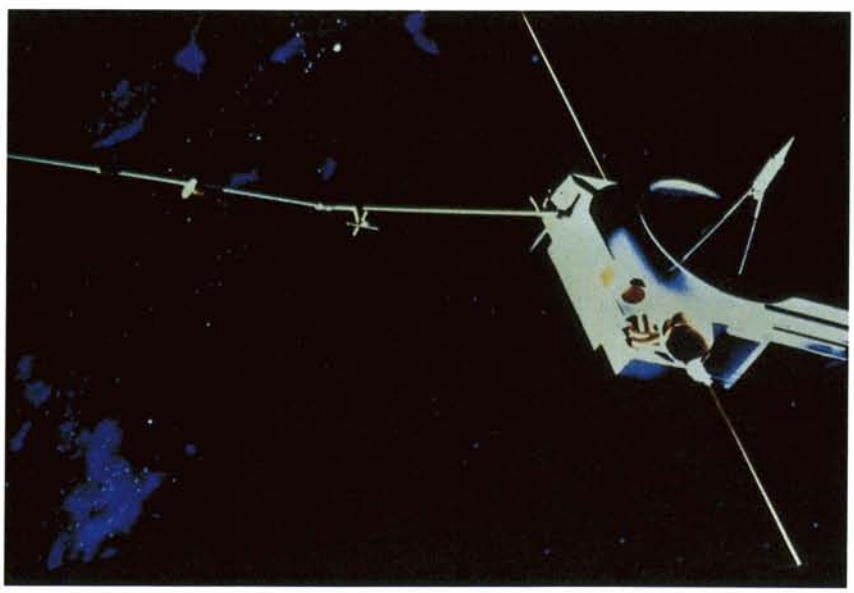
The unprecedented maneuver around Jupiter afforded scientists an opportunity to investigate Jupiter's magnetosphere, the region of space dominated by the giant planet's magnetic field. During the spacecraft's two-week journey through the magnetosphere, Ulysses' special complement of nine instruments returned data from the high latitudes of Jupiter, another area never before investigated. Science experiments generally examined the interaction of the magnetosphere with the solar wind and studied other phenomena within this magnetic bubble.

When Ulysses arrives in the vicinity of the Sun, it will spend four months studying the Sun's south polar region, then cross the solar equator (February 1995) and begin a four-month investigation of the north polar region. Closest approach to the Sun will be about 130 million miles.

During its passage by the Sun, Ulysses will study three general areas of solar physics: the Sun itself, magnetic fields and particles generated by the Sun, and interplanetary space above the Sun. Ulysses' instruments will seek data to help scientists understand how the Sun creates and controls virtually all of the major processes affecting the solar system.

A new planetary investigator joins the NASA solar system exploration spacecraft team with the 1992 launch of the Mars Observer (**right**). A multinational project involving the U.S., the United Kingdom, France, Germany and Russia, the Mars Observer will make a two-year global survey of Mars from orbit, providing data on the planet's surface and atmosphere with the highest resolutions yet obtained and collecting new information in two general areas: Mars geoscience and climatology. JPL manages the program for NASA; General Electric Astro Space built the spacecraft.

NASA's solar system exploration plans include a comprehensive examination of Saturn from orbit by the Cassini spacecraft, a cooperative NASA/ESA/Germany



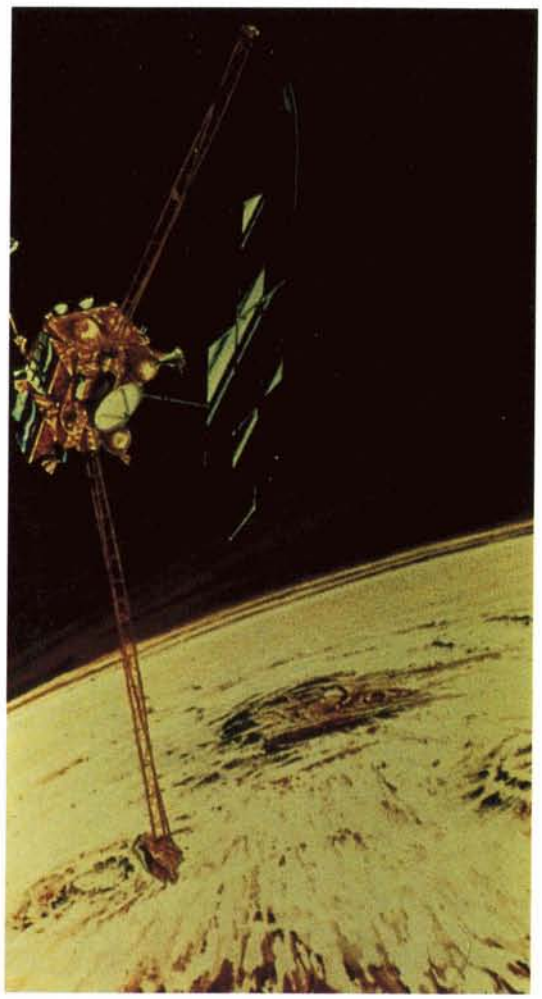
project. Targeted for launch in October 1997, Cassini will fly past Jupiter, then proceed to Saturn and go into orbit around the ringed planet for a four-year study of Saturn, its rings, its moons and its magnetosphere. Cassini will release an ESA-developed probe to descend into the atmosphere of Saturn's large moon Titan. JPL is NASA's program manager.

In May 1992, NASA announced the Small Planetary Mission Plan, which contemplates lower cost, more frequent missions to the planets by smaller spacecraft. Two initial missions are the Mars Environmental Survey (MESUR) Pathfinder, planned for launch in 1996, and the Near Earth Asteroid Rendezvous (NEAR) mission, to be launched in 1998.

NEW INTERPLANETARY INVESTIGATIONS ARE TARGETING THE SUN, MARS AND SATURN

The Small Planetary Mission Plan represents a change in solar system exploration philosophy. Most planetary missions of the past two decades involved relatively large spacecraft with broad science goals, and there were only a few such missions in each decade. The new, less expensive projects can be launched more often, affording timely new opportunities to many investigators and institutions. They can also fill data gaps in the planetary exploration program and revitalize educational interest in planetary science.

The MESUR Pathfinder is envisioned as a technical demonstration and validation flight for the MESUR program, which calls for construction of a network of about 16 small automated surface stations on Mars to study the plant's internal structure, meteorology and local surface properties. It is scheduled to begin in 1999. NASA awarded JPL a study contract for MESUR Pathfinder. The NEAR mission involves a "formation flight" in which the NEAR spacecraft would keep station with a near-Earth asteroid for up to one year. The NEAR vehicle would assess the asteroid's mass, density and spin rate, map its surface topography and composition, determine its internal properties and study its interaction with the interplanetary environment. Johns Hopkins University's Applied Physics Laboratory was awarded a contract to study the NEAR mission. ●



Mission To Planet Earth

Scientists know that mankind's activities are affecting Earth's global environment, but the outcome of the effects is unknown. Some of the effects are dramatic. The world's forests are being burned at the equivalent rate of one State of Tennessee per year. Earth's atmosphere is being loaded with carbon dioxide, a known greenhouse gas, at the rate of five billion tons per year.

Earth is the most complicated planet in the solar system. It is the only planet with oceans and life, and the interactions among the oceans and life, the atmosphere, the land surfaces and the ice produce a complex set of mechanisms that control Earth's behavior.

President Bush has proposed a comprehensive global change research effort to reduce the scientific uncertainties of pending global change, a program that represents an unprecedented level of coordination among federal agencies and additionally involves substantial research efforts on the part of many foreign nations.

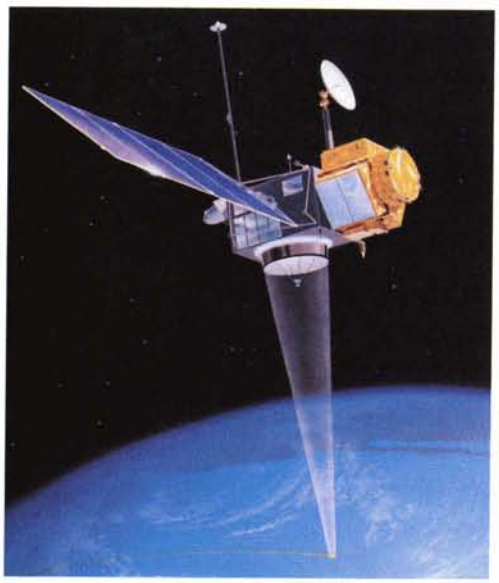
NASA's part of the program is the Mission to Planet Earth, a crash program designed to rapidly expand knowledge of Earth's environment in order to provide the scientific basis for sound policy decisions. The program involves a coordinated system of space observations, science, data processing and modeling designed to enable better understanding of Earth as a complete environmental system.

Phase 1 of Mission To Planet Earth is already under way. It embraces more than 30 missions over the next six years, including flights of individual spacecraft and Space Shuttle payloads, to study various aspects of the Earth system. These missions will pave the way for broader focus and coverage with the Earth Observing System (EOS), planned for initiation later in this decade.

September 1991 marked the start of Phase 1, the deployment by the Space Shuttle of the Upper Atmosphere Research Satellite, or UARS (**left**). UARS data has already significantly altered human understanding of atmospheric chemistry and revealed disturbing new information about the nature of ozone depletion.

Among 1992 missions are the April flight of a Shuttleborne Spacelab system, ATLAS-1, to study the atmosphere. At publication time, NASA was planning two other major missions for 1992: launch of the U.S./France Ocean Topography Experiment (TOPEX/Poseidon) spacecraft (**above right**), and the U.S./Italy Laser Geodynamics Satellite (LAGEOS II). Later in the decade, NASA will fly a series of Earth Probes to study focused topics in global change, such as ozone depletion, ocean winds and tropical rainfall.

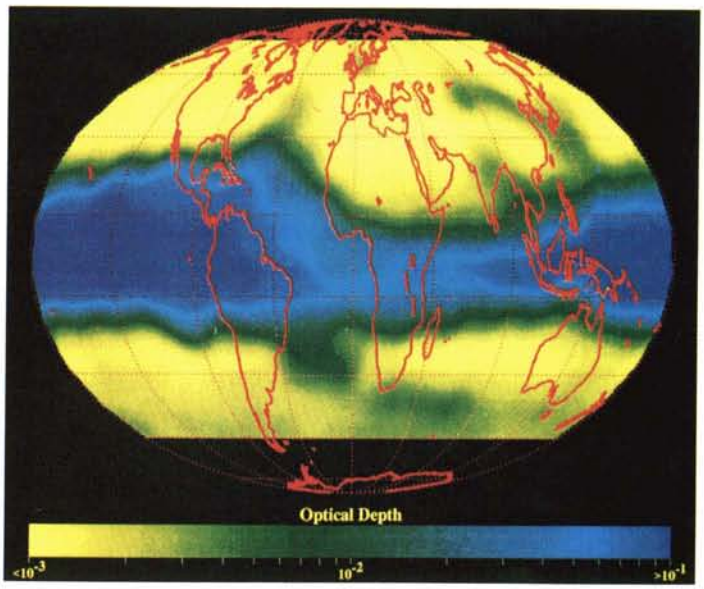
The next step will be the Earth Observing System (EOS), which will make the first long-term comprehensive measure-



ments of the interrelated elements of the Earth system. These measurements, along with important ground observations and scientific research, will enable scientists to model the Earth as a system and to project how human activity has affected and will affect the planet. The program is projected to double the size of the community of scientists studying global change. In addition, NASA is working closely with foreign governments and scientists to coordinate global change research efforts, fly instruments, and exchange data. During late 1991, NASA restructured EOS to fly the EOS instruments on intermediate and small spacecraft, an approach which gives the program added flexibility and focuses on the most critical issues of global climate change.

NASA has also already begun development of the state-of-the-art data system which will make information from EOS and all Mission To Planet Earth spacecraft available to thousands of researchers across the U.S. and around the world. Through current work on existing data sets and later data from upcoming missions, scientists will be able to conduct important analysis of global climate change issues and help improve the system prior to the launch of the first EOS spacecraft in 1998. The U.S. will have access to data from complementary spacecraft being launched by foreign nations, as well as to critical ground research conducted by other nations and other federal agencies.

NASA researchers have also participated in studies of the effects of the smoke from fires in the Middle East on the regional and global environment. In addition, scientists from NASA field centers are actively involved in research on the atmospheric effects of the spectacular eruption of Mount Pinatubo. The spectacular sunsets witnessed over the last year are the result of the global ring of particles which the volcano blasted into the atmosphere. Understanding the global effects of such an eruption, and its effects on the Earth's energy balance, could be critical in identifying aspects of global warming. **Below** is an image based on measurements of aerosol particles in Earth's stratosphere acquired by Langley Research Center's SAGE II (Stratospheric Aerosol and Gas Experiment) satellite-based instrument. The map shows that, within a month following the Pinatubo eruption, a dense belt of material had encircled the globe in the tropics and optical depths in the tropics had increased by about a factor of 100 compared with measurements taken prior to the eruption. ●



Space Physics

NASA'S space physics program seeks expanded knowledge of magnetic and electric fields, radiation and plasmas (streams of electrified particles) and other phenomena of the Earth/Sun relationship.

In 1990, NASA and the Air Force launched a satellite called CRRES (Combined Release and Radiation Effect Satellite) with dual objectives: to increase scientific knowledge of Earth's atmosphere and magnetosphere, and to gain practical benefit through monitoring the effects of space radiation on electronic equipment (the sophisticated electronics of modern spacecraft are vulnerable to radiation damage). NASA's portion of the CRRES mission involved a series of chemical release experiments designed to aid scientists studying the processes by which neutral gases become ionized, or electronically charged.

In 1992, NASA's space physics research continued with a related "campaign" of sounding rocket flights from Puerto Rico. Conducted by Goddard Space Flight Center's Wallops Flight Facility, Wallops Island, Virginia, the campaign represented the most intensive use of sounding rockets for active experiments in the ionosphere. Named Project El Coquí, it involved launch of eight suborbital rockets during the period May 17-July 13, 1992, carrying payloads to study the electrically conducting ionosphere layers that extend from 30 to 620 miles altitude and to trace the geometry of electric and magnetic fields. During the project, scientists from NASA, other government agencies and universities used chemical releases to create artificial disturbances in an attempt to learn more about how the ionosphere reacts to natural disturbances.

At left, a section of a payload is prepared for assembly with the sounding rocket's nose cone at Wallops Flight Facility. **Below** is a view of the Project El Coquí launch range at an abandoned airfield on the northern coast of Puerto Rico between San Juan and Arecibo; a rocket motor is being towed to the launch pad. **At right**, a rocket is ready for launch; three types of suborbital sounding rockets were used: one two-stage Nike-Tomahawk (pictured), one single-stage Black Brant VC, and six two-stage Black Brant IXs. At **far right**, a technician is checking out an optical tracking system.

Two of the eight sounding rockets carried instruments to measure the physical characteristics of the atmosphere. The other six released chemicals into the ionosphere, where they were ionized by the Sun's ultraviolet light, creating luminous clouds. The clouds elongated along Earth's magnetic field lines, briefly painting the invisible magnetic field with luminous particles. By observing the motion of the luminous

clouds, scientists were able to measure electric fields in space, to "see" how these fields interact with charged particles to form waves, and to better understand how Earth extracts energy from the solar wind.

A comprehensive array of instruments, on the ground and in the air, studied

the clouds, including tracking radars, telemetry systems and other equipment supplied by Wallops Flight Facility. The major facilities involved were the Arecibo Incoherent Scatter Radar and the Arecibo High Frequency Ionospheric Heater Facility, both part of the Arecibo radar/radio telescope complex operated by Cornell University for the National Science Foundation. These two facilities were used to diagnose the state of the ionosphere prior to, during and just after each chemical release. They also examined in detail the structures of the ionosphere and the artificial plasma clouds.

They were backed by an array of ground-based and airborne optical diagnostic equipment, including wide field cameras, high sensitivity television systems, spectrographs and interferometers. Portable radars diagnosed regions not accessible to the fixed radars, and radio receivers on aircraft measured disruption to satellite signals caused by the ionospheric disturbances.

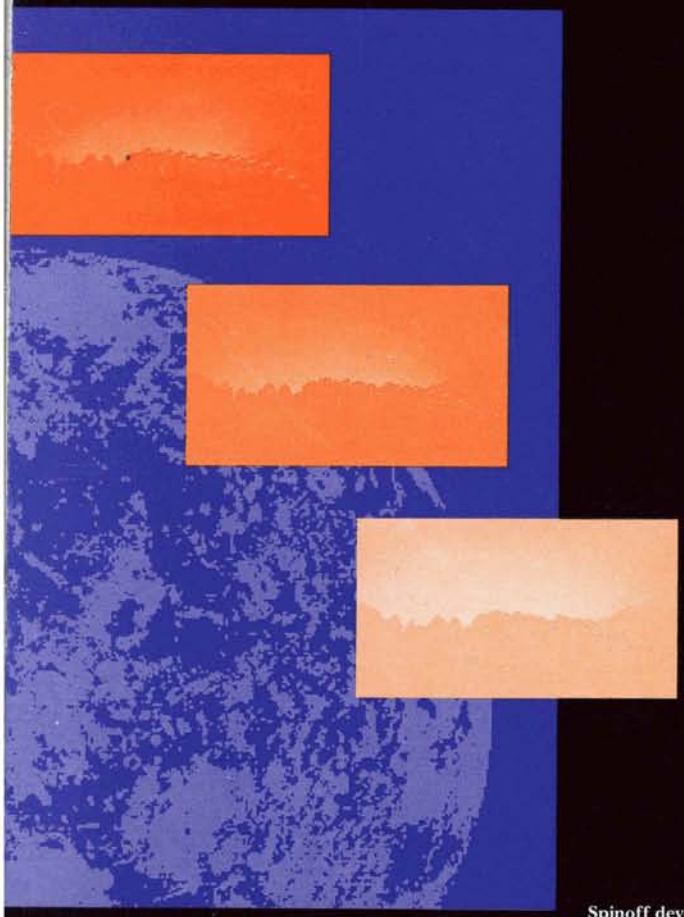
In another space physics program, the Solar, Anomalous and Magnetospheric Particle Explorer (SAMPEX), was launched from Vandenberg Air Force Base, California, on July 3, 1992. SAMPEX, the first of NASA's Small Explorers, is a collaborative mission with Germany that will study the composition of energetic particles arriving at Earth from the solar atmosphere and interstellar space.

SAMPEX is designed to support a minimum mission duration of one year, with a potential mission lifetime of three or more years. During its mission lifetime, SAMPEX is expected to provide scientists with unprecedented detail about the composition of energetic particles from the Milky Way galaxy (referred to as galactic cosmic rays) and from the Sun (solar energetic particles). In addition, SAMPEX will provide the opportunity to acquire dramatic new results from measuring the composition of "anomalous" cosmic rays, believed to be atoms of the local interstellar gas that enter the solar system, are ionized and then accelerated to cosmic ray energies.

SAMPEX was developed by the Small Explorer (SMEX) project at Goddard Space Flight Center. Two other Small Explorers are currently manifested: the Fast Auroral Snapshot Explorer (FAST), scheduled for launch in 1994, and the Submillimeter Wave Astronomy Satellite (SWAS), which will be launched in 1995. ●

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/economic benefits they provide



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

A Boom in Boomerangs

AMONG SPINOFFS FOR CONSUMER, HOME AND RECREATIONAL USE, NASA AIRFOIL TECHNOLOGY IS HELPING TO SPUR AN INTERNATIONAL UPSURGE IN BOOMERANG COMPETITION

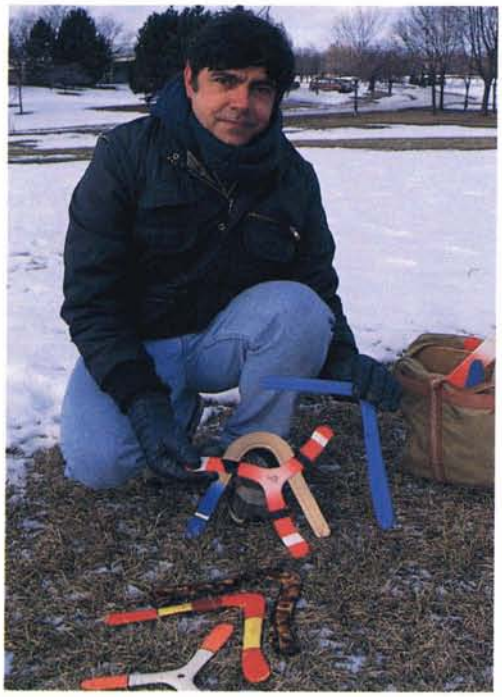
Though still of modest scope, the sport of boomerang throwing is experiencing rapid growth and regularly finding new devotees in many nations of the world.

The boom is recent. Although boomerangs have been used as war and hunting tools for more than 20 millennia, it was not until the decade of the 1970s that boom throwing became an organized competitive sport.

In the United States, there are now scores of local and regional contests annually and, since 1980, an annual national championship. There are similar competitions in a number of foreign countries, notably Australia, Canada, Belgium, France, Germany, Sweden, Poland, Italy, the Netherlands, Switzerland and Japan. And, for the last decade, there has been a series of well-attended international competitions.

Since the boomerang is most often associated with Australia, one might expect that the Aussies dominate world competition. Not so. Surprising as it might sound, the

This is a time exposure of a night boomerang flight launched by championship-level competitor Ron Tamblyn. Modified by designer Eric Darnell to include a light source at a blade tip, the L-shaped "boom" traces an elliptical path covering some 120 yards outward from the invisible thrower and back to him. Boomerang competitors use this night time exposure approach to obtain photographic information on performance characteristics that is useful in designing new types of booms.



Shown with some of his products, boom designer and thrower Ted E. Bailey pioneered use of NASA aerodynamics technology in boomerang shaping and became one of the sport's leading innovators.

United States—which had only a handful of "boom" hobbyists until the latter 1970s—has won every international boomerang event since 1984. And NASA technology has played a contributing role.

The boomerang is essentially an airfoil, like an airplane wing. In the same manner as the wing is designed to give the airplane a certain mode of performance, the boomerang's upper and lower surfaces can be shaped to get a desired aerodynamic effect, for example, the range, speed and accuracy of the tribesman's hunting stick, or the smooth, circular "return" flight of the sport boom.

In the U.S. and elsewhere, boomerang designers are applying aerospace technology from basic aerodynamics to computerized flight simulation. Generally, they design for optimum performance in a specific competitive event, such as accuracy, distance, catching, two-boom juggling or maximum time aloft. As a result, the traditional crescent shape is now just one of many design forms that include triangular, cruciform, multicurve and question-mark shapes.

The use of NASA technology in boomerang design is exemplified by the work of Ted Bailey of Ann Arbor, Michigan, a well-known name in the international boomerang community. An engineer with NTN Technical Center, Bailey is a highly-ranked competitive thrower, a designer and producer of advanced technology booms, and publisher of the quarterly *Boomerang Journal.*

AN AMERICAN NOVICE USED NASA TECHNOLOGY TO BECOME A LEADING INNOVATOR IN BOOMERANG DESIGN

With the help of technology gleaned from several years' study of NASA technical reports, some provided directly by NASA, others found in the technical library at his place of employment, Bailey has become a major contributor to advancing the state of the art in boomerang competition designs. His work has also helped give U.S. throwers a competitive edge.

Bailey's interest in boomerangs began in 1974 when he was still in college and taking courses in fluid mechanics and dynamics, subjects that are close cousins to aerodynamics. He bought a cheap plastic boomerang and spent days trying to make it return to him—without success. He finally discovered the problem: he was left-handed, the boomerang was not. So he built a mirror image copy out of hard wood and found it flew better than the plastic original. That started a long term interest in boom throwing and designing that was to make him a record-setting competitor and a leading innovator in boomerang design technology.

(Continued)

A Boom in Boomerangs (Continued)

The shaping and notching of these ancient boomerangs, from the collection of design innovator Ted Bailey, reflects a remarkable knowledge of basic aerodynamics.

Throughout the 1970s, Ted Bailey worked in solitude on his boomerangs; he didn't even know of another boomeranger. At that time, there were no boomerang competitions outside Australia, where boom designs rarely deviated from the traditional crescent shape. Aussie competitions were very limited in scope; they consisted of a single event that combined boom catching, distance and accuracy.

Bailey found a few books on the subject and began experimenting with various boomerang shapes and sizes. Then he discovered the wealth of information on aerodynamics and low-speed airfoils available in NASA technical reports, which were to become the cornerstone of his innovative research and development effort. These reports helped establish his hallmark approach to boomerang design: miniaturizing existing designs to enhance their competitiveness.

By 1980, a series of Smithsonian Institution workshops and competitions had spawned a fair-sized body of throwers in the northeastern United States and sparked a new direction in boom competition. Instead of the single-event Australian format, the American throwers decided to add a variety of other contests—separate events for accuracy, distance, catching, duration, etc.—to the competitive agenda.

In 1981, Bailey made contact with the growing band of U.S. throwers and it was in that year that the American group boldly challenged the Australians to a competition and, to everyone's surprise, won it. That was the first real international event.

The Australians continued to retain their single event format but the American throwers branched out further and added new competitive events as fast as they could think of them. Other countries, principally in Europe, took up the sport about this time and they adopted the American multi-event approach. Contestants from all nations started adding more and more types of boomerangs to their throwing kits, each with different flying characteristics tailored to specific events.

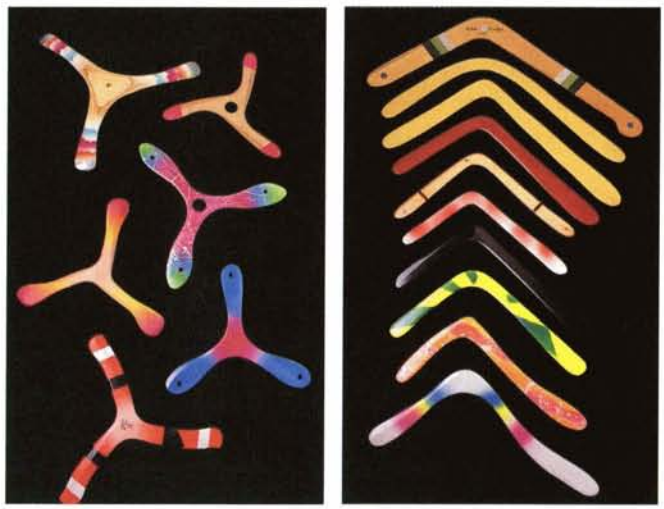
Modern competition-type boomerangs are sophisticated designs with flight characteristics tailored to specific events. The U.S. has established leadership in international competition and NASA airfoil technology has provided an assist.

Ted Bailey's trendsetting designs, based on NASA technology, are very popular in the U.S. and abroad. Bailey's booms are handcrafted from Finnish birch plywood, filed and drum-sanded to a predetermined aerodynamic shape, then hand-sanded and finished.

The technology race was on and Ted Bailey, armed with his library of NASA technical information and several years of self-taught know-how, became a leading designer and producer.

In 1981-84, Bailey introduced to competition his miniaturized booms and demonstrated the advantages of small size by winning several competitions. This started a size-reduction trend throughout the international boomerang community.

In 1984, Ted Bailey began to focus his R&D on a new MTA (maximum time aloft) type of boomerang that had originated in Germany. This large, hockey-stick-shaped boomerang could fly for as much as 40 seconds, compared with 10 seconds or so for the typical conventional boomerang. Bailey decided that MTA sticks could benefit from his miniaturization approach. Using four NASA reports as his primary input, Bailey began an intense program of experimentation with smaller booms of various designs, different arm length ratios, chord widths and angles between the two blades.



Boomerangs are shaped differently for different competitive events. The three-bladers pictured at left are used in "Fast-catch" events (multiple throw/catch sequences). At right is a sampling of maximum-time-aloft booms; still other shapes are used for catching, distance and accuracy.

The results were spectacular. Within a few weeks of starting his MTA design program, Bailey broke the one-minute barrier with a 67 second flight, then scaled the design down further to achieve a flight of 80 seconds.

In 1985, Ted Bailey and his advanced design boomerangs dominated MTA competition. He was the first to demonstrate a throw and catch of more than two minutes (the current record, just under three minutes, was achieved by another thrower using a replica of the Bailey design). Bailey was also the first to complete the difficult "Super Catch," which involves launching an MTA boomerang, then completing five throw/catch sequences while the original boom is still aloft, then catching the original. He shared his products with his American teammates, helping the U.S. establish leadership in international competition.

Today, Ted Bailey the thrower continues to dominate MTA competition and Ted Bailey the innovator has embarked on a new line of experimentation. He is looking into practical applications of the boomerang, for example, its use as a flare carrier in military operations and its application as a much more dynamic shooting target than the clay pigeon. He has also been approached by a toy company to market a stable child's version of the MTA boomerang. Bailey is still devouring all the pertinent technical literature he can find and he is still scanning the list of NASA reports for titles that might advance boom technology another notch. ●

Computer Game

Below, students are constructing a lunar base model from common materials, using components designed with the help of a MOONBASE® computer game. The game was developed and marketed by KDT Industries, Inc. and Wesson

International, both suppliers of software packages for computer simulations, both located in Austin, Texas.

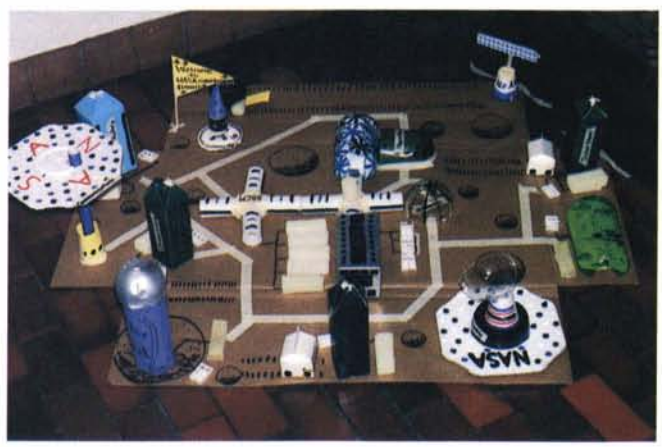
At **lower right** is the completed base. The various infrastructure elements—habitats, landing pads, power stations, processing plants and science facilities—are built by game players from graphic simulations constructed on the computer screen by the KDT-Wesson software package. The designs are realistic; they were drawn from NASA studies of advanced lunar exploration and colonization. KDT has been engaged for several years in such studies, working under NASA contract. KDT chose Wesson International to help develop MOONBASE because of the latter company's success with its TRACON multiplayer air traffic control simulator.

NASA LUNAR STUDIES PROVIDED A BASE FOR DEVELOPMENT OF A COMPUTER GAME

MOONBASE makes the player commander of a team charged with building and operating a lunar base using NASA technology. The player has 10 years to explore the lunar surface (via his personal computer), select the best site, bring structures from Earth and assemble them intelligently into an efficient base. He must, in the process, contend with fluctuations in resources availability and with such potential disasters as meteorite strikes, solar flares and other difficulties of life on the Moon.

MOONBASE was introduced to student and teacher space enthusiasts in the summer of 1991 through a series of lunar base modeling workshops sponsored by the Texas Space Grant Consortium, also of Austin. The students pictured were among 50 outstanding minority students participating in the MITE program at the University of Texas-Austin; they used MOONBASE to get the design information, from which they built the base out of soft drink bottles and cans, styrofoam cups, cardboard and similar materials. The Consortium has also conducted six lunar base modeling workshops for students and teachers, including a three-day program, Liftoff '91, co-sponsored by NASA at Johnson Space Center. ●

®MOONBASE is a registered trademark of KDT Industries, Inc. and Wesson International.



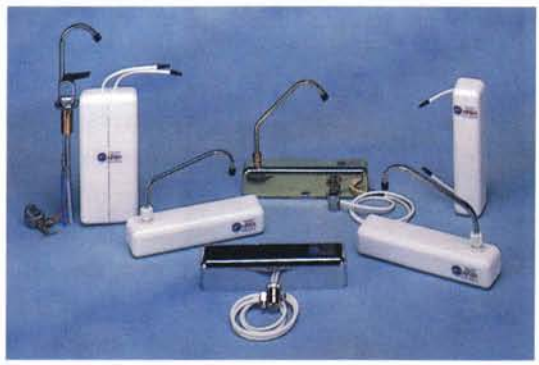
Water Purifiers

To purify the water carried aboard manned spacecraft, NASA contracted with Chemtric, Inc., Rosemont, Illinois for development of a compact, lightweight electrolytic sterilizer. The unit generates silver ions in the Orbiter's water system in concentrations of 50 to 100 parts in a billion; the ions serve as bactericides and deodorizers.

This technology has spawned a number of spinoff applications, the latest among them the Ambassador line of bacteriostatic water treatment systems exemplified **above**; the mother pictured is demonstrating to an interested tot the Space Saver 5000 unit, designed for compact kitchens with little counter space.

Other members of the new Ambassador line, shown **at right**, include the Magnum Pressure Unit, a Travel Unit, the Ice Maker unit for refrigerators and the Invisible unit used under the kitchen counter. All of the units employ high grade, high absorption media to inhibit bacteria growth and remove the medicinal taste and odor of chlorine.

The Ambassador bacteriostatic water devices are marketed by Ambassador Marketing, Lebanon, Oregon, a new company formed by inventor Ray Ward, who was among the first to commercialize the Shuttle water purification technology. In 1976, Ward



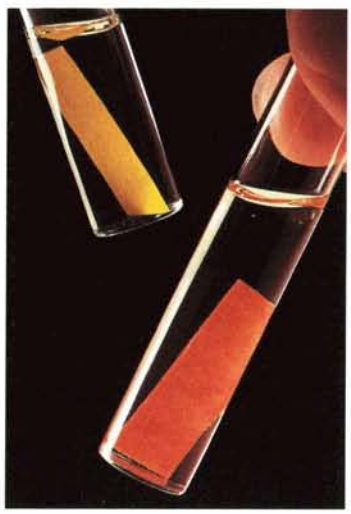
sought to develop a water filter for his own personal use to remove the "rusty" taste of his local water supply. He learned of the NASA technology and requested a technical information package from NASA's Center for AeroSpace Information, Baltimore, Maryland. Using that information as a departure point, Ward invested $27 and developed his own homemade device.

The unit was so successful he began marketing it as the Bon Del line of water filters, which boomed into a $50 million a year business. The new Ambassador line employs the same basic NASA-derived technology, but Ward has substantially refined it and introduced new production technology for the smaller, highly efficient Ambassador units. ●

Water Sensors

Michael J. Morris, president of pHish Doctor, Inc. and Ocean Optics, Inc., Dunedin, Florida is an inventor formerly employed by the Southern Technology Application Center (STAC) at the University of South Florida in Tampa.

STAC is a NASA-sponsored industry assistance center operating a special Services for Inventors Network that provides technical and marketing help for product innovators.



In 1986, Morris had an idea for a novel product — a pH monitor for home aquariums. The pH factor is an indication of the acidity or alkalinity level of a solution. Morris developed immobilized dyes that offer a way of measuring the pH level, a technique somewhat analogous to the familiar litmus test, in which a treated paper changes color when exposed to acidity or alkalinity.

Morris, then associate director of STAC, became his own client and asked STAC for assistance in measuring the market potential of the invention, which he called the pHish Doctor. STAC conducted the necessary market research and reported that the outlook was positive. Morris then formed pHish Doctor, Inc. to develop a product for freshwater aquariums. He subsequently used STAC's service for technological guidance, business planning, funding opportunities, and manufacturing/distribution information.

The pHish Doctor consists of an arc-shaped sensor strip and a seashell-shaped color chart. Mounted in an aquarium with a suction cup (**below**), the sensor continually measures pH levels in the water and changes color as the pH factor changes; by comparing the color of the sensor strip with the color chart, the aquarium owner gets an instant pH reading. The photo **at left** shows the different color swatches of a sensor that has been exposed to three distinct levels of pH.

The reading is important. A changing pH level is an indication of trouble. When the level gets too high, the ammonia that fish excrete becomes highly toxic; at low pH, there is a danger that the bacteria that normally break down waste products in water will stop functioning. The continually monitoring pHish Doctor eliminates the need for periodic sample testing.

A designer-aquarium sales company, GM Aquatics, Fort Worth, Texas now handles manufacturing and marketing of the pHish Doctor, whose sales have run into the tens of

thousands and are still expanding. Morris still supplies the sensor strips himself and keeps secret how they are made.

The success of the pHish Doctor prompted Mike Morris to shift his focus toward pH detection in seawater. Salt water aquariums have a different pH range than freshwater tanks, so a different dye was needed. NASA technology provided a clue.

In *NASA Tech Briefs*, a monthly publication that describes new NASA technology available for transfer, Morris read of research on an immobilized enzyme used in a colorimeter test for alcohol. A follow-up information package supplied by NASA led him to try alternative strategies that resulted in a salt water version of the pH Doctor and development of several viable immobilization techniques that could be used with dyes.

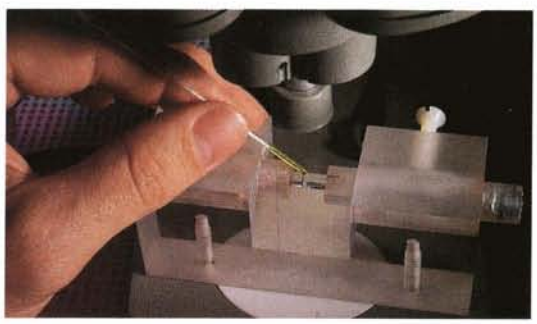
This shift of focus was instrumental in the formation of Ocean Optics, Inc. to pursue technology for sensing pH in seawater. Ocean Optics won Phase I (feasibility determination) and Phase II (application) Small Business Innovation Research grants from the Department of Energy (DoE) for development of a pH sensor that will operate unattended on sea buoys for long periods and collect continuous data on how much carbon dioxide the ocean is absorbing from burning of fossil fuels.

Knowing the rate of oceanic carbon dioxide flux is critical to researchers studying the "greenhouse effect" of carbon dioxide buildup. Satellite ocean color measurements provide basic data; DoE wants the pH data to provide corroborating "sea truth" information. Ocean Optics is developing a fiber optic sensor employing the company's proprietary process that produces tough, thin, transparent coatings of pH indicator dyes. Optical transmission provides highly accurate pH readings, independent of pathlength, dye concentration and sensor-to-sensor variation

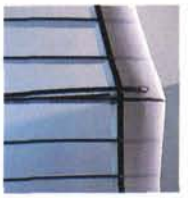
There are a number of commercial applications for the fiber optic sensor, such as pH meters for process control, general laboratory work, or implantable sensors for blood gas monitoring.

At left, Mike Morris is preparing to deploy a sea buoy for testing in the Gulf of Mexico. Ocean Optics' fiberoptic sensor is housed in the small white tube at the bottom of the buoy. The sensor itself is shown **below**; a laboratory technician is testing it with a color dye.

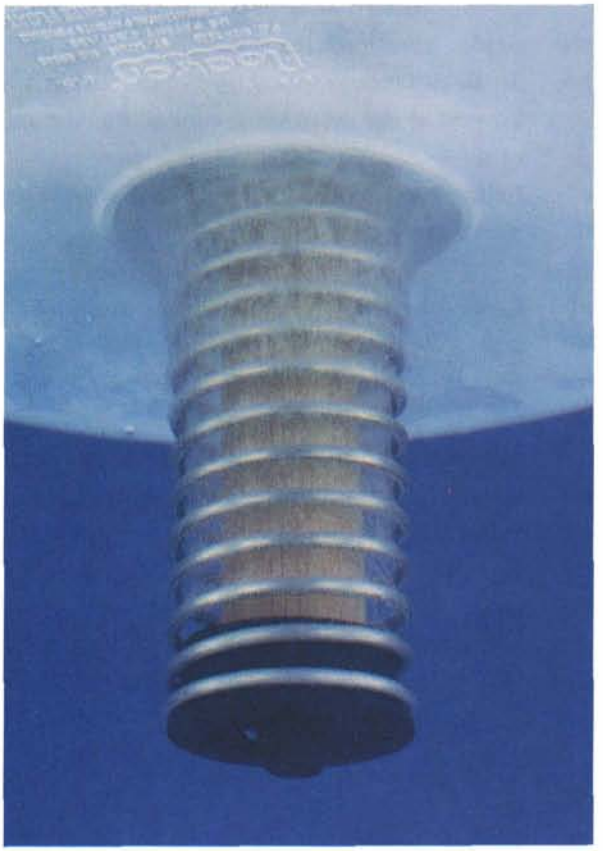
The newest evolution of Ocean Optics' technology is shown in the **bottom** photo. It is a miniature spectrometer to be used in conjunction with the fiber optic sensor. Measured in inches and weighing less than a pound, it is designed for use in many situations inaccessible to a normal spectrometer, typically an instrument weighing 60-150 pounds. ●



Water Purifier



Below is the Floatron® water purifier, a product that combines two space technologies: NASA ionization technology for water purification and solar electric power generation. Marketed by Floatron Inc., Phoenix, Arizona, the Floatron device measures only 12 inches in diameter but it can purify a swimming pool, pond, fountain or other water container holding up to 50,000 gallons.



Floatron provides an alternative to chemical control of algae and bacteria through a process developed by NASA for purifying water aboard manned spacecraft (see page 110). The process involves introduction to the water of ionized minerals that kill microorganisms, such as algae and bacteria.

In use, the unit floats on the water, its solar panel (**below**) collecting sunlight that is converted directly to electricity. The harmless, low power current thus generated energizes a specially alloyed mineral electrode below the waterline and causes release of metallic ions into the water.

Floatron costs nothing to operate. The only part requiring replacement is the electrode, which has a service life of approximately two years and can be changed in one minute.

Floatron-purified water falls within drinking water standards established by the Environmental Protection Agency. Additionally, the water remains clear and stable for extended periods because the minerals do not evaporate. ●

®Floatron is a registered trademark of Floatron Inc.

Lightplane Wing Design

NASA ANTISTALL TECHNOLOGY IMPROVED THE SAFETY AND PERFORMANCE OF A NEW HOMEBUILT AIRPLANE

The airplane pictured is a two-place Venture, a "homebuilt" assembled by the buyer from a kit of components designed and manufactured by Questair, Greensboro, North Carolina. It is a high performance lightplane that can cruise at more than 250 knots and climb at 3,000 feet a minute. Additionally, it has excellent low speed characteristics and enhanced safety due to NASA technology incorporated in its unusual wing design.

The Venture has a high aspect ratio wing, long in span in relation to its chord, with relatively high lift and low drag. For that reason, it was selected as the airplane to be employed in a joint NASA/North Carolina State University (NCSU) research project involving new techniques for preventing aircraft stall at high angles of attack (the angle between the wing and the air through which it is moving).

A stall, which can cause loss of control, occurs when the airplane loses lift due to disturbance of the smooth airflow over and under its wing. At high angles of attack, the airflow breaks away, or "separates" from the wing surface and causes stall.

The standard industry method of countering separation is the addition of "stall strips" that fence and direct air to improve the wing's stall characteristics, but this technique involves some loss of wing lift. NASA had developed another solution that employed drooped wing leading edges to bar separation; experimentation, however, was incomplete. The method had been tested extensively on conventional moderate aspect ratio wings but much less work had been done on high aspect ratio.

NCSU, in the form of graduate students Holly Meyer Ross and Bruce Owens, advised by Dr. John N. Perkins, associate head of the Department of Mechanical and Aerospace Engineering, joined with Langley Research Center to advance the database of the antistall technology and extend it to aircraft with high aspect ratio wings.

Ross, Owens and Perkins, together with NCSU lecturer Robert J. Vess and Langley engineer Long P. Yip, spent seven months of 1987 working on the Venture project. They performed wind tunnel and radio controlled model tests at Langley, analyzed the results and recommended a wing modification for the Venture.

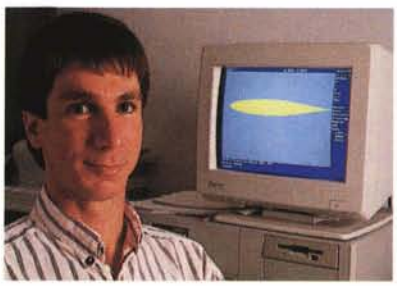
The modification consisted of a droop in the leading edges of the wings near the tips, plus two "slots" cut into the leading edge of each wing. The slots create small whirlpool-like airflows called vortices that add energy to the airflow and prevent separation. Wind tunnel tests showed that the NCSU/Langley droop/slot combination delayed airflow separation and improved control, thus providing more usable lift than the stall strips. Flight tests with the Venture confirmed the effectiveness of the droop/slot configuration.

The modification was adopted on the Venture prototype, which was further tested by the company; the airplane subsequently set 10 world speed records for small single engine aircraft. The homebuilt is now in production and commercially available. Questair officials state that the NCSU/NASA work enabled the company "to establish a new standard in stall departure/high angle of attack flying qualities for general aviation aircraft. ●

Sailboard Fin Design

In the latter 1980s, the popular sport of boardsailing moved into high performance sailing, with speeds approaching 40 knots. Such speed became possible with the introduction of a new type of hull called the "short board" and new high aspect ratio sails, which feature higher lift with less drag.

The sail's lift force is exerted laterally, or sideways. To offset that force, short board hulls employ a vertical fin or "skeg" near the stern; its job is to maintain equilibrium by generating sufficient underwater horizontal lift to balance the sail's lateral lift.



The higher performance of short boards places greater performance demands on the skeg, and that often creates a problem known as "spinout." This phenomenon occurs when the skeg suddenly loses horizontal lift, which creates a force imbalance and causes the tail of the board to slide sideways.

Windsurfing enthusiast Richard A. Caldwell, now president of RACE Technology, Inc., Melbourne, Florida, sought a solution to the spinout problem, found one in NASA technology, designed a new type of fin and formed a business on the basis of it.

In 1986, after graduating from Florida Institute of Technology, Caldwell (**above**) pursued a Master of Science degree in aeronautical engineering. He joined the Joint Institute for the Advancement of Flight Sciences program, a graduate program co-sponsored by George Washington University, Washington, D.C. and Langley Research Center. Interested in airfoil design, he proposed — and got approval for — a research project involving adaptation of NASA airfoil technology to solution of the spinout problem that plagued boardsailors.

Caldwell first determined that spinout resulted from air ventilating down the low pressure side of the underwater fin. Researching NASA technical papers, he found that a similar problem with seaplane airfoils was caused by air "separation," in which the laminar (smooth) flow of air over a wing is disrupted and the airflow breaks away, or separates from the surface of the wing; this causes loss of lift. He concluded that ventilation was creating separation "bubbles", interrupting the smooth flow of water around the fin, hence the loss of lift.

Caldwell drew on other NASA technology for the solution to the spinout prob-

lem, notably a computer program developed at Langley Research Center that models the airflow required for a low drag airfoil: the airflow must be kept laminar and free of bubbles over most of the wing's fore-aft dimension to decrease unwanted drag. Since the sailboard fin is a close cousin to the airfoil, he adapted the technology to the design of a short board skeg that would not only overcome the ventilation problem and provide spinout resistance, but would offer a bonus in low drag — meaning improved sailboard performance. He designed a foil section, known as the RACE 145, specifically for the sailboard fin; subsequent tests confirmed its low drag, spinout resistance characteristics.

NASA AIRFOIL TECHNOLOGY PROVIDED THE ANSWER TO A MAJOR BOARDSAILING PROBLEM

Upon graduation, Caldwell patented his method of designing low drag, ventilation resistant foil sections and formed RACE Technology, Inc. to manufacture sailboard fins and other sailing products.

Later, looking for further improvements, Caldwell turned again to technology developed at Langley Research Center relative to low drag wings called "sheared elliptic planforms," which offered further drag reduction. This technology, too, was adapted to the sailboard skeg.

The RACE 145 foil section is now in production in several models for different types of sailboards; four representative skegs are shown in the photo **at left**. The patented foil design coupled with the sheared elliptic planform offers a very low drag fin with spinout resistance and greater maneuverability than conventional fins. This was confirmed in a 1991 speed trial on the Columbia River in Oregon, when a sailor using a Caldwell fin design was timed at 49 miles per hour in a 35-40 mile per hour wind.

Shown **above** is the newest product developed by RACE Technology, Inc., a rigid sail for windsurfing that once again incorporates the NASA technology. Unusual for windsurfing sails, the rigid design employs carbon fiber reinforcement in its structural components for reduced weight and improved strength; it weighs only 20 pounds, about the same as the lightest conventional mast/sail combinations available. Wind tunnel tests have confirmed excellent performance for the rigid sail. ●

Terrain Simulation

Below is a view of Planet Earth from orbit. It is a frame from the 42-minute Imax film *Blue Planet*, which has been seen by more than eight million people at giant screen Imax theatres. Produced by Imax Space Technology, Inc., a subsidiary of Trax Corporation, Toronto, Ontario, *Blue Planet* is presented by the Smithsonian Institution's National Air and Space Museum and Lockheed Corporation in cooperation with NASA.

Much of *Blue Planet* features breathtaking views of Earth filmed in orbit on five Space Shuttle flights by astronauts trained to operate the IMAX® cameras, which produce an image three times larger than standard 70-millimeter motion picture film. The film, says Imax, "gives audiences worldwide a view of their global home that is as close to being in orbit as one can possibly get."

Blue Planet, however, is more than an orbital travelogue; it is a film with a message, a depiction of the powerful forces that affect Earth from within and without, and the effects of natural and man-made influences on the delicate balance among those forces.

A highlight of the film is a 100-second computer-generated animation of a flight and earthquake simulation along California's San Andreas Fault. This sequence, created by the Visualization and Earth Sciences Application (VESA) Group of Jet Propulsion Laboratory (JPL), employed new three-dimensional perspective rendering (3DPR) techniques, a technology in development at JPL since 1985. The *Blue Planet* sequence marked a milestone in transferring 3DPR technology to the private sector; it had been employed in earlier films, but never on the scale demanded by the San Andreas simulation.

The accompanying images are sample frames from the computer-animated sequence, developed from data sent from orbit by the Landsat Earth resources monitoring satellites. At **top right** is a view of California looking northwest over the Salton Sea with San Diego at far left and a portion of the Colorado River at far right. The **lower right** photo is centered on San Francisco with Mt. Shasta on the horizon at left photo and the Sierra Nevada Range at center and right.

The 3DPR work at JPL is part of a broader program of scientific visualization, a field devoted to exploring new ways of presenting voluminous data to scientists, allowing experts in various fields to understand large volumes of data quickly and easily.

One such technique is terrain rendering, a type of scientific visualization employed by scientists as an effective means of recognizing patterns in remotely sensed data. Terrain rendering involves superimposing image data on digital elevation maps to produce a three-dimensional simulation of the actual terrain. When image and eleva-

tion data are thus combined, the topography and imagery become much clearer and may suggest further information, for example, what is *beneath* the surface.

The *Blue Planet* task required development of new technology to make possible terrain rendering of very large digital images within the short period allowed by the film company's schedule. The data that made the animation possible was an image mosaic of California constructed from Landsat Multispectral Scanner scenes, combined with more detailed Landsat Thematic Mapper data for the San Francisco area. Elevation data for terrain mapping was obtained from the U.S. Geological Survey.

To create the San Andreas flight simulation, the VESA Group used 727 megabytes of image and elevation data to create 2,160 frames, which were sent on tapes to Imax and there transferred to film. Development and use of an advanced pyramidal terrain rendering technique reduced what would have taken close to a year of computer time by earlier methods to about 50 days.

In addition to the commercial spinoff, the new techniques have provided NASA an important payback. Large mosaics of Venus were assembled from the data supplied by the Magellan spacecraft. The visualization group at JPL and the Magellan science team were able to produce high-resolution terrain animations of Venus from these mosaics. JPL continues to develop new perspective rendering technologies as a means of coping with the vastly increased volume of remote sensor data expected in the coming decade. ●

®IMAX is a registered trademark of Imax Corporation, Toronto, Ontario.

A Tool for Medical Research

HEADING A SELECTION OF SPINOFFS IN HEALTH AND MEDICINE IS AN INSTRUMENT PLAYING A VITAL ROLE IN RESEARCH ON AIRBORNE DISEASE TRANSMISSION

Aerosols are tiny solid particles or liquid droplets deposited in the atmosphere by natural events or human activities. In a hospital operating room environment, they pose a potential danger: they may be sources of disease transmission.

The AIDS epidemic has focused attention on the various possible routes by which the HIV (human immunodeficiency virus) is transmitted. One route identified is through inhalation of aerosols that contain blood, generated in health care settings where bleeding occurs, such as surgery or dental procedures. When such particles are inhaled and penetrate deeply into the respiratory tract, they have potential for spreading the HIV and other disease bearing organisms and thus pose a threat to health care personnel.

In 1988, Dr. Don L. Jewett, Head of the Special Studies Unit, Department of Orthopaedic Surgery, Medical Center of the University of California at San Francisco, initiated a research project to broaden understanding of the formation and character of aerosol particles in the medical environment.

A SYSTEM FOR ANALYZING ATMOSPHERES OFFERS SPECIAL UTILITY IN MEDICAL/DENTAL INVESTIGATIONS

The Jewett team sought answers to some specific questions:

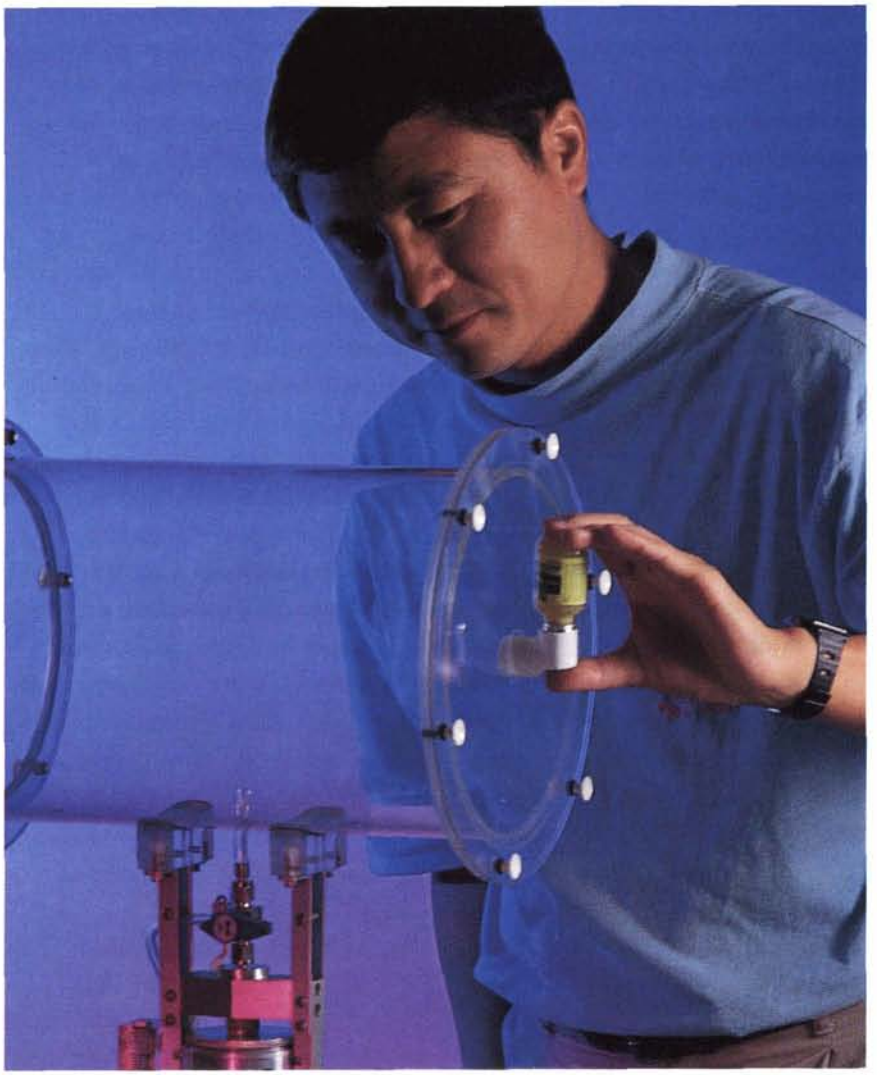
- What types of aerosols are generated during different surgical procedures?
- What are the size ranges and mass concentrations of the particles?
- Do the particles contain blood and are health care personnel adequately protected from inhaling them?

To get the answers, Dr. Jewett needed a versatile instrument. It must not only be capable of measuring particle mass concentrations and size distributions, but must also be able to retain samples for later analysis to determine whether they contain blood. He found such an instrument already in existence, in active use as an aerosol analyzer for air pollution studies, and commercially available from California Measurements, Inc., Sierra Madre, California.

Known as the PC-2 Aerosol Particle Analyzer, the instrument incorporates technology developed by Jet Propulsion Laboratory (JPL) to determine the sizes and quantities of aerosols in the atmosphere at a particular time. The technology employs a dual-crystal sensor whose oscillating frequency changes in direct proportion to the amount of mass collected on the sensor. Electronic processing of the frequency changes provides mass collection data in real time.

William Chiang, president and founder of California Measurements, Inc., looks over the design of a customized version of his company's PC-2 aerosol particle analyzer, which is based on NASA technology.

William Chiang, a former JPL engineer, founded California Measurements and obtained a NASA license for the JPL crystal oscillator technology. With Langley Research Center, he developed a particle analyzer for NASA use; later the company produced a modified PC-2 for commercial applications, such as atmospheric research, studies of smoke particles in fires, and environmental health research. It is also useful in testing filters for safety masks and in medical research related to drug delivery by inhalation.



Engineer Tom Chen is testing the size of particles dispensed by a commercially available inhaler. California Measurements' spinoff particle analyzer has a number of important applications in medical, atmospheric and environmental health research.

Dr. Jewett's team used a PC-2H 10-Stage Aerosol Analyzer as their primary research tool. It enabled measurement of particle sizes over the entire breatheable range and determination — in real time — of mass concentrations for each size. With this instrument, the team was able to get multiple sets of data repeatedly and accurately in short intervals during an experiment.

Dr. Jewett's conclusions, widely disseminated through technical forums since 1989, were that significant amounts of aerosols are indeed generated during surgeries where power tools are employed; most of the particles are in the respirable size range; almost all particles tested positive for blood or hemoglobin content; and ordinary surgical masks do not provide adequate protection. Further research is planned to answer the big question of whether the HIV and other viruses can be transmitted by aerosols, and the PC-2 analyzer will again play a central role.

Dr. Robert L. Miller, an Arizona dentist and aerobiologist, also used the PC-2H in research to determine the presence of blood aerosols during oral surgery and other dental procedures involving use of power tools. His findings paralleled those of the Jewett team. Dr. Miller, who has accomplished considerable research of this type, states that the PC-2H detected large amounts of submicron-size blood plasma particles that in earlier research had escaped detection because they simply passed through conventional particle samplers.

In a letter to California Measurements, Dr. Miller wrote:

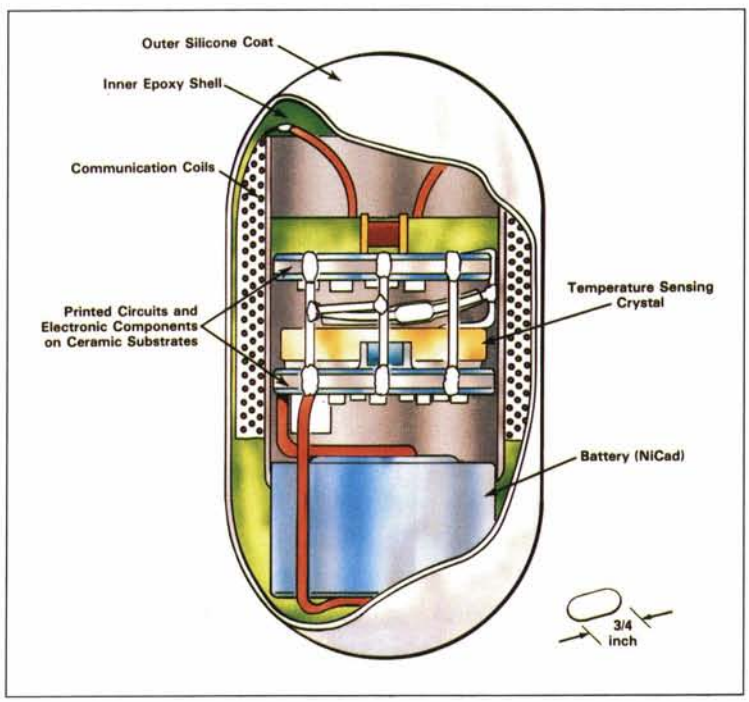
"The PC-2H has made a quantum leap forward in dental microbiology possible. Without this instrument, my work would have been abandoned and again dental aerosols would have gone undetected. Your instrument will be required to capture and quantify airborne virus when we become equipped to safely study blood aerosols containing the AIDS virus. The future quantitation of dental blood aerosols may become one of the most significant spinoffs of NASA technology." •

Temperature Capsule

At left, Dr. Protagoras Cutchis of Johns Hopkins Applied Physics Laboratory, Laurel, Maryland is holding an ingestible mini-thermometer capable of measuring and relaying internal body temperatures. Developed by APL and Goddard Space Flight Center, the capsule is now being marketed for medical use as the CorTemp System, produced by Human Technologies, Inc. (HTI), St. Petersburg, Florida. CorTemp incorporates a number of space technologies, among them telemetry (wireless signal transmission) and microminiaturized circuit, sensor and battery technologies.

In medical use, the CorTemp system offers a research tool to provide data never before accessible. The system includes the ingestible capsule and a recorder, which may be used for in-patients, ambulatory patients and out-patients. Shown in cutaway view **below**, the three-quarter-inch capsule is ingested to make its way through the digestive system, continuously monitoring temperature by means of a quartz crystal sensor, which vibrates at a frequency that varies according to temperature. The sensor telemeters signals to the recorder, which displays and stores the data; a clinician can transfer the data to a disc, print a report or conduct in-depth computer analysis.

According to HTI, CorTemp offers one of the most accurate body core temperature readings available to medicine and research in an ambulatory environment. Free of catheters, probes and direct wire connectors, CorTemp provides greater patient comfort in post-surgery or intensive care environments and allows clinicians to monitor outpatients at home, work or play. CorTemp facilitates research and treatment related to sleep disorders, sports medicine and physiology, metabolic disease, tumor treatment by radiation, gerontology (aging), basal temperature analysis, substance abuse and other conditions.

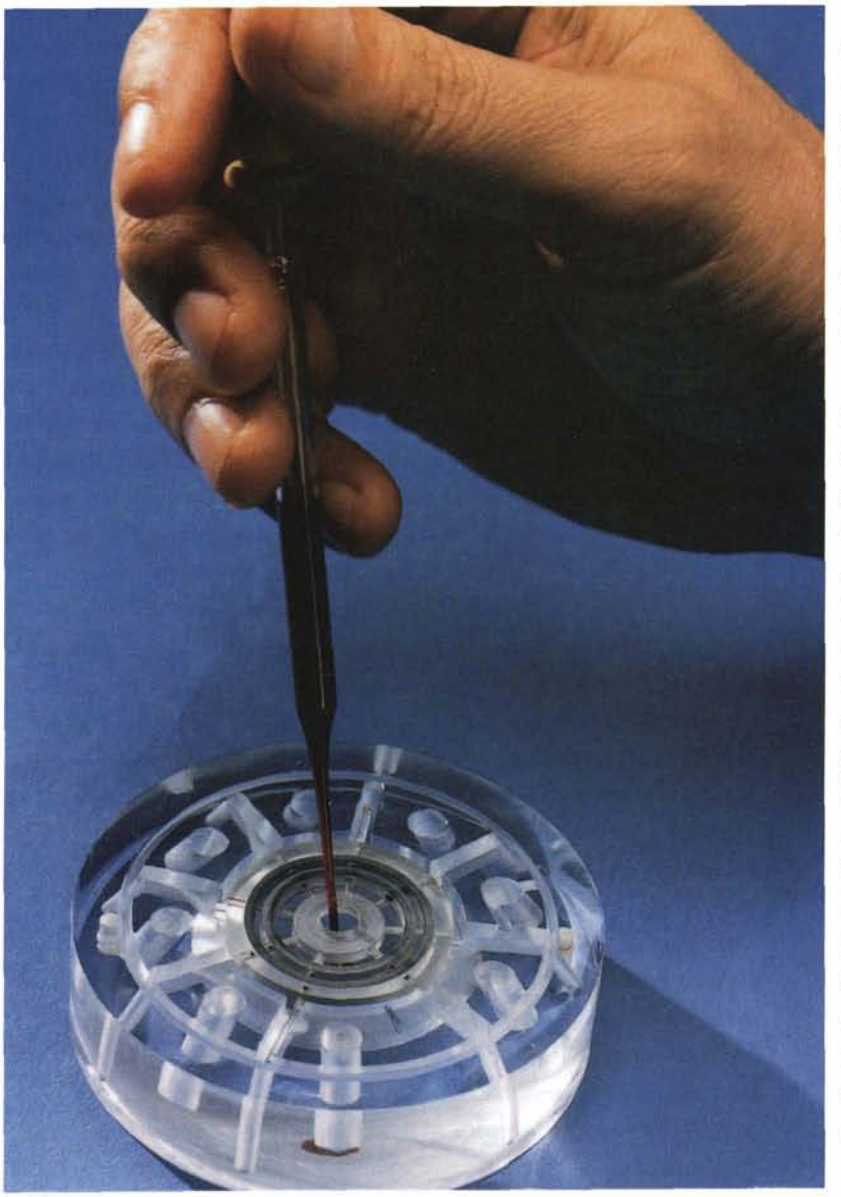


A division of HTI — Commercial Sensor Concepts — offers industrial variants of CorTemp known as the CSC-100 Series telemetric/sensory systems for internal temperature monitoring of commercial products. Specially sized and configured to a particular use, the system has wide utility in electronics, food processing, general manufacturing, pharmaceutical and agriculture/veterinary applications. ●

Blood Analyzer

In the 1970s, Oak Ridge (Tennessee) National Laboratory (ORNL), operated for the Department of Energy by Martin Marietta Energy Systems, undertook development of an automatic blood analyzer for the Skylab manned orbital laboratory under funding provided by NASA.

Because an existing mechanical analysis system was far too large for spacecraft use and would not have functioned properly in microgravity, ORNL took a new approach and developed the technique of "dynamic loading," which employed a spinning rotor as the basic step in loading, transferring and analyzing blood samples by centrifugal processing. In the **accompanying photo**, blood is being introduced to the processing rotor of the ORNL CPA-2 system, an advancement of the CPA-1 developed for NASA.

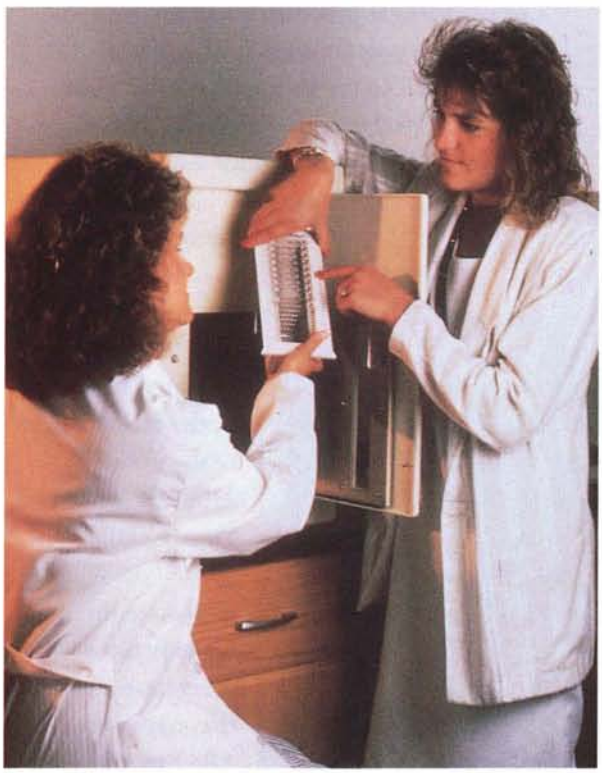


ORNL's centrifugal analysis technology served as a developmental base for a refined, commercial version of the blood analyzer produced by ABAXIS, Mountain View, California.

Designed to obviate the need for expensive laboratory based testing, the toaster-sized ABAXIS MiniLab MCA is a portable system intended for use in a physician's office. Using a single drop of whole blood, the equipment can perform 80 to 100 chemical blood tests and report results in about five minutes. ABAXIS is continuing advanced development of the system. ●

Microbiology System

Below, a technician is explaining the operation of a VITEK automated microbiology system, a time-and-labor-saving device that detects harmful microorganisms in the human body, identifies the type of microorganism causing infection, and indicates the degree of susceptibility of the offending organism to various types of antibiotics.



The VITEK system speeds up the process of treating a patient by providing the physician clear, accurate diagnostic information and quick identification of the most effective medication. It makes available in a few hours results that formerly required upwards of 24 hours to obtain, thereby contributing to reduced hospital stay.

The technology that made the VITEK system possible originated in a NASA-sponsored study aimed at a system for manned spacecraft that could rapidly and accurately measure microbial growth, even in zero gravity. The technology spawned formation of a new company and served as the cornerstone for a broad line of medical and industrial diagnostic devices. The company — bioMerieux Vitek, Inc., formerly VITEK Systems, Inc., Hazelwood, Missouri — is now one of the world's largest medical diagnostic corporations.

In the traditional manual method of testing for harmful organisms, or pathogens, specimens of a patient's body fluid are prepared in cultures, which are incubated for two to three days and studied for growth; from such study, microbiologists can determine the presence of pathogens and identify them.

The VITEK system does not replace the microbiologist, it simply allows greater speed and flexibility in testing. The process begins with the Test Card, a disposable plastic kit approximately the size of a playing card. Each card contains 30 wells, which are loaded with the biochemical reagents or antimicrobials needed for the test to be performed; one series of cards is used to identify the organism, the other is used to determine its susceptibility to various antibiotics.

Below, a Test Card is being marked with a sample number that the system's computer will read automatically. **At right**, the card is being prepared to receive a sample by means of a transfer tube. After the samples are vacuum-drawn into the card's wells, the cards are sealed and loaded into the Reader/Incubator (**far right**).

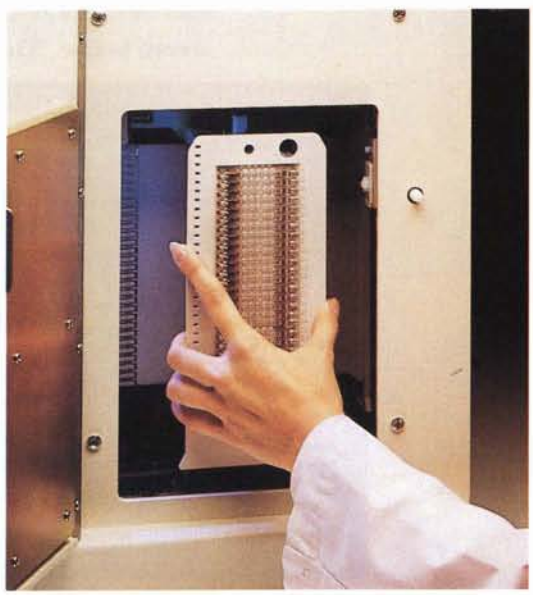
During a four to 24-hour incubating cycle (depending on the nature of the test), a photo-optical scanner periodically scans each specimen, monitoring changes in cell growth, which are reported to the computer. When growth reaches a predeter-

mined level, it indicates the presence of pathogens. A preliminary report may be requested at any time; the final report is printed automatically as soon as the results are available.

This basic technology is employed in two configurations: the VITEK, with a test card capacity from 60 to 240, and the VITEK JR., a scaled down version (30 cards) designed to maximize laboratory efficiencies at both large and small hospitals.

A companion system called VIDAS (VITEK Immune Diagnostic Assay System) is a totally automated system that detects bacteria, viruses, toxins and antibodies directly from patient specimens and provides immunochemistry results. VIDAS can operate as a stand-alone system or team with VITEK or VITEK JR.

McDonnell Douglas Corporation was the contractor for the initial NASA project begun in 1966. Aware of the commercial potential, McDonnell Douglas invested several years of company development effort in what became known as the AutoMicrobic System, the ancestor of VITEK SR. and VITEK JR., then created VITEK Systems as a subsidiary to produce and market the system. When VITEK was divested by McDonnell Douglas in 1989, the company became part of the well-known globally-operating French pharmaceutical diagnostics company bioMerieux. With that merger, the combined firm became the eighth largest medical diagnostic corporation in the world. ●



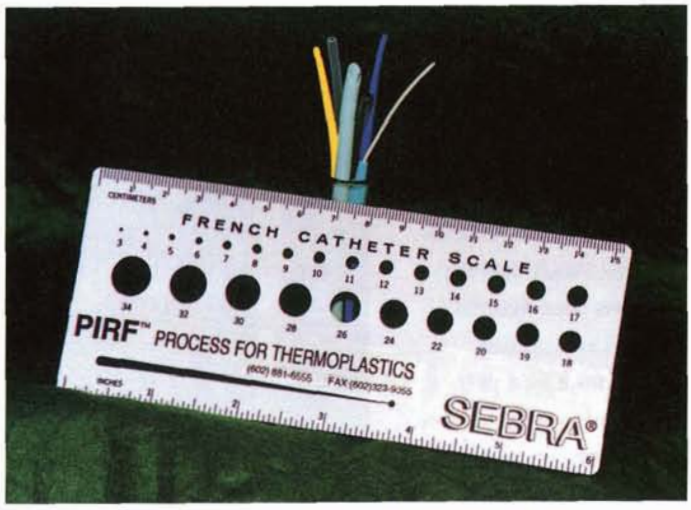
Precision Heating Process

SEBRA® Engineering and Research Associates, Inc. (SEBRA), Tucson, Arizona, a company engaged in research, development and manufacture of medical and scientific instruments, has developed an innovative heating process for precision medical equipment plastics manufacture based on technology that originated in work with NASA.

Specifically, SEBRA teamed with Jet Propulsion Lab (JPL) a decade ago on development of a sterile fluid transfer system. The project involved finding a way to connect and transfer blood and other fluids from one sterile plastic container to another, always maintaining a closed system. The key requirement was a reliable method of heat sealing and connecting various types of plastics to keep contaminants out of the bag and simultaneously to destroy any organisms that might exist in the area of the seal connection.

A HEATING PROCESS DEVELOPED FOR SPACE USE IS BEING APPLIED TO MEDICAL EQUIPMENT MANUFACTURE

SEBRA successfully developed such a method and has adapted it — under the trade name PIRF™ Process — to manufacture of medical catheters, such as those shown **below**. The PIRF Process is a precisely controlled method of heating thermoplastic materials in a mold to form or weld catheters and other products. The process employs a computer-controlled radio frequency generator with temperature feedback connected to one of various welding and forming heads. Due to the mold's low thermal mass, it can be heated to more than 300 degrees Centigrade and cooled to room temperature in less than five seconds. This rapid, efficient heating/cooling permits the use of a low power generator, typically producing 30 to 200 watts. The PIRF generator, attached to one of the forming heads, is shown **above**.



The PIRF Process offers advantages in fast, precise welding or shape forming of catheters; quality and production yield improvements due to accurate temperature control; and elimination of toxic chemicals or fumes.

In addition to its use in medical equipment manufacture, the process has applications in the aerospace, electronics, chemical, food processing and material processing industries. ●

®SEBRA is a registered trademark of SEBRA Engineering and Research Associates, Inc.

™PIRF is a trademark of SEBRA Engineering and Research Associates, Inc.

Research Instruments

At right is the Geneti-SCANNER™ Automatic Metaphase Finder, the newest product of Perceptive Scientific Instruments, Inc. (PSI), League City, Texas. Combining computer, digital imaging, recognition, robotics and biology technologies, the Geneti-SCANNER rapidly scans a batch of 60 slides and locates, digitizes, measures and classifies specific objects and events in research and diagnostic applications, for example, providing information for bone marrow diagnosis. The Geneti-SCANNER was introduced in Japan as a tool for chromosome research and is now being marketed in the U.S.

PSI is a technology transfer company, one whose primary product line is based on NASA image processing technology. The company was founded by Dr. Kenneth Castleman, who had worked on image processing at Jet Propulsion Laboratory (JPL) for 15 years, and Don Winkler, who had served 15 years with the Cell Image Laboratory of Johnson Space Center. Many other PSI employees are former NASA image processing specialists.

The company's initial development was an extension of work in computerized chromosome analysis Castleman and others had started at JPL. The product is the Genetiscan line of digital karotyping instruments, now widely used by hospitals, universities and imaging businesses in the U.S., Japan, the Middle East, Europe and, most recently, the Commonwealth of Independent States.

NASA IMAGE PROCESSING TECHNOLOGY SPAWNED A LINE OF DIGITAL IMAGING SYSTEMS FOR MEDICAL AND INDUSTRIAL USE

Karotyping is a process employed in analysis and classification of chromosomes, the bodies within a cell that carry the genes which determine heredity. Formerly, karotyping was a laborious, time- consuming task that involved photographing the chromosomes through a microscope, then manually cutting and pasting the images to put together a classification.

The Genetiscan Workstation™ and the Genetiscan Master Station™ (**above**) eliminate the need for photography and the tedious manual assembly of karotypes. The systems employ a video camera mounted on a microscope to capture the chromosome images, which are converted to digital form for processing. This makes it possible to improve the quality of the images, for example, to enhance the contrast of the chromosomes, correct shading in the microscope, or perform several other types of image enhancement operations. Karotyping, once a job requiring hours, can be accomplished in less than 10 minutes, thus increasing productivity and lowering costs in the research laboratory.

PSI also produces a line of quantitative digital imaging systems for industrial, scientific and clinical applications. ●

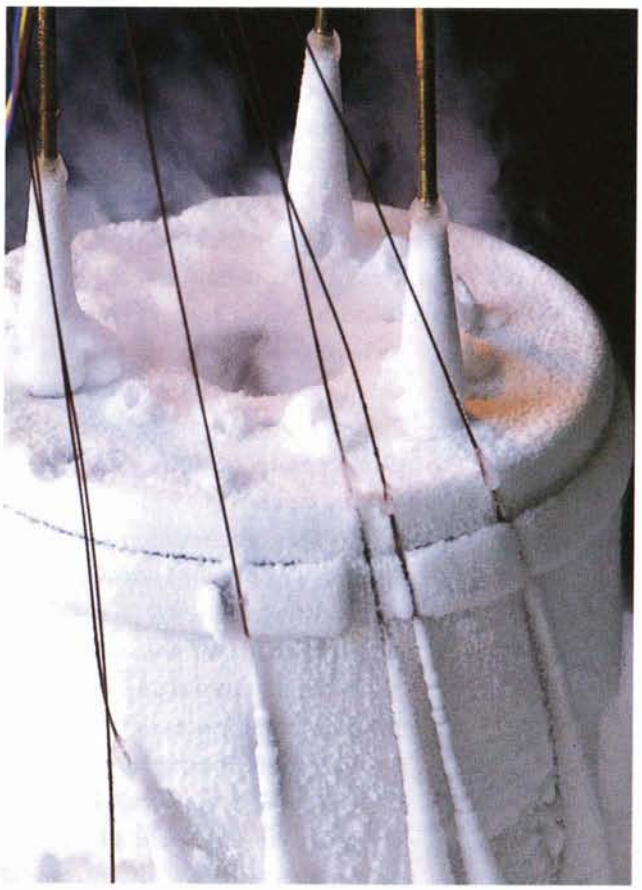
™Geneti-SCANNER, Genetiscan Workstation and Genetiscan Master Station are trademarks of Perceptive Scientific Instruments, Inc.

Low Current Magnet

A low current superconducting magnet, developed under NASA contract by Cryomagnetics, Inc., Oak Ridge, Tennessee, is now being marketed by that company as a commercial product for medical and industrial applications. The low current feature offers several advantages over conventional high current magnets.

The NASA development was initiated by the Cryogenics Section at Goddard Space Flight Center to meet a need to cool sensors aboard the Advanced X-ray Astrophysics Facility (AXAF), the third of NASA's Great Observatories series of astronomical satellites, planned for initial service in the late 1990s. The superconducting magnet is employed in a Goddard-designed AXAF subsystem known as the ADR (Adiabatic Demagnetization Refrigerator). **At left**, Cryomagnetics president Michael Coffey displays one of the magnets.

In the AXAF application, a bath of liquid helium is used to cool the ADR to 1.5 degrees Kelvin, which corresponds to about 450 degrees below zero on the Fahrenheit scale. The ADR will then cool the observatory's X-ray sensors further, down to 0.1 degrees Kelvin, almost absolute zero; that greatly increases the sensitivity of the X-ray detectors.



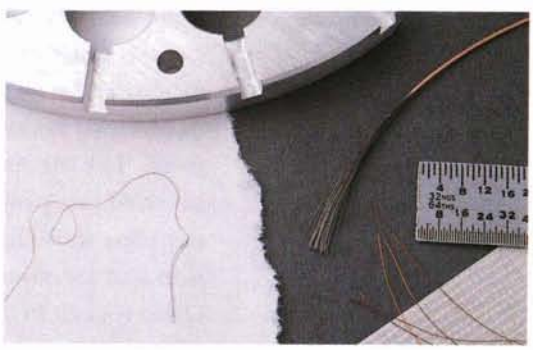
The liquid helium bath that cools the ADR also cools the superconducting magnet's electrical leads. The conventional high current magnet requires thick electrical leads, which cause high heat flow into the helium bath and rapid boiloff of the helium. Such depletion of the helium supply shortens the useful life of the instruments. **Above,** a low current magnet is being supercooled. At **right below** is a close-up of the electrical lead, much finer than human hair.

Cryomagnetics' low current magnet was developed as a means of reducing the rate of helium consumption to extend the mission lifetime of the AXAF's X-ray Spectrometer. The low current feature enables use of thin electrical leads, which reduces the electrical heating of the helium bath to an acceptable level.

In Earth applications, low current magnets offer a way to reduce operating costs through smaller, less expensive power supplies and reduced use of coolant. There is further advantage in some applications, such as hospital operation of an MRI system, which employs a magnetic field and radio waves to create inner body images from which radiologists can extract diagnostic information.

When high current magnets are used, a common way of curbing the heat in helium coolant baths is to remove the magnet leads when they are not in use. That could pose a safety problem among, for example, hospital workers engaged in MRI activities who are not thoroughly familiar with safety procedures for handling extremely low temperature materials, due to the fact that the leads are in supercold condition.

The low current magnet obviates the need for removing electrical leads, thus it not only makes MRI operation safer and more convenient for medical workers but also provides a bonus in lower maintenance requirements since there is no need for frequent removal and replacement of the leads. •



AN OFFSHOOT OF SPACE INSTRUMENTATION TECHNOLOGY, A NEW LINE OF MAGNETS OFFERS ADVANTAGES IN MEDICAL AND INDUSTRIAL APPLICATIONS

Critical Care Dialysis System

Below, Matthew Blake, 22, of Georgetown, Pennsylvania is undergoing blood-cleansing dialysis in the den of his home, using the portable REDY®2000 Sorbent Hemodialysis System. The REDY (REcirculating DYalysis) is the latest in a line of dialysis machines developed by Organon Teknika Corporation and predecessor companies over a span of 25 years.

Organon systems employ technology originally developed under NASA contract by Marquardt Corporation, an ancestor company. The Marquardt work in the late 1960s involved one project aimed at purifying and recycling water for long duration space mission and another investigating desalinization of sea water. In the course of this work, Marquardt researchers discovered that the chemical process developed for the project could be applied to removing toxic waste from used dialysis fluid. This discovery sparked a company project to develop a kidney dialysis machine.

The discovery marked the birth of what is known as "sorbent" dialysis, a method of removing urea from human blood by treating a dialysate solution. Sorbent dialysis differs from conventional single pass dialysis in one major respect: in the sorbent system, used dialysate is chemically reprocessed into fresh dialysate and sent back to the dialyzer instead of being flushed down a drain.

This regeneration process leads to a number of advantages: replenishing the small (six liter) supply of dialysate saves the electricity used to pump and heat large volumes of dialysate; makes it easier to alter the composition of the dialysate to meet individual needs; eliminates the need for a continuous water supply and drain; and provides home dialysis patients greater freedom, since the machine need not be confined to a particular room.

The company that started as Marquardt's Astro Division has been through several name evolutions. Marquardt merged with CCI Corporation in the 1968 and in 1972 a subsidiary — CCI Life Systems — took over the dialysis machines and began marketing the first version of the REDY system. In 1978, CCI Life Systems was sold to AKZO N.V. of Arnhem, The Netherlands and Life Systems became Organon Teknika, which markets REDY machines worldwide. ●

®REDY is a registered trademark of Organon Teknika Corporation.

Reflective Insulation

A COATING FOR INFLATABLE SATELLITES LED TO A FAMILY OF COMMERCIAL METALLIZED PRODUCTS

The reflective material pictured is NRC-2® Superinsulation, designed for superconducting magnets used in body-scanning magnetic resonance imaging (MRI) systems and in particle accelerators. Introduced in 1990, it is the latest in a long line of spinoff products manufactured by Metallized Products, Inc. (MPI), Winchester, Massachusetts.

NRC-2 is a thin film polyester film with a high purity aluminum deposit on one side for maximum reflectance in high vacuum applications. Used by two major producers in their manufacture of MRI equipment, the material is characterized by a unique crinkled surface that provides surface stand-off between layers and minimizes heat transfer in multilayer applications. A companion material, NRC-2/Two®, is available for special applications requiring two-sided metallized film.

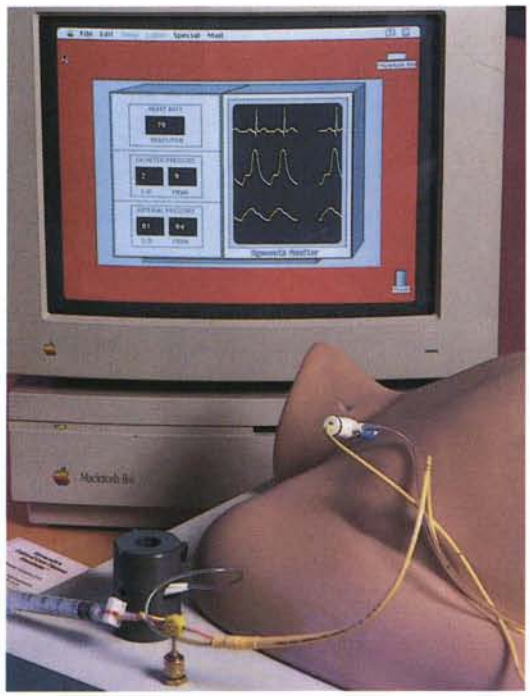
NRC-2 and scores of other metallized products trace their origins to the early years of the space program, when NASA was experimenting with large balloon-like satellites intended as orbital relay stations for reflecting — or "bouncing" — communications signals from one point on Earth to another. NASA needed a special kind of material for the balloon's skin. It had to be highly reflective; it also had to be extraordinarily thin and lightweight, in order to be carried to space in a beach-ball-size canister, then inflated to a diameter roughly the height of a 10-story building. The answer proved to be a metallized material, a plastic film coated with a superfine mist of vacuum-vaporized aluminum to create a foil-like effect.

The balloon-satellite idea didn't pan out and metallized plastics might have gone nowhere except that NASA discovered another, more important application for the metallized film: as a reflecting insulator, or thermal barrier, for protecting astronauts and sensitive space equipment from solar radiation and extremes of temperature. That discovery triggered an ever-increasing demand for metallized film in space applications and spurred development of a broad line of commercial metallized products.

MPI was one of the companies that worked with NASA on development of the original material. The company continues to supply metallized materials for a variety of space uses, but over three decades MPI has developed an even broader line of industrial and consumer-oriented metallized film, fabric, paper and foam. ●

®NRC-2 and NRC-2/Two are registered trademarks of Metallized Products, Inc.

Medical Training Aid



Below, Dr. Steven S. Saliterman (seated) of Minneapolis, Minnesota is explaining use of the Dynacath Critical Care Patient Simulator™ to a medical resident. Incorporating NASA simulation technology, Dr. Saliterman developed the system as a means of training physicians, students and nurses in critical care management and hemodynamic monitoring (monitoring the pressures associated with heart catheterization procedures). He founded Dynacath Corporation, also of Minneapolis, to market the system.

Linked to an Apple Macintosh computer, the main components of the Dynacath simulator are a computer program, a display unit (shown in closeup **at right**) and a lifelike replica of a human torso.

Hemodynamic monitoring is typically performed by a physician in a hospital's intensive care unit. Its purpose is to measure accurately the pressures within the heart and the pulmonary artery to determine the type and extent of cardiopulmonary disease, to monitor heart function and to evaluate treatment options. Where training in this procedure was formerly conducted at the bedside of a live patient, the Dynacath system allows training to develop both patient care and procedural skills through repetitive simulation.

The system's display unit shows patient histories, progress notes, consultations, treatment options and results. Patients' responses change based on the treatments selected. The torso and its internal sensors permit repetitive practice of catheterization, with realtime simulation of heart rhythms and pressures displayed on the screen. In addition to its value as a training aid, the system is useful as an aid to physician certification or as a tool for evaluating the quality of care delivery.

Since its introduction in 1990, many hospitals and research universities have adopted the system and a number of heart catheter-producing companies have purchased units.

The Dynacath system is based on Dr. Saliterman's own extensive medical and engineering background and on NASA simulation and instrumentation technology acquired during his employment at two NASA centers. He attended Mayo Medical School and Mayo Graduate School, Rochester, Minnesota from 1973 until 1980. During that time, he also served as a summer intern at Johnson Space Center (1973-74) and as a life sciences research fellow at Ames Research Center (1976). Dr. Saliterman is currently a practicing physician at a Minneapolis clinic; a consultant at Methodist Hospital in Minneapolis; an instructor in advanced cardiac life support for the American Heart Association; and senior aviation medical examiner for the Federal Aviation Administration. ●

™Critical Care Patient Simulator is a trademark of Dynacath Corporation.

Stress Reducing Chair

NASA HUMAN FACTORS RESEARCH CONTRIBUTED TO DEVELOPMENT OF A RELAXING CHAIR FOR HOME OR OFFICE

Shown **below** is the Flogiston Chair, a product designed to minimize internal and external physical stress at work or home. Developed by Scotland-born design engineer Brian V. Park (shown)and marketed by Park's Flogiston Corporation, Webster, Texas, the chair incorporates NASA technology to provide a close approximation of the Neutral Body Posture, the natural position a body assumes in weightless space. In such a posture, says Park, "all the muscular forces are in balance, the body is in biomechanical equilibrium, physical stress is at a minimum."

Flogiston Corporation sees as its principal market for the chair the rapidly growing force of information workers who, studies suggest, may encounter stress from working with computers. Computer users such as designers, architects, process control monitors, software developers and data processors all require high levels of concentration for extended periods; the chair is intended to provide a suitable environment for maintaining concentration.

In addition, the chair has utility in the home for relaxed television watching, music listening, reading or general meditation. And, Brian Park suggests, the chair offers an ideal base for virtual reality ventures, wherein one can "virtually" enter, explore and interact with a computer generated artificial environment.

The Flogiston Chair consists of two principal parts: the structure and the supporting cushion. The aluminum structure provides the mechanical support and shapes the posture. The cushion, covered with soft fabric or leather, is cut from one piece of long memory foam (similar to the foam used in the Space Shuttle Orbiter seats), which responds to body heat and pressure, softens and feels as if it is molding to the body. The chair may be fixed, rockable or suspended from the ceiling; it comes in two standard sizes, medium and large, and it can also be customized to an individual fit.

Brian Park credits NASA with a "key role" in development of the Flogiston Chair. Planning to design a chair for relaxation and meditation, he came across an article in *NASA Tech Briefs* on the Neutral Body Posture, based on research in the Skylab manned orbital laboratory of the early 1970s. He wrote NASA requesting additional detail on the Skylab experience and received an invitation to visit Johnson Space Center (JSC) from JSC engineer John Jackson.

Jackson provided personal help and documentation on the Neutral Body Position and human factors in spacecraft design. Park was also provided an Anthropomorphic Source Book, a three-volume compendium of knowledge about the size, shape and motion characteristics of the human body developed by NASA as a comprehensive guide to workstation design. Park drew on these and other sources in designing the chair, whose posture ultimately was a compromise between the Neutral Body Posture and Sasavana, a Yoga posture of relaxation. ●

Food Service System

In a hospital that must serve a thousand or more meals a day, food must be cooked well in advance, stored hot until mealtime, then delivered to patients some distance from the central kitchen. In the process, meals can lose heat, moisture, flavor and nutrients.

A recently-introduced answer to that problem is the 3M Food Service System 2, a system whose origin is rooted in space technology. Developed by 3M Health Care, St. Paul, Minnesota, the system employs a "cook/chill" concept for plating, storing, heating and serving daily meals on a volume basis. It allows hospital and food service staffs to prepare food well in advance, separating the food preparation function from the meal schedule, while maintaining meal quality.

The advantages to the patient, says 3M, are foods that are still hot at serving time, look more appealing, taste better and suffer no loss of nutritional value, because the cook/chill technology helps retain nutrients. The advantages to hospital administrators and food service directors are scheduling flexibility, labor costs estimated at 10-15 percent lower than traditional hot food sytems, and reduction of total operating costs by as much as 20 percent.

The key to the cook/chill approach is the technology of integral heating, in which each 3M plate and bowl heats independently, so that hot foods stay hot and cold foods stay cold. This integral heating method was developed by 3M under NASA contract in 1966-67 for meal service aboard the Apollo lunar spacecraft.

The main component of the Apollo development was a unique, electrically heated, insulated dish that served as both plate and oven when slipped into a control module. The module provided electrical contact and a resistive coating on the bottom of the dish-oven converted electrical energy to heat. In the 1970s, 3M developed a commercial version of the Apollo system that was used by a large number of hospitals and nursing homes. That system, shown **at left**, served as the cornerstone for the Food Service System 2 introduced in 1991.

In the new 3M process, the hot portions of meals are cooked a day or more in advance and chilled in bulk containers. On serving day, the meals — still cold — are portioned and plated (**above**), then assembled on trays in 3M Thermalization Carts. The fully-loaded carts are stored in a refrigerator unit.

At mealtime, the carts are removed from the refrigerator and plugged into a power source in the central kitchen or in separate pantries on each floor. The cart's power module supplies electricity to the 3M dishes which, like their Apollo predecessors, convert electrical energy to heat. Each plate has built-in sensors that monitor and control the heat to maintain each dish at ideal serving temperature.

In just 24 minutes, the thermalization process is completed. The trays are removed from the thermalization cart (**right**) and served to the patient (**below**); the double-walled dish is insulated so that the outside is cool to the touch. According to 3M, patients have expressed high satisfaction with cook/chill meals and with the trayware, round dishes and bowls in an array of contemporary colors, designed to resemble more closely the dishes used at home. ●

Cell Growth Enhancement

In the **accompanying photos**, laboratory technicians of Exogene Corporation, Monrovia, California are engaged in bioprocessing experiments. A company formed in 1987, Exogene teams with pharmaceutical, biotechnology and chemical companies in applications of Exogene's advanced technologies to enhance production of bioprocessed substances, such as proteins, antibiotics and amino acids.

A long standing problem in bioprocessing is ensuring adequate oxygen to achieve the desired cell growth and productivity; cells starved for oxygen often create compounds that inhibit or even terminate cell growth. Where efforts to improve oxygenation usually focus on increasing the amount of oxygen transported to the cell, Exogene takes an entirely new approach to the problem: it employs genetic modification of the cells to enable synthesis of a novel hemoglobin molecule that allows the cells to use the available oxygen more efficiently, resulting in higher product yields.

Another Exogene innovation is an oxygen-sensitive genetic switch, or promoter, that facilitates increased production of pharmaceutical proteins. The promoter provides high levels of protein synthesis while eliminating some of the problems and costs associated with traditional promoter systems.

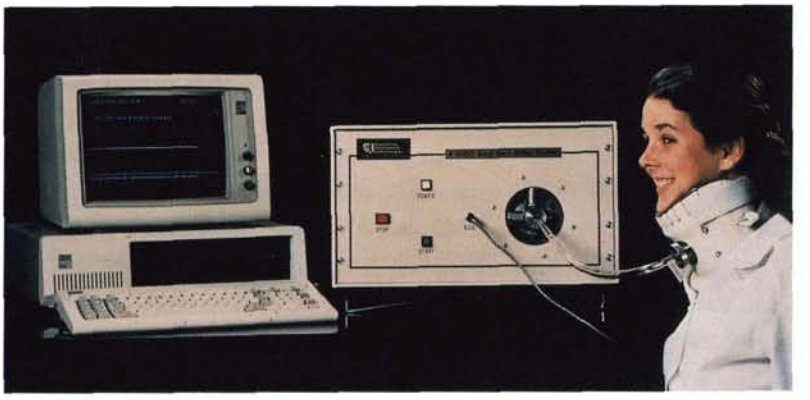
These and other Exogene technologies originated in research performed for NASA's Jet Propulsion Laboratory by Professor James E. Bailey and Chaitan Khosla of the California Institute of Technology (Caltech) Chemical Engineering Department. In the latter 1980s, Bailey and Khosla conducted extensive experiments in cell growth through production of hemoglobin as a way to improve oxygen supply to cells. Exogene was granted a worldwide exclusive license to commercialize the Caltech work.

By improving the efficiency of oxygen use by the cells, Exogene says, major operational expenses associated with oxygen transfer can be reduced. Greater product yields result in decreased raw material costs and more efficient use of capital equipment. Increased concentrations can lower downstream processing costs and, with fewer batches needed to meet manufacturing requirements, quality control costs are also reduced. The company cites a broad range of applications for its core technologies, including a variety of products and processes in the areas of biotechnology, pharmaceuticals, specialty chemicals and waste treatment. ●

Blood Pressure Control

AN ASTRONAUT MONITORING SYSTEM OFFERS UTILITY IN MEDICAL RESEARCH

Below, a model is demonstrating use of the E-2000™ Neck Baro Reflex System developed for NASA by Engineering Development Laboratory, Inc. (EDL), Newport News, Virginia. The device was invented by EDL president Ross L. Goble, a former NASA engineer. The E-2000 system was developed for cardiovascular studies of astronauts, who experience greater than usual blood pressure and heart rate instabilities while weightless, suggesting that microgravity may impair the body's normal blood pressure controls.



A space-qualified version of the E-2000 is being used regularly on Space Shuttle missions to study blood pressure reflex controls and the possibility of "resetting" such controls by stimulation; the system stimulates the carotid arteries by electronically controlled applications of pressure to the silicon/latex neck cuff pictured.

The civil applications of the system were apparent from the start and EDL developed a parallel version intended as a research tool for studies of patients with congestive heart failure, chronic diabetes mellitus and other conditions in which blood pressure reflex controls behave abnormally. EDL has delivered a number of commercial E-2000s to hospitals, universities and physiology laboratories in the U.S. and abroad.

The E-2000 consists of the neck cuff, a motor-driven bellows for delivering stimulus and a PC-controlled electronic system. In 1991, EDL introduced the advancement pictured **at bottom**: the Programmable Pressure Controller-1000 or PPC-1000™. This system is based on the E-2000, but EDL substantially refined the technology to produce a new device that is less expensive and more versatile than the E-2000.

As its name indicates, the PPC is a controller that provides an accurate means of generating pressure for a broad array of laboratory applications. It can be used as a blood pressure research system with arm and leg cuffs as well as the neck cuff, for monitoring any part of the body. EDL is also developing an improved version of the E-2000 known as the E2010™ Barosystem. The E2010 does not need a PC; the computer is integral. ●

™E-2000, PPC-1000 and E2010 are trademarks of Engineering Development Laboratory, Inc.

Earth Observation Services

A NASA INITIATIVE IS SPURRING PRIVATE INVESTMENT AND EXPANDING COMMERCIAL REMOTE SENSING TECHNOLOGY FOR ENVIRONMENTAL PROTECTION AND RESOURCES MANAGEMENT

More and more ocean-going vessels are taking advantage of the streams of information beamed to them by weather satellites of several nations — information about cloud formations, storms, weather paths, ocean current patterns, winds, temperatures and even — for those equipped with special receivers — positioning data.

It's valuable information. Long distance yachts, for example, use it to find the best winds and best currents for a speed edge, or for shaving time off a voyage through precise satellite-aided routing. Commercial fishing boats use the information to locate upwellings, areas of temperature differences that indicate the presence of certain species of fish. And all mariners can sail safer by using the information to locate and avoid severe storms.

A small but growing industry supplies marine operators — and land-based users too — the satellite receivers and image processing systems needed to acquire and interpret the data. Among these companies, one that is making a name for itself is Systems West, Carmel, California, whose motto is "We bring affordable weather technology to the world." Systems West's compact, lightweight, easy to operate weather data microprocessors, the company declares, cost about one-third the price of conventional machines.

The marine market has been a major target for Systems West, due in part to the fact that the company was able to expand its expertise in that area through participation in NASA's Earth Observation Commercialization Applications Program (EOCAP). This effort, managed for NASA by Stennis Space Center, provides government co-funding to encourage private investment in, and broaden use of, NASA-developed technology for gathering and analyzing information about Earth and ocean resources. EOCAP seeks increased innovation in the commercial applications of largely proven remote sensing technologies and supports the transition of such innovations to the commercial marketplace; it is, essentially, a NASA-managed effort to generate expanded spinoff benefits to both industry and the user public.

The commercial fishing boat *Dakota* carries its own Systems West weather satellite data processing station, whose information guides the crew to the most productive fishing waters. Systems West developed the equipment as a participant in NASA's EOCAP program.

Systems West was among the first EOCAP participants. The company's EOCAP project involved development of both software and hardware for a shipboard system that receives, processes and displays images from polar orbiting satellites.

Company technicians check out a Systems West Model 5300 ground station, which receives and processes data from geostationary weather satellites.

A NASA PROGRAM HELPED A COMPANY DEVELOP A LINE OF COMMERCIAL IMAGE PROCESSING SYSTEMS

Systems West now markets a family of microprocessor-based systems for processing data from both polar orbiting and geostationary satellites. Typical of the line is the Model 4000 Marine Weather Satellite Information System, which offers automatic, unattended operation and allows users to view real-time images of weather systems, day and night, of areas covering as much as four million square miles — or to zoom in on a few square miles for closer analysis of specific matters of interest.

The images that appear on the color monitor allow mariners to locate subtle currents and eddies and optimize vessel speed to save time and fuel; to interpret wind direction and frontal movement; to improve safety with pictures and data on severe storms; or to use 256 colors or 64 shades of gray to identify sea surface temperature ranges and pinpoint fishing areas promising the best catch.

The company's product line is by no means limited to shipboard systems. The "affordable" and easy to use characteristics of Systems West equipment have built a market for the company among developing nations with small budgets and few trained weather station personnel; customers include Peru, Bangladesh, Mexico, Colombia and the Azores. Systems West also offers small tactical units for military operations and desktop models for local airports and rural/regional weather bureaus.

Systems West was formed in 1986 by space and weather expert Kenneth W. Ruggles, who is now president; electronics engineer Dick Reins; and retired Navy captain Bill Hubert, a specialist in marine technology. They saw an opportunity to bring down the cost of satellite weather stations by developing special software to enable satellite image processing by personal computer. The EOCAP program, says Systems West's president Ken Ruggles, not only created a new line of commercial systems for weather processing, it also provided a significant boost to the company's technological capability.

(Continued)

Earth Observation Services (Continued)

In the 1970s, NASA pioneered research in satellite remote sensing technology with the Landsat family of Earth resources monitoring satellites. The Landsat technology was commercialized in the 1980s and that step spawned an expansion of the complementary technology of airborne remote sensing.

NASA's EOCAP program represents a new step toward broadening the benefits of remote sensing technology, a step that not only fosters new applications of the technology but also gives participating companies an opportunity to improve their technical expertise.

EOCAP was launched late in 1987 and since that time NASA has selected more than 30 proposals from industry and universities for co-funding contracts to develop new remote sensing applications and equipment. Here are some additional examples:

San Diego State University (SDSU), teamed with Environmental Systems Research Institute (ESRI), Redlands, California; ERDAS, Inc., Atlanta, Georgia; and the San Diego Association of Governments (SANDAG), a regional planning agency, to demonstrate a cheaper, easier way to derive information on regional land use and land development.

Accelerating change in the San Diego area — and in many other areas — makes it difficult to keep geographic information systems (GIS) up to date. The team, headed by principal investigator Douglas Stow, SDSU associate professor, is applying satellite imaging and image processing techniques to GIS updating.

The project employs a system known as ARC/INFO Live Link, an integration of a processing program developed by ERDAS, Inc. and a computerized GIS developed by ESRI. Commercial activities include marketing the Live Link system and County-in-a-Box, which includes geocoded satellite image data that can be used with Live Link to update GIS data layers. The cost effectiveness of Live link and County-in-a-Box has been demonstrated by SANDAG, which used these products for land use and other applications, such as mapping vegetation distribution and preserving wildlife habitats in San Diego County.

This composite image of an area in San Diego, California is a computer generated representation of the land use changes that occurred over a two-year span, obtained by combining satellite imagery acquired in 1986 and 1988. Part of an EOCAP project led by San Diego State University, the image shows newly completed construction (red), areas where land use changed (green) and areas that did not change (black, gray, white).

Another of the early EOCAP efforts involves Professors Greg S. Biging of the University of California at Berkeley and Russell G. Congalton of the University of New Hampshire, who applied remote sensing technology to commercial forest inventory. They demonstrated that satellite data, used in conjunction with ground data, can produce forest classifications of the same or better accuracy than can be obtained by traditional techniques applying aerial photography. A completely accurate comparison of satellite observations and aerial photo interpretation has not hitherto been available.

Photo by Jerry Morse

Shown analyzing forest imagery, Professor Greg S. Biging of the University of California at Berkeley heads a team demonstrating that satellite data can generate forest classifications with equal or better accuracy than traditional aerial photography techniques.

The project is being conducted jointly with Sierra Pacific Industries (SPI), Anderson, California, a major California timber company.

Biging and Congalton assembled the computer programs and analysis techniques developed in the EOCAP effort into a processing package called CALFIRST (California Forest Inventory and Remote Sensing Technology). CALFIRST is undergoing pilot testing on SPI land in the Sierra Mountains, using some 300 test sites ranging in size from 50 to 250 acres. The first year's results showed that CALFIRST can discriminate forest species, size class and density for the mixed conifer species stands in northern California better than professional aerial photography interpreters.

The University of California at Berkeley team plans to market CALFIRST to forest companies and government agencies using several technology transfer routes, including the University of California Extension Service. Commercialization is being aided by two consulting firms whose job it is to take the technology developed under the EOCAP program and move it into the marketplace; they are Pacific Meridian Resources, Emeryville, California and VESTRA Resources, Redding, California, both engaged in remote sensing and natural resources management activities.

In another EOCAP project, Research Planning, Inc. (RPI), Columbia, South Carolina, in cooperation with Stennis Space Center and the University of South Carolina, has developed advanced techniques for "environmental sensitivity" oil spill mapping.

Traditional techniques for developing Environmental Sensitivity Index (ESI) maps for oil spill response are expensive, often inaccurate and unavailable in many parts of the world. The RPI/EOCAP project sought an advanced method of providing decision makers with timely, highly accurate, more readily updatable and more comprehensive ESI maps incorporating satellite remote sensing and GIS technologies.

A Landsat image shows the spread of a Persian Gulf oil slick that occurred during the war-caused spill of February 1991. Research Planning, Inc. developed a remotely sensed information system for prioritizing protective measures during oil spills.

RPI successfully achieved that goal and the company demonstrated the efficacy of its system in February 1991, following the oil spill in the Persian Gulf that occurred during the Gulf war. Dr. Jacqueline Michel, RPI vice president, headed an effort to provide remotely sensed information to military and civilian officials involved in assessing the damage potential of the oil slick and identifying the natural and socioeconomic resources threatened by the spill.

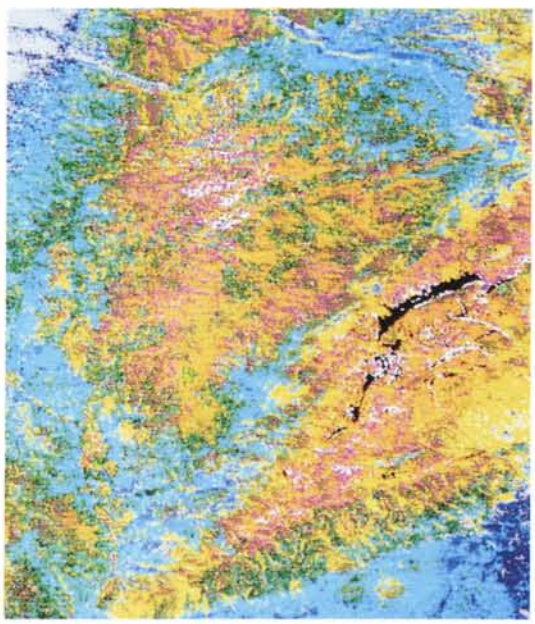
As a result of its EOCAP work, RPI is marketing a commercial ESI product that focuses on oil spill response, coastal zone development and environmental assessment using remote sensing and GIS technology. ●

Forest Imaging

Below is a color-coded image showing the various types of vegetation in Cibola National Forest, which includes lands in New Mexico, Texas and Oklahoma. Acquired by reflectance sensors aboard a NASA developed Landsat satellite and created by NASA's ELAS image processing software, the image is one of many being used by the Forest Service of the U.S. Department of Agriculture to map ground characteristics of the forest in support of a variety of activities, such as timber analysis, wildlife habitat, range measurement, and development of general vegetation maps for use in the area's geographic information system (GIS).

SPACE REMOTE SENSING TECHNOLOGY IS BEING EMPLOYED IN FOREST VEGETATION MAPPING

Unlike the EOCAP-sponsored commercially-oriented applications of satellite remote sensing technology (see pages 82-85), the work at Cibola is a cooperative technology demonstration involving several government and academic agencies.



"By pooling resources and cooperation," says Forest Service soil scientist Steve McWilliams, who coordinates remote sensing activities, "we hope to provide technology transfer for improved resources management using a fast, accurate and less expensive method of inventorying vegetation over a large, complex area at a point in time."

And, McWilliams adds, the multi-agency synergistic approach offers benefits beyond vegetation typing: "Concepts of diversity and ecosystem associations can be depicted in a manner unlike any previously available technology. This (remote sensing) technology will enhance conventional assessments when addressing the requirements of the National Environmental Policy Act; assist in updating forest plans according to the National Forest Management Act; and facilitate the delineation of special areas, such as riparian areas."

NASA is part of the multi-agency team, through its Technology Applications Center at the University of New Mexico (Albuquerque), which provides image acquisition, analysis and processing support. The Water Resources Division of the U.S. Geological Survey contributed a computing platform and GIS software. The Rio Puerco (New Mexico) district office of the Bureau of Land Management aids in management of adjacent lands, studies limits of acceptable change and analyzes vegetation. The Cibola effort also supports the University of New Mexico's Long Term Ecological Research site. The Forest Service has extended the benefits of remotely sensed data to the City of Albuquerque and New Mexico State Forestry for assistance in recreation/open space analysis and forest/urban interface. ●

Image Processing Software

Shown **below** is a satellite image of a convective cloud system over Alaska, a composite made from four different overflights by a polar orbiting satellite. The image typifies the type of satellite data collected by the National Weather Service (NWS) Alaska Region, Anchorage. To convert the streams of raw data into

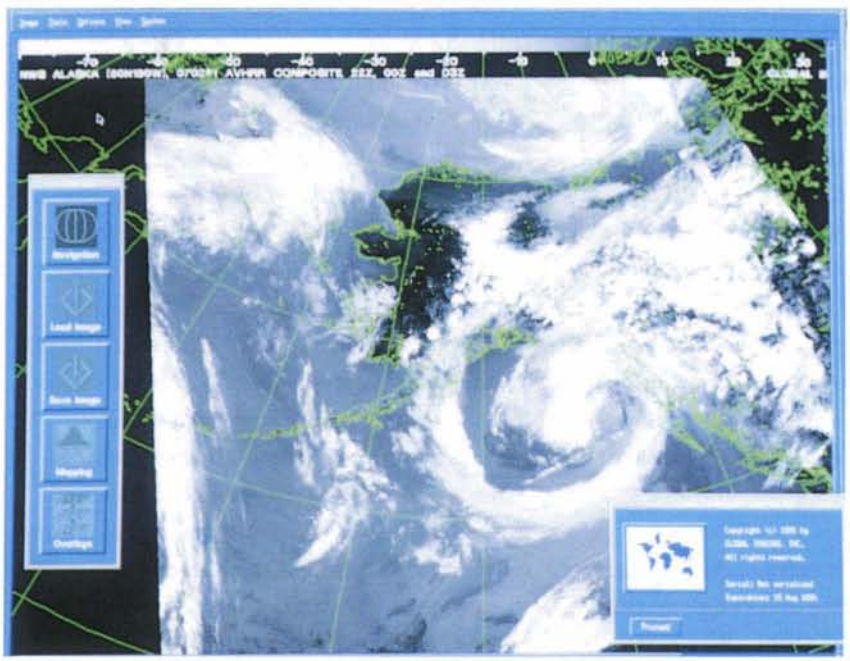


Photo by Gary Hufford, Ph.D., NWS Anchorage

environmental products, NWS uses a spinoff Global System 9000 image processing system marketed by Global Imaging, Inc., Solana Beach, California.

Global System 9000 combines HP Apollo workstation hardware, manufactured by Hewlett-Packard Company, Palo Alto, California, and advanced Global Imaging software to offer, according to Global Imaging literature, "Cost-effective imaging software in a workstation environment incorporating capabilities previously found only in supercomputer or mainframe systems." Designed exclusively for the HP 9000 family of computers, Global System 9000 is intended for a wide variety of applications in the fields of remote sensing, resource exploration, medicine, education, oceanography and military reconnaissance.

The spinoff element in Global System 9000 is the Global Applications Executive™(GAE) software package, an enhanced version of the NASA developed Transportable Applications Executive (TAE). Originally developed by Goddard Space Flight Center to support remote sensing and image processing applications, TAE was designed to lower the cost of system development by providing software and structures for commonly recurring requirements, such as menu and command interfaces, information displays, parameter processing, error reporting and on-line help. Over the years, TAE has evolved from a traditional command and menu-oriented system to a state-of-the-art user interface development system supporting high-resolution-graphic workstations.

Global Imaging's version of the NASA software — GAE — "makes the system easy to learn and even easier to use." GAE can be operated in one of three interchangeable modes; menu, command or tutor. In the menu mode, the user selects from a list of application functions. In command, the user communicates with the system in simple English commands. In the tutor mode, the user is prompted for all parameters that must be supplied to an application program.

Among Global Imaging's customers, in addition to NWS, are the National Bureau of Standards, the Scripps Institute of Oceanography, universities, hospitals and industrial corporations. ●

™Global Applications Executive is a trademark of Global Imaging, Inc.

Air/Water Purification

At left is Dr. B.C. "Bill" Wolverton, a member of the Space Technology Hall of Fame and perhaps the world's leading pioneer in utilizing plants and microorganisms to solve air and water pollution problems.

Wolverton, a retired NASA researcher who served 18 years at Stennis Space Center, (SSC), recently formed his own company — Wolverton Environmental Services, Inc. (WES, Inc.), Picayune, Mississippi — to provide technology and consultation in such areas as indoor air pollution abatement; domestic/industrial wastewater treatment; and aquaculture, the use of aquatic plants to remove pollutants from wastewater at relatively low cost.

At right is part of Wolverton's Picayune home that is actually a laboratory for one of WES, Inc.'s research programs. It is the first combined indoor wastewater treatment/air purification system employing common houseplants.

The plants absorb potentially harmful gases and chemical compounds to purify home or office air and water. Wastewater is pumped from the bathroom and fumes from the kitchen into a living room filtration system of plants — ferns, ficus and philodendrons — reinforced by activated carbon filters. The wastewater is used as water fertilizer for the plants, which purify the indoor air and at the same time convert the wastewater to clean water. The system, operational for three years, has demonstrated the practicability of this concept. WES, Inc. has licensed several companies to manufacture and market high efficiency indoor air filtering devices.

The first public building to use the technology is a new math and science complex at Northeast Mississippi Community College (Booneville). The design of Wolverton's Booneville plant filtration system calls for routing ventilation air through a two-story atrium equipped with filter boxes of plants, clay and charcoal. The plants purify the air and additionally cleanse sewage from the building's bathrooms, recycling the water for use on campus gardens.

Wolverton and his aides at SSC's Environmental Research Laboratory (ERL) began experimenting almost two decades ago on ways to cleanse, detoxify and reuse over and over the initial supplies of water and oxygen to be carried by future long duration spacecraft. In 1974, the ERL started investigations of aquaculture, with initial focus on the water hyacinth, which can absorb astonishing amounts of pollutants. After successful demonstrations at SSC, a large number of communities adopted aquaculture for either primary or supplementary wastewater treatment.

Since water hyacinth applications are confined to warm weather areas, Wolverton's group developed a second

generation cold-tolerant "artificial marsh" system employing a combination of pollutant absorbing plants and sewage-digesting microbes. More than 100 U.S. communities have since adopted the artificial marsh technology.

WES, Inc., has continued research and application of aquatic plant/microbial wastewater treatment systems started at SSC. WES, Inc. systems are in operation in a number of U.S. towns, particularly in Mississippi and Louisiana. Wolverton also offers designs for treating industrial wastewater in facilities ranging from poultry processing to chemical manufacturing plants. The first chemical company to adopt aquatic/microbial technology as part of its wastewater treatment process is Degussa Corporation, Theodore, Alabama.

A new application is treating water for fish farming; because of the tremendous amount of water needed for intensive fish culture, WES, Inc. is working with fish farmers on applying aquatic plant/microbial filters to treat and recycle their water.

There are about 100,000 acres of catfish ponds in Mississippi. Certain forms of nitrogen become toxic to catfish, particularly in intensively stocked ponds. There is a further problem in that noxious effluent from the catfish ponds pollutes rivers feeding into the Gulf of Mexico, a major concern of the U.S. Department of Agriculture (USDA).

Artificial marsh technology is being evaluated as a purification system at the catfish farm of Truman Roberts in Purvis, Mississippi by the University of Southern Mississippi (USM), working under a grant from the Gulf of Mexico Program with technical assistance by USDA's Soil Conservation Service.

At the Roberts farm, a one-acre wetland filter cleans water from the catfish production pond, removes toxic nutrients and recycles the water back to the production pond. At **left above**, water from the Roberts catfish pond is flowing into the filter pond for cleansing; at **right above** the cleaned water is being sprayed back to the catfish pond. Initial evaluations by USM biologists indicate that the artificial marsh is effectively improving water quality and removing toxic substances. Bonuses include the farmer's ability to increase stocking rates per acre, creation of wildlife habitat, and cleaner discharges into local waterways that feed into the Gulf of Mexico. ●

Airborne Remote Sensing

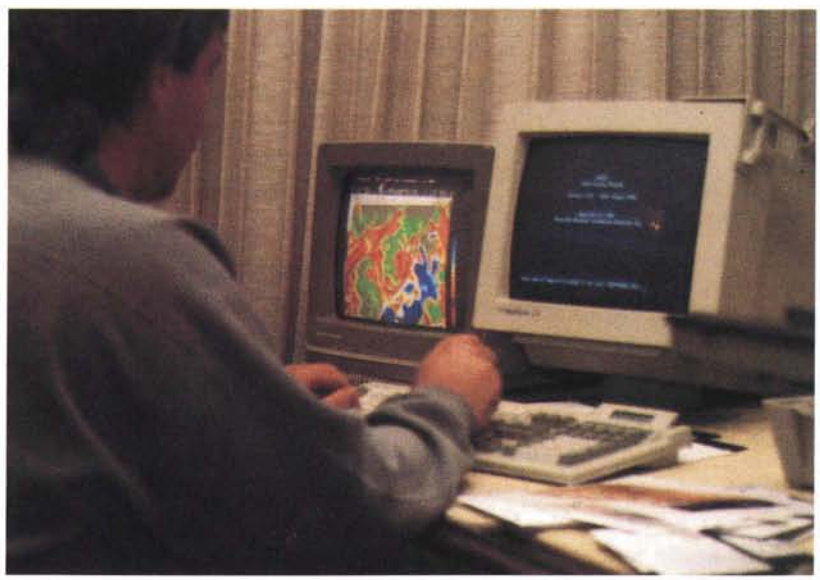
AG-RECON (Agriculture Aerial Reconnaissance), Kirkland, Washington exemplifies a small but growing number of companies providing commercial remote sensing services employing digital imaging, image analysis and image enhancement techniques pioneered by NASA.

AG-RECON is headed by David Olson, who holds an engineering degree from California Polytechnic State University. **At left**, Olson (left) is shown with pilot Curtis Holmes identifying ground landmarks prior to a data acquisition flight in AG-RECON's Riley Turbo-Stream aircraft. Olson is pictured **at right** processing data from a flight and at **upper right** comparing actual ground conditions of a field with data acquired by airborne imaging.

AG-RECON provides information from airborne sensors and aerial photography, satellites and ground databases on agriculture, forestry and the environment. The information is used by farmers, foresters, geologists, hydrologists, cartographers, consultants and other decision makers.

The company's aerial reconnaissance system monitors reflectances from the ground in visible, infrared and ultraviolet light bands of the spectrum. Computer processing of the discrete frequencies of light reflected from the ground reveals the presence — or absence — of a particular condition that may warrant investigation or special treatment, for example, crop disease and pest infestation.

Other types of agricultural management information collected by AG-RECON overflights include detection of nutrient deficiencies, soil type changes, irrigation scheduling and distribution problems, frost damage and yield projections. In forest management, AG-RECON information delineates forest fire areas, monitors selective timber cutting and estimates stand survival. Information for environmental management includes extent of range or forest fire damage, oil spill



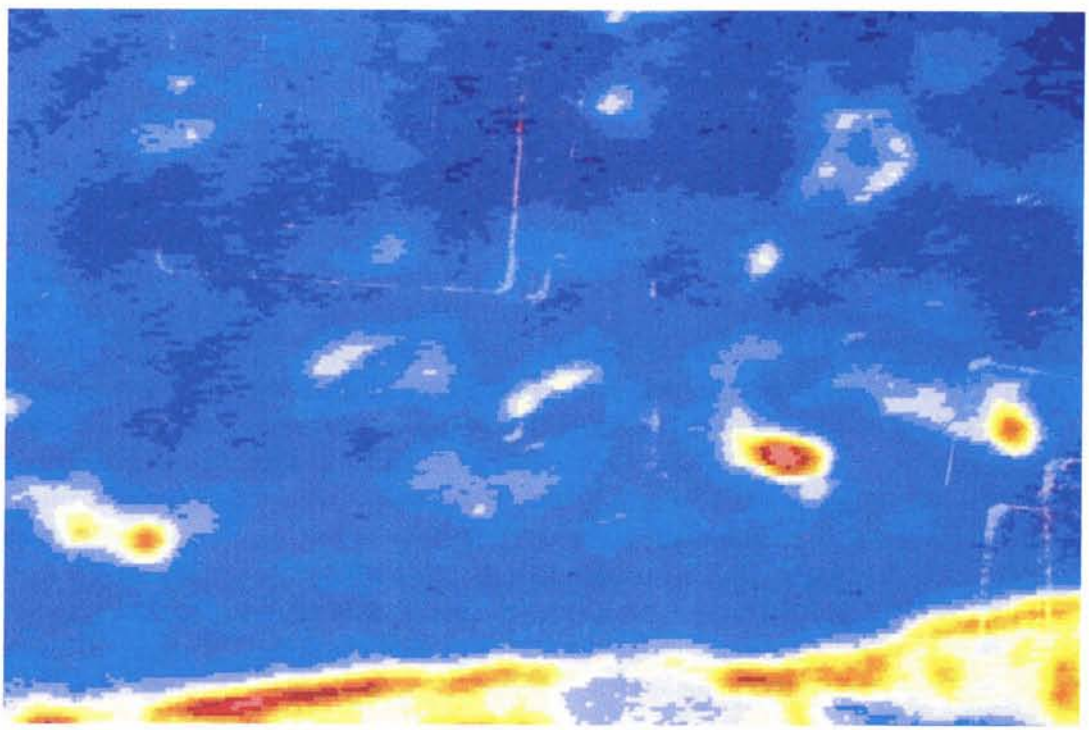
NASA IMAGING TECHNOLOGY PROVIDES A BASIS FOR A COMMERCIAL AGRICULTURAL RECONNAISSANCE SERVICE

boundaries, spray damage and thermal plumes, among a wide variety of other applications.

AG-RECON's basic product is a computer-generated color "map" of Earth conditions. These maps, accurate to scale and containing indications of absolute and relative differences, are delivered within hours of the time the conditions were actually observed.

There are a number of different types of specialty maps, for example, COLORMAP, in which natural colors are enhanced so that problems represented by changes in crop color can be detected earlier, or GROWTHMAP, in which different colors identify stands of trees and their densities for forest inventory.

Another example, shown **below**, is STRESSMAP, a forest analysis product in which each shade of color represents a one degree Fahrenheit change of temperature, with red the warmest areas and blue the coolest. Temperature changes can indicate changes in species, drainage problems, fire damage, and water disease and pest stress. If canopy temperature in an area is proportionately warmer to its canopy density, compared with similar areas within an image, there may be a disease or pest problem that calls for on-site investigation. With products like STRESSMAP, forest professionals can increase the speed and accuracy of their surveys and improve work documentation and tract histories. Other types of STRESSMAPs define temperatures for agricultural crops; any field condition that affects plant stress will show up as a change in one of 20 color categories. ●



Water Purification

Over the past two decades, NASA and its contractors have conducted extensive research on how to assure pure water for manned spacecraft crews and how to recycle wastewater for reuse on future long duration spacecraft. This work has given rise to a large number of spinoff products and products for cleansing and detoxifying water (see also pages 55 and 110-113) and in some cases inspired the formation of new companies to commercialize the technology.

Among the latter is Sensible Technologies, Inc. (STI), Irmo, South Carolina, a company formed in 1989 to exploit a particular NASA-developed water purification technology known as silver ionization. In this method, developed in the mid-1960s by Johnson Space Center, a small lightweight generator dispensed silver ions in the potable water supply of the Apollo spacecraft to kill bacteria in the water.

STI originally focused on using the technology for cleansing swimming pools, but its effectiveness in purifying water and eliminating corrosive chemicals led company president Tommy Wood to seek other applications, such as industrial cooling towers and industrial process coolers.

Wood recognized that, although copper/silver ionization could successfully eliminate algae and bacteria, something more was needed to fulfill all the water management needs of recirculating and evaporative cooling water systems; the purification system must also be capable of eliminating corrosion, debris and scale, the plaque-like mineral precipitate that builds up in a water system's plumbing, reduces the system's efficiency and elevates maintenance costs.

STI therefore developed a system that employs three distinct technologies. The NASA copper/silver ionization process is the core technology, to which STI added capabilities for centrifugal separation of solids from liquids and magnetic field water modification. Says STI's Tommy Wood:

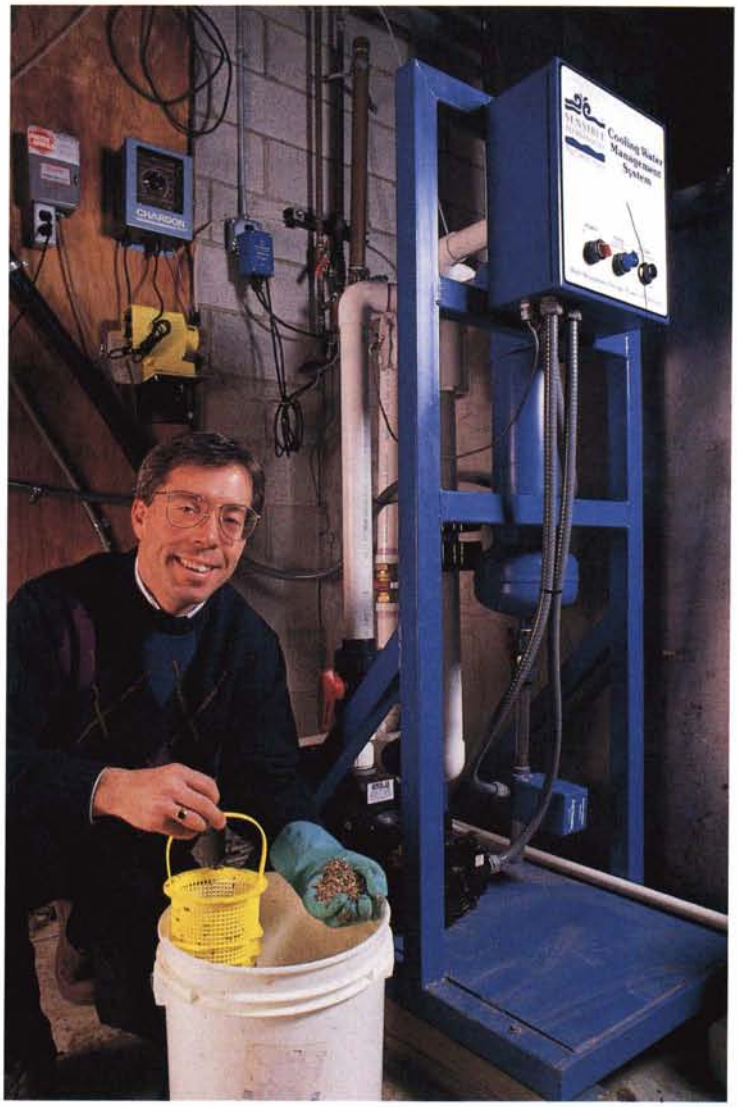
"Our systems do an excellent job of eliminating scale, corrosion, algae, bacteria and debris from process water, but there is an additional benefit; because of the NASA technology we employ, our systems destroy waterborne bacteria and viruses, including *Legionella pneumophila,* the bacterium responsible for Legionnaire's Disease."

The STI Cooling Water Management System integrates a pump, the centrifugal solids separator, the copper/silver biocide generator and magnetic field generators into a simply installed, easily operable equipment package that takes up only six square feet of space in most applications and totally eliminates the need for water treatment chemicals and water bleeding.

STI manufactures the system in three capacities: the STI-400, STI-1100 and STI-2200 for evaporative cooling systems of

up to 400, 1,100 and 2,200 tons respectively. Larger systems are custom built on request.

At **far left** is the STI-1100 unit and in the **top left** photo a closeup of the biocide generator (the STI-400 has two pairs of electrodes, the STI-1100 three pairs and the STI-2200 four pairs). The copper and silver ions produced by the generator kill the algae, bacteria and viruses in the water. The centrifugal separator removes all waterborne debris. The magnetic field generators remove existing scale, bar further scale buildup and prevent corrosion. **At bottom left** is a control panel with a gloved hand displaying a sample of scale removed from an industrial cooling water system.



STI systems have found a wide range of applications. For example, a system is operating on a cooling tower at General Motors Truck and Bus Engineering Center, Troy, Michigan; **above right**, STI's Jeff Jones is cleaning the pump strainer basket of a unit installed at the center. The GM cooling system was completely descaled within the first month, corrosion was eliminated and the water, once rust colored and opaque, is now clear. Other examples of industrial cooling water installations are a system in a process cooling tower at AVX Corporation, Myrtle Beach, South Carolina, and another in a closed-loop process cooling system at Canbraco Industries, also at Myrtle Beach.

Other systems are operating in amusement parks, to prevent corrosion and cleanse the water of such facilities as bumper boat pools and miniature golf ponds; in ice manufacture, protecting pure water in atmospheric tanks from bacterial infestation; and in commercial/residential pools and spas, where the systems offer chemical savings and labor savings in addition to sanitary water. ●

A Boon for the Architect Engineer

A SYSTEM FOR IMPROVING PREPARATION OF CONSTRUCTION SPECIFICATIONS LEADS SPINOFFS IN INDUSTRIAL PRODUCTIVITY AND MANUFACTURING TECHNOLOGY

In the early 1960s, when NASA was a fledgling organization engaged in large scale construction of research facilities, the agency launched a major effort to obtain quality construction at substantially reduced cost by developing a more efficient, computerized approach to preparing building specifications.

Written technical specifications, which spell out materials and components to be used on construction projects and the quality tests each item must pass, can have major impact on construction costs. Poorly formulated "specs" can lead to unacceptable construction, excessive material costs, safety hazards, disputes and often additional costs due to delays and litigation.

The nucleus of the NASA system for improving construction specifications originated at Langley Research Center, which developed an automated system called SPECSINTACT (Specifications Kept Intact). The system contains a comprehensive catalog of master specifications applicable to many types of construction. It enables designers of any structure to call out relevant sections from computer storage and modify them to fit the needs of the project at hand. Architects and engineers can save time by concentrating their efforts on needed modifications rather than developing all specifications from scratch.

The SPECSINTACT system, originally used only by Langley, was eventually adopted by all NASA field centers, later by the Army Corps of Engineers (CoE) and the Navy Facilities Engineering Command (NAVFAC). Today the system is becoming a government/industry standard for the preparation of project specifications. It is jointly owned by NASA, CoE and NAVFAC; NASA holds the copyright for the software and Kennedy Space Center is responsible for maintaining and updating it.

Photos by Glenn Benson, TGS Technologies

At left, a project engineer is using the NASA-developed SPECSINTACT, an automated system designed to save time and money on construction projects through greater efficiency in preparing building specifications.

At right is a SPECSINTACT spinoff, the Construction Criteria Base compact disc, a "one-ounce library" that contains the equivalent of 250,000 pages of specification-related data.

Over more than a quarter of a century, successful use of SPECSINTACT led to a number of spinoff systems. The current commercially-available SPECSINTACT system is an integral part of the Construction Criteria Base (CCB), a low-cost optical disc system described as a "one-ounce library." In a single disc it contains the complete texts of hundreds of documents needed for the design and construction of facilities and civil works, together with built-in software for processing the information and developing specifications for individual projects.

Developed by the National Institute of Building Sciences (NIBS), a Washington, D.C. non-profit organization working in behalf of the $500 billion-a-year American building industry, CCB incorporates SPECSINTACT as a major element of the system but goes much further; it includes federal guide specifications of 10 government agencies; private industry guide specifications, including the American Institute of Architects' MASTERSPEC®; standards and regulations; federal design and technical manuals; model building codes; and federal cost estimating systems.

CCB employs Compact Disc-Read Only Memory (CD-ROM) technology based on the same principle as music CDs. To collect, organize, store and update the data on a single CCB disc, says NIBS, would take "10 filing cabinets, three bookcases, at least $12,000 in checks to 150 different organizations, over 200 thousand pieces of paper, three dozen boxes of floppy diskettes, a reliable copier, one consultant, a state-of-the-art word processing system, at least one speed typist and one extremely talented administrative assistant/librarian who works overtime for nothing."

CCB is available from NIBS on a subscription basis at less than $1,000 a year; a subscription includes quarterly updates, a "Help Desk" telephone technical assistance service, a user's guide and supporting software, and a quarterly CCB user's newsletter. CCB has more than 1,600 subscribers, including some 900 among government agency offices and 700 among private architect/engineer firms.

In a NIBS survey of CCB users, respondents reported substantial savings in both clerical and professional time, with many users indicating improvements of 75 percent or better in comparison with the way they previously prepared specifications. The system offers additional savings, says NIBS, "in higher productivity, drastically less time worked on paperwork, fewer costly construction errors and delays, and lowered risk of liability due to increased accuracy and thoroughness."

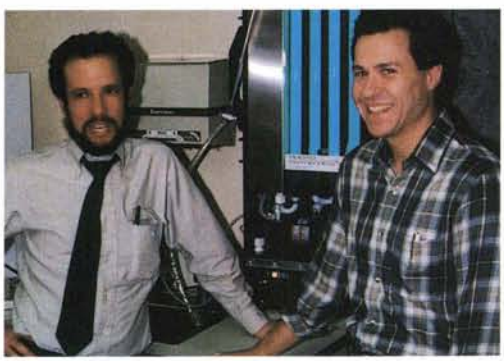
The President's Council on Management Improvement found that "the SPECSINTACT/CCB system is one of the most significant improvements in the management of federal construction specifications that has surfaced in recent years." ●

®MASTERSPEC is a registered trademark of the American Institute of Architects.

Water Purification Systems

Over a quarter century or more, NASA has developed or studied several different types of water purification/recycling systems to meet the varying needs of manned spacecraft and future space outposts. This research has made water purification one of the broadest areas of aerospace technology transfer (see pages 55 and (110-113).

One of the most recent systems developed for NASA is one designed by Photo-Catalytics, Inc. (PCI), Boulder, Colorado. A closed-loop system that repeatedly cleanses and recycles the same water for possible application in long-duration spacecraft, it employs a "photocatalysis" process in which light or radiant energy is the catalyst that sparks a chemical reaction.



The innovative technology uses chemically stable semiconductor powders — titanium dioxide, for example — to destroy microorganisms and other organic water contaminants. Added to water polluted by organic compounds, the powder absorbs ultraviolet (UV) light from the Sun or from an artificial UV light source; the UV light triggers a reaction in which the organic pollutants are oxidized — literally "eaten up" — and converted to harmless carbon dioxide.

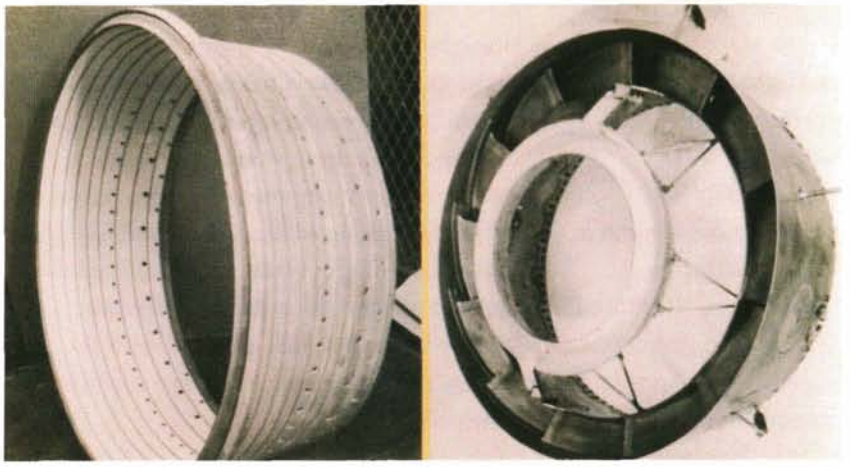
PCI is now marketing the technology for commercial use as the Photo-Catalytic Ultrapure Water System with initial focus on biomedical research and pharmaceutical manufacturing applications, where extremely pure process water is a requirement. **Above**, genetic researchers Drs. Larry Borish (left) and Jack Routes display the PCI unit they are using in their work at the Jewish Center for Immunology and Respiratory Medicine, Denver, Colorado. The **photo below** offers a closer look at the PCI system.

The technology also has obvious application in manufacture of microchips, where water purity is essential to semiconductor efficiency, and it could find a broad market in cleansing industrial wastewater.

"The process can take anything organic out of water," says PCI president Gerald Cooper, a scientist who led the design effort on the company's NASA photocatalytic water purifier. Laboratory tests indicate that the process can remove organic compounds from extremely polluted wastewater, such as that generated by oil refineries. Cooper adds that heavy metal ions in the wastewater, such as lead or mercury, could be removed by variations of the same process. ●

Engine Coatings

For more than 30 years, aircraft propulsion researchers have been investigating ways to increase the operating temperature of turbine engines, which can provide enormous benefits in reduced fuel consumption and overall engine efficiency. To do so, it is necessary to find ways of protecting engine components from the extremely hot environment.



Researchers have explored — and continue to explore — advanced, temperature resistant materials and a variety of concepts for cooling interior engine parts. Lewis Research Center came up with a promising approach: to protect hot components by use of thermal barrier coatings, or TBCs, plasma-sprayed substances deposited on the components in thicknesses measured in thousandths of an inch.

A TBC consists of an outer layer, or "top coat" of ceramic material, plus a metallic "bond coat" inner layer. The low-conductivity ceramic coating insulates the component from the hot gases of the engine; the bond coat offers oxidation and corrosion resistance to the component and increases the adherence of the top coat. Research testing has shown that TBCs can reduce component surface temperatures by 200 degrees Centigrade or more.

Lewis Research Center, together with industry firms working under Lewis contract and on their own, have successfully developed TBCs that have been routinely operating on certain parts of aircraft engines for some time and ongoing research is paving the way for extending the coating process to "hotter" engine components.

An example of industry use of the NASA-developed TBC concept is the application of the coating to engines produced by General Electric Aircraft Engines (GEAE), Cincinnati, Ohio. GEAE was one of three contractors that evaluated TBC performance under contract to Lewis (the others were Pratt & Whitney Division of United Technologies and Garrett AiResearch). GEAE applied this experience to a TBC now in regular service as a coating on production engines.

The company's primary TBC application is a coating on combustor liners in both commercial and military aircraft engines, along with coatings on exhaust liners, flaps, seals and afterburners in military engines (**in the photo**, the component at left is a combustor liner for the CF6 engine that powers commercial jetliners and the other component is a flameholder for the F404 engine that powers military fighter aircraft).

The coating system used for combustors and exhaust components, based on the one developed by Lewis Research Center, consists of a plasma-sprayed nickel/chromium/aluminum/yttrium bond coat and an yttrium-stabilized zirconia top coat. These coatings extend component life from 1.3 to two times by reducing the temperature of the metal in the component. GEAE is also testing TBCs on components that operate at higher temperatures, such as stator vanes and turbine blades, and plans to expand production applications of TBCs. •

Valve Packing

At left is a sample of Style 287-I valve stem packing manufactured by John Crane Inc., Morton Grove, Illinois and **below** the packing is shown in a valve application. The material is a non-asbestos, high temperature, high pressure packing that incorporates as one of its components a proprietary "S Glass" yarn. The yarn was originally developed by Marshall Space Flight Center for high temperature space and aeronautical applications.

John Crane Inc. officials first learned of the S-2 Glass while developing a gasket for a catalytic converter for Ford Motor Company. Ford required a material that would handle temperatures greater than 1200 degrees Fahrenheit, the upper limit that standard gasket materials could accommodate. John Crane discovered that S-2 glass, being manufactured by Owens-Corning Fiberglas Corporation, offered tensile strength, good compressive and impact strength, and high performance levels. The company became interested in using the S-2 Glass as a replacement for asbestos packing, but a heavier fiber was needed.

John Crane officials then contacted Owens-Corning, which had developed a number of aerospace and defense applications of S-2 Glass, such as filament-wound oxygen bottles for space use, aircraft radomes and the Space Shuttle rocket motors, and arranged for production of the heavier fiber. Working with John Crane on manufacture of Style 287-I packing is Amatex Corporation, Norristown, Pennsylvania, which purchases the S-2 glass yarn from Owens-Corning, texturizes it and combines it with Inconel® wire for additional strength. John Crane combines this finished raw material with other components to make up Style 287-I packing. The yarn is one of three components and Style 287-I is the only packing made with the NASA-developed yarn.

The packing can handle temperatures up to 1200 degrees Fahrenheit and pressures up to 2500 pounds per square inch. It can be used in chemical/petrochemical processing operations; fossil fuel and nuclear power generating stations; hot/cold water; organic acids and bases; strong inorganic acids; and petroleum products. Advantages claimed include greater leakage control, increased service life, reduced product loss, reduced maintenance/operation costs, and less torque to effect a seal. ●

®Inconel is a registered trademark of International Nickel Company, Inc.

Profiling System

A COMPANY'S WORK FOR NASA SPAWNED A NEW LINE OF FLAW DETECTION SYSTEMS

Below is the Dynamic Laser Speckle Profilometer (DyLASP), a commercial version of a non-destructive testing system originally developed for Langley Research Center under a NASA Small Business Innovation Research contract. It was developed by McMahan Electro-Optics, Winter Park, Florida, a small business enterprise specializing in development of state-of-the-art laser and electro-optical systems for defense and industrial applications.

The DyLASP NAS 1 shown is part of a family of automatic, highly accurate, vibration insensitive systems for two-dimensional surface profiling and three-dimensional surface measurements. The DyLASP profilometer locates defects in composite and metallic materials and assemblies. It operates in real time and displays results as a contour map of the assembly under test, with defects indicated by size and location. DyLASP incorporates advanced laser targeting and imaging technologies developed by McMahan Electro-Optics for Air Force weapon systems.

DyLASP is intended for a variety of applications in the general area of non-destructive testing and evaluation, and the company can customize a system to a user's particular requirements. Among specific applications, DyLASP can determine the quality of bonds and detect debonding in laminated composite materials; it has utility in product design and quality control vibration analysis; in thin weld inspection, stress and strain/finite element verification, fracture mechanisms, hydraulic strain and volume viscoelasticity.

DyLASP was developed by McMahan Electro-Optics Research and Development Division, which is separately located from the headquarters facility in Research Triangle Park, North Carolina. ●

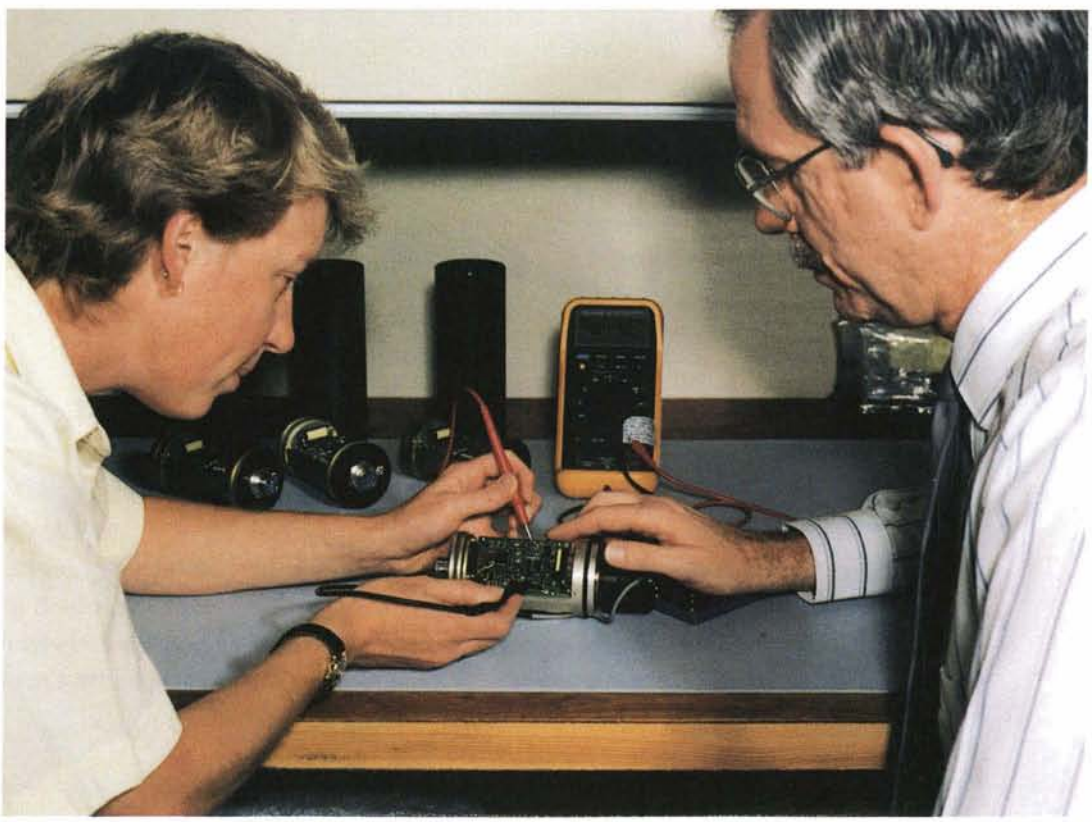
Ruggedized Minicamera

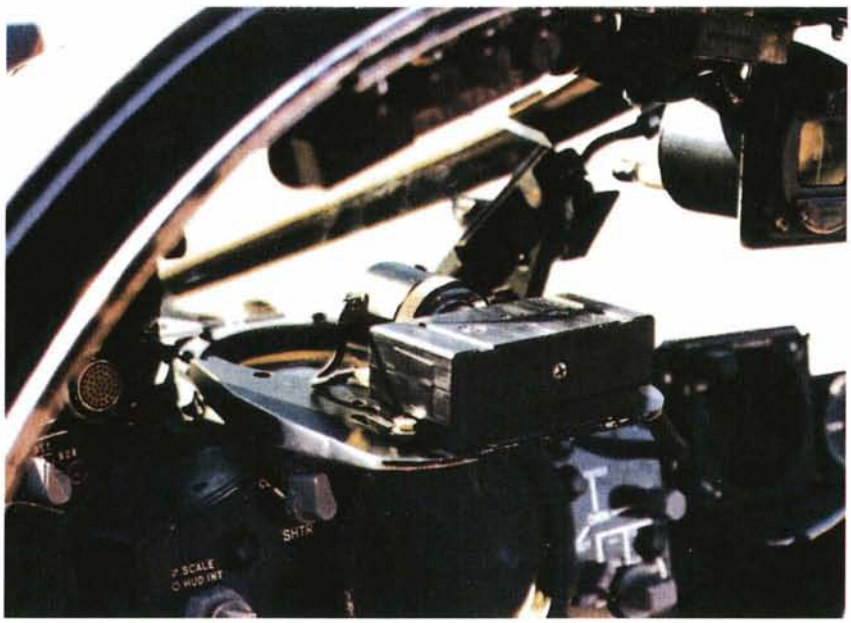
On September 1, 1985, scientists of Woods Hole Oceanographic Institute were able to view once again the ocean liner *RMS Titanic*, which had sunk 13,000 feet below the surface of the North Atlantic 73 years earlier. The camera that was able to penetrate the darkness of the ocean depths and withstand the extremely high pressures of the deepwater environment was a Videospection Model 865 manufactured by Videospection, Inc., Salt Lake City, Utah, a company that specializes in design and production of cameras for unusual and demanding applications.

When NASA sought a video camera for use aboard the Space Shuttle, the agency turned to Videospection for development of a minicamera "ruggedized" to NASA specifications. The camera, now used on Shuttleborne research packages, is 7 1/2 inches in diameter with its lens affixed. The camera and lens are enclosed in a lightweight, extra-durable sealed aluminum housing that protects the optics and the Charged Coupled Device (CCD) from the effects of the harsh orbital environment or from conditions encountered in other aerospace environments, such as sounding rockets, military aircraft and robotic systems.

The NASA camera spawned two new models that are now being marketed by Videospection for commercial and aerospace applications where ruggedness, high resolution and high reliability are required. The commercial versions are the Model 885 Intensified CCD Camera and the Model 891 CCD Video Camera.

Below, Videospection chief engineer Donald Stewart (striped shirt) and a technician discuss a production matter





relative to the Model 891. Designed to accommodate a wide range of temperature fluctuations and severe vibration/shock, the camera system has been temperature-tested from minus 45 degrees to plus 85 degrees Centigrade. The Model 885 features an advanced GEN II image intensifier optically coupled to the Model 891. The latter camera, says chief engineer Stewart, "is finding its way into many applications in the military and consumer markets."

Other members of the Videospection family of cameras are being used for such applications as color TV inspection of the walls of a gas well; monitoring the hook-up between a military air refueling tanker and a "customer" aircraft; internal inspection of nuclear reactors; and digital radiography, for either medical diagnostic or industrial flaw detection applications.

At left is a Videospection Model 2531-A Color Camera in a military fighter installation and **below** is a Videospection underwater camera used aboard the *Perry* oceanographic research vessel to provide high reliability in high pressure environments; the photo shows a pan and tilt unit with a camera and a light assembly attached, mounted just in front of the diver's viewing portal. ●

Infrared Measurement

NASA TECHNOLOGY AIDED DEVELOPMENT OF AN INDUSTRIAL PROCESSING SYSTEM

Norplex Oak Inc., LaCrosse Wisconsin, a division of Allied Signal, is a leading manufacturer of laminates for printed circuit boards. A laminate is made up of sheets of "prepreg" placed between copper foil. Prepreg is created by impregnating a continuous glass cloth, or web, with epoxy resin and partially curing it by the application of heat.

To reduce emissions and lower the cost of producing prepreg, Norplex Oak decided to switch to infrared treating towers for curing instead of the hot air systems in use. This required development of infrared treating towers and involved extensive research for designing a tower with optimal heat transfer characteristics for prepreg. NASA technology provided an assist.

Norplex Oak engineer Bruce Kline read an article in *NASA Tech Briefs* (see page 141) about a technique developed by Jet Propulsion Laboratory (JPL) for processing data obtained by an infrared radiometer via a straightforward mathematical model into a map of thermal irradiance over a large area. This technique was developed in the course of JPL's work on simulation of the solar and planetary infrared heat loads on a spacecraft. Kline requested and received from NASA a Technical Support Package that provided full details of the irradiance measuring technique described in *Tech Briefs*.

The NASA information proved very helpful to Norplex Oak, says Bruce Kline. First it enabled confirmation of the company's own computer model prediction of the heat flux pattern. Additionally, it provided information that allowed Norplex Oak to make modifications to its infrared treaters to enhance consistency of the curing process, and it provided a theoretical basis for development of optimal heater placements, allowing the treater tower to produce an even infrared heat transfer to the web.

The new generation of infrared treaters, with the results of computer models incorporated, is now being used in production. The treaters are successfully operating at increased speeds with improved product consistency. **At left**, a technician is operating one of the treaters at Norplex Oak's Riverview Plant in Hoosick Falls, New York. ●

Controllable Mirror Devices

Controllable mirror optics is a new technology for putting light to work in high speed processing of visual information. An alternative to traditional combinations of lenses and other light transmission devices as a means of processing information encoded by light, the technology involves the use of electronically "deformable" (moveable) micro-mirrors for controlling light on a microscopic scale.

NASA scientist Dr. Richard Juday and his Johnson Space Center research team are working closely with scientists and engineers of Texas Instruments, Inc. (TI), Dallas, Texas on a new family of components known as Deformable Mirror Devices (DMD). A DMD is a type of spatial light modulator (SLM) in which mirrors fabricated monolithically on a silicon chip are deformed, or tilted, under electronic control to modulate, or change the direction of, light that falls upon the mirror.

The SLM modulates light in one or more dimensions. In the TI work cosponsored by NASA and the U.S. Army Missile Command, two-dimensional SLMs are being used to modulate all the rows and columns of a digital image in parallel, rather than in conventional row-by-row fashion. This greatly accelerates certain types of image processing and opens up a new range of space, military and civil use applications.

Texas Instruments Peripheral Products Division, Temple, Texas has started commercialization of the technology with a one-dimensional DMD that selectively steers a line of light in a new high speed printing process. The initial application is the DMD 2000™ Travel Information Printer (**in photo**) for high speed, high volume printing of airline tickets/boarding passes (ATBs).

In the DMD 2000, the DMD chip with 840 tiny moveable mirrors is controlled

to selectively reflect light onto a photoconductor drum, which subsequently transfers the image produced on the drum to paper. The TI system can image 1.2 million black dots in one second. The result, says TI, is that "images and text can be integrated on ATB tickets with the quality and speed of xerographic printing and the reliability of a semiconductor chip."

Applications of the two-dimensional DMD being explored by NASA and TI range from real-time object tracking to new ways to achieve autonomous spacecraft landings on other planets, where communications travel time is so great that the spacecraft must operate on its own without the command or informational signals from Earth. Among applications being developed by the JSC team is a hybrid machine vision system that can support autonomous spacecraft rendezvous and docking. The DMD technology also offers promise for advanced industrial machine vision systems. ●

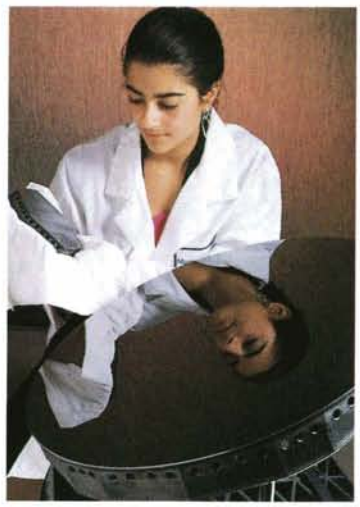
™ DMD 2000 is a trademark of Texas Instruments, Inc.

Mirror Technology

LIDAR (light detection and ranging) is a technique employed by NASA and other research organizations for remote measurement of atmospheric characteristics. The performance of a spacecraft-based LIDAR system depends in great measure on the efficacy of the primary mirror in the system's receiving telescope. Seeking to improve LIDAR mirrors, Langley Research Center awarded a contract to CVD Incorporated, now a subsidiary of Morton International (MI-CVD), Woburn, Massachusetts, for development of lightweight silicon and silicon carbide mirrors for space-based LIDAR applications.

Silicon carbide (SiC) is a material used in many high temperature engineering applications, such as furnace components in semiconductor processing chambers. However, SiC produced by traditional methods cannot be optically polished to the high degree of surface finish needed for LIDAR mirrors. MI-CVD developed a process for producing bulk SiC by means of a chemical vapor deposition (CVD) process; this technology allows growth of a high purity material with superior mechanical/thermal properties and high polishability, making it ideal for mirror applications. MI-CVD employed the technology in developing three research mirrors for NASA-Langley, which were delivered in 1990.

MI-CVD is now marketing the technology for space, military and commercial applications under the trade name CVD SILICON CARBIDE™. In the **photo above** is an assortment of the company's mirror products, illustrating how the mirrored surface can be polished for various applications from very high reflectivity to a seemingly dull finish. **Above**, a technician is finishing a large, half-meter-diameter SiC mirror; the mirrors can be produced in sizes ranging from a few centimeters in diameter to 1.5 meters.



CVD SILICON CARBIDE offers advantages in the space-based mirror market because of its light weight, high stiffness and thermal stability; it does not display the thermal distortion sometimes experienced with other materials. Its high reflectivity and thermal properties offer advantages for its use in synchrotron (nuclear research) facilities and it is also generating interest among industrial users of high power lasers. In industrial use, the optics of the laser are often exposed to dust, dirt and welding slag. The hardness of CVD SILICON CARBIDE allows an uncoated optic to be easily wiped clean without damage to the surface. A coated SiC optic offers another advantage: when the coating becomes damaged, the entire optic can be acid-dipped to prepare for application of a new coating, eliminating the time-consuming and costly step of refurbishing the substrate. ●

™CVD SILICON CARBIDE is a trademark of CVD Incorporated, a subsidiary of Morton International, Inc.

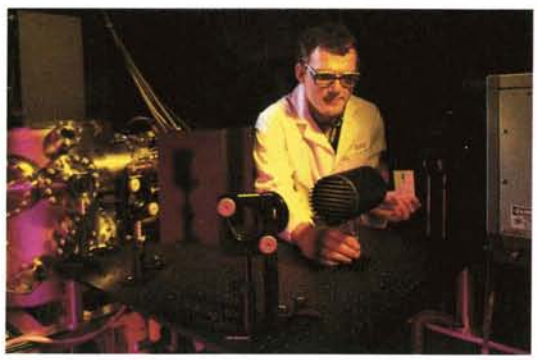
Laser Safety Device

NASA Tech Briefs is a publication designed to inform potential users of NASA technology available for transfer. It frequently inspires development of a spinoff product, more often finds utility as a problem-solving tool for its government and industry readers. An example of the latter use of NASA technology is the experience of Air Products and Chemicals, Inc., Allentown, Pennsylvania.

The company's Laser Applications Laboratory is a recent addition established to support Air Products' current business and technical growth. A major focus of the laboratory's work is on use of ultraviolet (UV) radiation using high energy excimer lasers. This poses a safety problem because light within the wavelength range of excimer lasers is invisible and it can cause serious damage to eyes and tissue.

Therefore, it was necessary to develop an apparatus to contain the laser beam. An essential component of such an apparatus is a beam block for effectively trapping laser light. However, because the output power of these lasers can exceed 500 watts, there were very few commercially available beam stops capable of absorbing UV light at such power for long periods, so Air Products decided to develop its own.

While planning an approach, company scientists E.J. Karwacki, Jr. and S.D. Hanton read in *NASA Tech Briefs* of related work on UV light absorption conducted by Jet Propulsion Laboratory (JPL). They requested and received a Technical Support Package describing in detail the JPL invention, which involves use of a graphite plate mounted to an aluminum heat sink for absorbing light from high energy lasers.



Air Products incorporated the NASA technology into its beam stops. The main body of the company's beam stop is an aluminum cylinder, its inner surface roughened by machining turns to maximize light reflection and capture (**left**). Tap holes are provided along the exterior of the cylinder for placing metal rods to mount the beam online with the laser beam. A piece of graphite bolted onto an aluminum heat sink is attached to the rear of the cylinder; it absorbs the light trapped within the cylinder. **Above**, a physicist is aligning the beam stop so that it interrupts the laser pathway and absorbs the beam, allowing him to work in the target area without shutting off the laser. ●

Self Cooling/Heating Devices

Below left, Dennis Thomas is describing a self-chilling can, a major innovation for packaging food and beverage developed by the company he founded and heads, International Thermal Packaging (ITP), West Lake Village, California.

The self-chilling can and two other ITP developments are based on a company-developed process for heating packaged food without an oven and chilling beverages without refrigeration. The development of these products was aided by a NASA technical assistance center and exemplifies the type of help such centers provide their industrial clients. The products also incorporate NASA-developed polymer technology.

NASA TECHNOLOGY PROVED TO BE THE ANSWER TO A DEVELOPMENTAL PROBLEM

In the mid-1980s, Dennis Thomas formed a company to conduct research on self-cooling beverage containers using the principle of expanding gases. The ensuing R&D resulted in a prototype self-cooling device that used liquid carbon dioxide (CO_2) as the cooling agent. He formed the company — then known as Liquid CO_2 Engineering, Inc. — to develop the concept further.

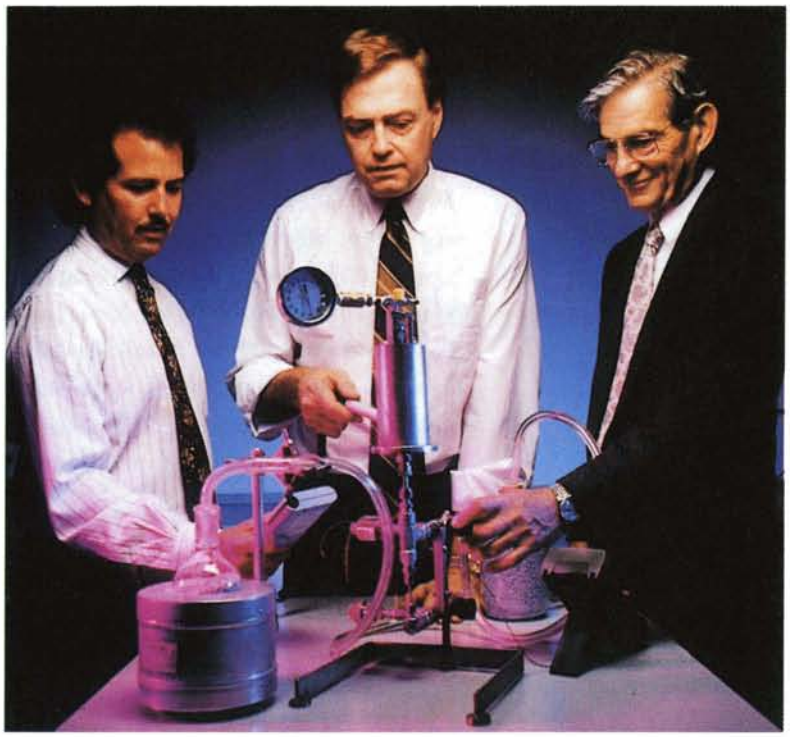
In 1988, the company formally became ITP and it was bolstered by the addition of development engineers Dr. Cullen Sabin and Gary Steidl, who directed an effort to get away from use of CO_2 because it required a large, heavy container for the pressurized gas, thus induced prohibitively high production costs and limited practical applications. Continuing R&D led to a new concept whereby self-chilling was accomplished by water evaporation and a heat exchange process without the inherent high pressure of carbon dioxide gas.

The missing ingredient was a desiccant that could absorb water vapor up to 200-240 degrees Fahrenheit and remain stable. After trying several desiccants and finding them unsuitable, ITP enlisted the aid of the NASA Technology Transfer Center (TTC) at the University of Southern California in Los Angeles.

The TTC staff, working with a technology counselor at Ames Research Center, located eight government/industry sources and ITP conducted tests of a variety of desiccants. Eventually they boiled the candidate list down to one material that seemed ideal

for the ITP project: a NASA-developed synthetic polymer that can absorb 1,000 times its weight in water.

ITP used the desiccant in its process and tests of working models successfully demonstrated that the Self-Chilling Device, as the company was now calling it, worked well and that it could be safely used in aluminum beverage cans, glass bottles and cardboard food/beverage containers. The refrigeration device is a small cylinder fully incorporated into the can or package; it is not an add-on. An experimental unit is shown **at left**, wherein Gary Steidl is transferring the desiccant to the refrigeration device. **Above**, Gary Steidl, Dennis Thomas and Cullen Sabin are monitoring a test of the Self-Chilling Device.



While the Self-Chilling Device has a wide range of potential uses, its immediate application is as an insert in beverage containers. When the top of the can pops and relieves the internal carbonization pressure, the drop in pressure induces the self-chilling reaction.

It works this way: water is the basic refrigerant; when the can is opened, the device uses the heat present in the beverage to boil the water. The device boils the water at one location to absorb heat, pumps the vapor to another location, condensing the vapor in the high performance desiccant to reject the heat, then stores the rejected heat in a heat sink. When the hot vapor from the boiling reaction is absorbed by the desiccant, the beverage is chilled; the device can lower the temperature significantly in 30 seconds and reduce the entire can by 40 degrees Fahrenheit in three minutes from any starting temperature.

ITP continued its packaging R&D and expanded the product line to include two related products: a Heater/Cooler Device, which combines a self-cooling and a self-heating process for take-out and fast food operations, and a Heat-Only Device for such applications as pizza delivery and shelf-stable foods.

ITP does not manufacture the devices: it provides the technology to be incorporated into existing food and beverage packages by licensees. The company has signed several option/license agreements for production and distribution of ITP products in the U.S. and abroad. ●

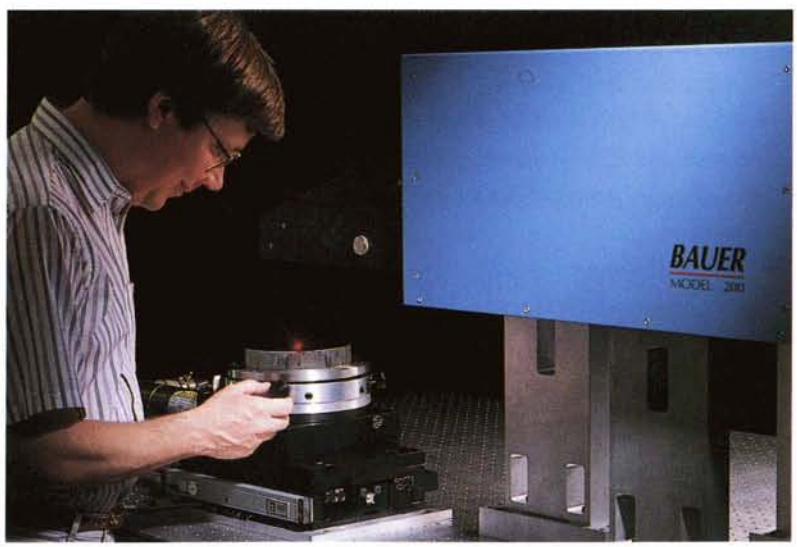
Mirror Measurement Device

Below, president Paul Glenn of Bauer Associates, Inc., Wellesley, Massachusetts is adjusting a Bauer Model 200 Profilometer, an instrument that measures the shape profile of mirror surfaces used in astronomical telescopes and other scientific instruments. The Model 200 is based on a new measurement concept conceived by Bauer Associates and developed under NASA Small Business Innovation Research (SBIR) contracts funded by Goddard Space Flight Center.

Virtually all earlier profilometers are based on the principle of interferometry wherein the path length of a light beam reflected by the surface being measured is compared with the path length of some other light beam. The Model 200 works on an entirely different approach: the local curvature of the mirror's surface (the exact degree to which it is convex or concave) is measured at many points and the collection of curvature data is computer-processed to yield the desired shape profile (**above**). This basic approach to curvature measurement was the "useful innovation" that inspired the SBIR contracts.

Bauer Associates was awarded a six-month Phase I study to evaluate the feasibility of the concept, then a two-year Phase II project to build and test a prototype instrument. The prototype's exceptional performance prompted Bauer to commercialize the instrument. The company is now marketing the Model 200 for full service measurements and the Model 100 for single line measurements. The system, says president Glenn, "gives unprecedented accuracy as well as immunity to common problems with the measurement environment, such as vibration and turbulence."

Bauer Associates used the technology again as the foundation for another new profilometer, the Model 400, which measures the entire surface shape profile of large aspheric mirrors, accommodating both polished and unpolished surfaces. This concept similarly won Phase I/II SBIR contracts funded by Goddard. The Phase II effort was successfully completed in 1992 and commercialization is expected soon. ●



Advanced Polymer

In the mid-1980s, Langley Research Center invented a new type of polymer, a plastic that has utility as a matrix resin to bind together the fibers that reinforce composite materials. The compound is a thermoplastic polyimide that is thermally stable and resists solvents.

The Langley development, a polyimide sulfone, combines the desirable properties of two major classes of polymers: polyimides and polysulfones. The latter are easy to process but are very soluble and cannot be used in applications where solvents—such as aircraft fluids—are present, because they might damage components fabricated from such materials.

However, composites and other products made from polyimide sulfone *can* be used in the presence of solvents and corrosive fluids; they offer the advantages of light weight, low cost and ease of fabrication for a broad range of industrial uses. Applications, in addition to matrix resins for fiber reinforced composites, include molding resins, adhesives and foam.

Noting the broad commercial potential of the polyimide sulfone, High Technology Services, Inc. (HTS), Troy, New York obtained a NASA license to adapt the compound to specific applications. HTS had already made the material available as a solution (polyamic acid), but the company saw that considerable processing flexibility could be obtained if the material were available in both polyamic acid and fine powder forms.

In 1990, HTS was awarded Phase I/II NASA Small Business Innovation Research contracts to pursue development of polyimide sulfone in fine powder form. A successful development program led to production of polyimide sulfone in both acid and powder forms and introduction of the material to the commercial market for high temperature applications.

The principal use of the material among HTS customers is as a matrix resin for composites. HTS is also marketing the polyimide as a high temperature structural adhesive for aircraft structures and as a coating to provide protection from radiation and high temperature for electronic components. The company is also exploring the material's use in flame resistant foam for marine and aerospace applications; **below left** an engineer is torch-testing a sample of the material.

HTS was founded in 1983 by Milton L. Evans (pictured **below** in his laboratory), now president, a veteran of 20 years service with the General Electric Company in scientific, marketing and general management posts. In addition to the polyimide sulfone, the company has licenses for several other NASA patents and the HTS core product line is based on that technology. ●

Technology for Water Treatment

WATER MANAGEMENT TECHNOLOGY THAT OFFERS EFFECTIVE PURIFICATION, DISEASE PREVENTION AND MAINTENANCE SAVINGS HEADS A SELECTION OF SPINOFFS IN PUBLIC SAFETY

In the United States there are an estimated 500,000 water cooling towers, employed by industry, hotels, office buildings, hospitals, universities and other activities to remove excess heat from heat exchangers and air conditioning/refrigeration condensers. Tower tanks and plumbing must be kept clear of "scale" and corrosion, and free of such pollutants as algae, viruses and bacteria.

There are, in addition, countless swimming pools, spas, decorative fountains, ponds and other water facilities that must similarly be cleansed. Until recently, the standard method of controlling pollution was by use of chemical disinfectants. But stricter government rules regarding discharge of chemicals into public water supplies, and attendant increased cost of compliance with environmental rules, have sparked growing interest in non-chemical water treatment systems.

NASA technology offers two different, highly effective aproaches to cleansing water facilities without use of chemicals. A number of companies have acquired licenses from NASA to use these technologies and provide chemical-free water management systems and services for the broad and growing market.

One of the NASA technologies is based on the use of ozone to reduce biological growths and provide corollary benefits of corrosion and scale control, plus water and energy savings; that type of system is detailed on pages 112-113. The other method is based on a mid-sixties development by Johnson Space Center: a small, lightweight electrolytic generator that dispensed silver ions in the potable water supply of the Apollo spacecraft and thus eliminated bacteria in the water.

The Automatic Pool Sanitizer produced by Electron Pure®, Ltd., Cookeville, Tennessee is an example of the latter type of system. The basic Automatic Pool Sanitizer

This 650,000 gallon pool at the University of Tennessee (Knoxville) is kept clear of algae, bacteria and odor by the Electron Pure water management system shown at right. The system is a commercial model derived from technology developed for NASA's Apollo lunar spacecraft in the mid-sixties.

These before/after views attest to the efficacy of the Electron Pure Automatic Pool Sanitizer. In the upper photo is a clearly polluted residential pool in Lansing, Michigan; in the lower photo is the same pool three days after the spin-off ionization system was installed.

consists of two copper/silver electrodes placed in a chamber mounted in the recirculation system of a pool or spa or other water supply. A microprocessor sends signals to the chamber to dispense ions of copper and silver as the water passes through the chamber. The copper destroys the algae, eliminating the need for a chemical algaecide; the silver kills the bacteria, eliminating the need for chlorine.

Electron Pure manufactures a number of different models of the Sanitizer ranging from the SPA-1000, which treats up to 1,000 gallons of water in residential hot tubs or spas, to the EPC-500, designed for commercial pools containing as much as 500,000 gallons. The company also produces customized units for any size body of water, including cooling towers with several million gallons capacity.

In addition, the company manufactures the Hydro Cooling Tower Conditioner (HCTC), which combines the Electron Pure ionization system with a Superior® Water Conditioner, along with a pump, a centrifugal solids separator and a timer. The HCTC prevents formation of scale and corrosion in cooling towers and removes any existing scale buildup. It offers exceptional savings in water usage while eliminating algae and bacteria and operating free of maintenance and free of chemicals.

Electron Pure was formed in 1988 to exploit the copper/silver ionization technology and the company has experienced impressive growth in a short time. There are now more than 100 Electron Pure distributors in the United States and others in 20 foreign countries serving hotels, universities, hospitals, boat builders, theme parks, YMCAs, industrial customers and thousands of residential pool owners.

The company has a file of testimonials from satisfied customers. A sample, from the chief engineer of Cookeville General Hospital, Cookeville, Tennessee: "This system will provide a saving of about $3,500 a year in chemical cost, eliminate the hazard of handling the toxic water treatment material, and stop the dumping of spent chemicals into the sewer system." ● (Continued)

Electron Pure president Dennis Ivey (left) and Cookeville (Tennessee) General Hospital chief engineer Carmel Lee examine the clarity of the water from the hospital's 700-ton cooling system.

®Electron Pure is a registered trademark of Electron Pure, Ltd.
®Superior is a registered trademark of Kemtone, Inc.

Technology for Water Treatment (Continued)

Although the technology was not fully developed, ozone has been used for more than 100 years to treat drinking water and wastewater. It removes odor, prevents mold, mildew, fungi and algae growth, and eliminates LDB (Legionnaires' Disease Bacterium) and other bacteria.

A National Water Management draftsman draws up plans for a cooling tower ozonation system. The company is a licensee for NASA-developed ozone-based water treatment technology.

In the late 1970s, NASA's Jet Propulsion Laboratory (JPL) conducted a research program investigating the potential of ozone as an alternative to chemicals for treating cooling water towers; JPL was particularly interested in ozone's ability to prevent buildup of scale and corrosion, the most costly maintenance problems in cooling tower operation. JPL successfully developed a non-chemical system that not only curbed scale, corrosion, bacteria and algae but also offered additional advantages in water conservation, elimination of "blowdown" (toxic chemical discharge), improved cooling tower performance and operating cost savings.

In the JPL system, ozone — an electrically-charged form of oxygen — is produced from air or water by an on-site generator and introduced to the cooling tower water. As the ozone and water mix, organic impurities are rapidly oxidized. The dissolved ozone travels through the cooling circuit, where it "passivates" metal surfaces, attacks slime or bacterial deposits, removes scale and prevents its further buildup.

NASA patented this technology in 1980 and in subsequent years licensed a number of companies to market the technology commercially. Some of them are now experiencing rapid expansion as more cooling tower operators are turning to ozone-based water treatment under the impetus of rising chemical costs and more stringent environmental regulations concerning chemical discharges.

Extensive testing of water samples in National Water Management's laboratory supports the company's ozonation of cooling towers.

An example is National Water Management Corporation (NWM), San Jose, California. NASA licensee NWM has installed its Ozone Advantage™ systems at some 200 cooling towers in more than 100 sites. The company estimates that its customers, many of them Fortune 1000 companies, will collectively save 350 million gallons of water and eliminate 500 million pounds of chemicals this year.

NWM has a number of success stories to tell. An example: the company was awarded a contract by Rockwell International's Digital Communications Division (DCD), Newport Beach, California to install Ozone Advantage systems at four DCD cooling towers. For the first six months of operation, savings — from elimination of chemicals, lower energy requirements, reduced water consumption and labor saved — amounted to $96,000. DCD projected that cumulative savings for the first two years would top $300,000.

"The cost of National Water Management ozonation system and services is no greater than the cost of multichemical water treatment," company literature states. "Ozonation also brings the added benefits of dramatic water savings and the elimination of chemical storage and discharge, benefits that are becoming increasingly important in today's environmentally conscious world." ●

National Water Management provides water treatment for these ammonia condensers at a Pillsbury Company food processing plant in Watsonville, California. It is estimated that the ozone-based system will save Pillsbury annually nine million gallons of water and $87,000 in combined energy, water, chemical and manpower savings.

Another National Water Management installation, this one treating cooling tower water at the Everex electronics plant in Fremont, California; the ozonation system is shown at lower right.

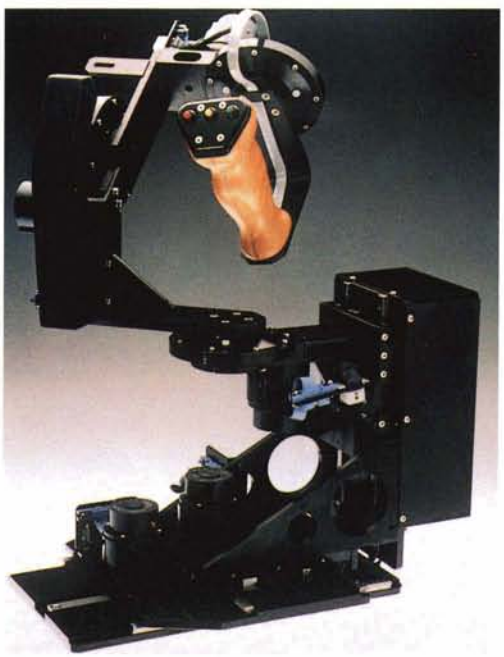
™Ozone Advantage is a trademark of National Water Management Corporation

Robot Handcontroller

Shown **below** is the PER-Force™ robotic force-reflecting handcontroller, which provides a sense of touch, or "feel," to an operator manipulating robots or other objects. This force simulation, together with a wide range of motion, greatly enhances the efficiency of robotic and computer operations that require manipulation and dynamic control of objects in multi-dimensional space.

The PER-Force handcontroller (Programmable Environment Reality through Force) is the first commercial product of Cybnernet Systems Corporation, Ann Arbor, Michigan, a company formed in 1988 to focus on high technology R&D and derivative products. The handcontroller was originally designed for use aboard Space Station *Freedom*; it was developed under Small Business Innovation Research contracts sponsored by Johnson Space Center.

A ROBOTIC DEVICE DEVELOPED FOR SPACE STATION USE IS NOW A COMMERCIAL PRODUCT



The PER-Force handcontroller is a small backdriveable robot that moves in six degrees of freedom: three linear positions (x, y or z) and three attitudes (roll, pitch and yaw). The operator uses the motorized handle for precise positioning of robots or graphically displayed objects to a given location (x, y or z) and tool angle (roll, pitch, yaw). Manipulation and "feeling" of multi-dimensional objects is accomplished by a host computer — or a robot control system — that reads handcontroller joint position, velocity and force through interface ports.

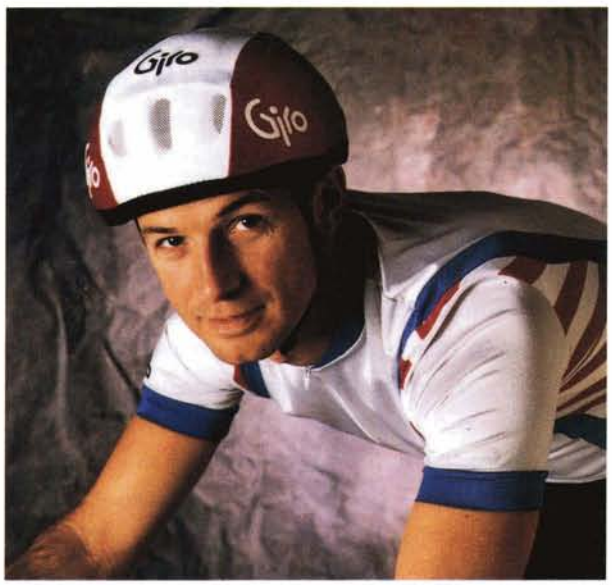
The handcontroller generates "force feedback" on each axis, using six small brushless DC servo motors. For example, if a robot system is equipped with force sensing devices, the output of the sensors can be used to apply contact forces to the handle, allowing the operator to feel contacts remotely.

More exotic force-reflection operations involve communicating tactile or "virtual" information. An example: When a camera mounted on a robot is used for visual inspection of a surface, the force generating handle can accentuate optically measured defects in the surface by providing a bumpy — rather than smooth — feel to the operator, even though no physical contact actually occurs.

The PER-Force handcontroller has special utility for teleoperations where visibility is limited — murky underwater environments, for example, or areas with obstructions and reduced light, such as underground excavations. There are other robot control applications in research laboratories, hazardous waste handling, the nuclear and utility industries, and in certain manufacturing operations where it is unsafe, impossible or impracticable for humans to touch a worksite directly. ●

Bike Racing Helmet

In 1985, industrial designer and bicycling enthusiast Jim Gentes decided to build an aerodynamic bike helmet that would provide a racer an advantage in speed. He formed Giro Sport Design, Inc., Soquel, California and developed a prototype, but a decision that year by the U.S. Cycling Federation (USCF) caused him to change direction. The USCF ruled that all racing bikers must wear helmets that met American National Safety Institute standards.



Suddenly there were 20,000 cyclists who needed helmets, and many of them felt that existing helmets were hot and heavy. There was a solid market for a cool, lightweight, aerodynamic helmet. So Gentes started anew on a second product, the Giro Prolight he is wearing **above**; it was designed with the help of NASA airfoil technology.

Gentes made contact with Raymond M. Hicks, an aerodynamicist at Ames Research Center. Hicks reached a long way back to employ technology from a "NACA 6-series" airfoil section developed during World War II by NASA's predecessor organization, NACA, to reduce fighter aircraft drag. The 6-series was designed for laminar (smooth) flow over a large part of the airfoil, hence low drag.

Hicks helped Gentes adapt the airfoil technology to the helmet application and created an aerodynamic helmet shape specifically designed for bike racers and triathlon participants. Subsequent wind tunnel tests confirmed that the reduced drag offered by the helmet could save one second in each kilometer pedaled, compared with bareheaded racing.

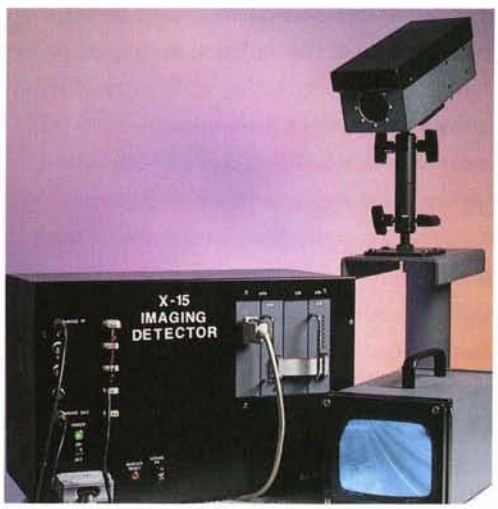
The design features vents in the front and rear of the helmet, arranged to let air flow through the helmet. The air flowing past the rear vents creates a vacuum to pull new air into the helmet; the air exhausted from the helmet smoothes normally turbulent air, making the flow laminar and thus reducing drag. This was a compromise design intended to minimize drag while maximizing cooling ventilation. To make the helmet as light as possible, Gentes made the Prolight of expanded polystyrene foam with a removable Lycra cover instead of a hard plastic shell.

Since its introduction in 1986, the Giro helmet line has undergone considerable evolution and expansion. In 1986, Gentes added to the line by creating a new foam helmet called the Aerohead, advertised as "the most aerodynamic helmet on the market." Later, Giro introduced the Hammerhead, a Prolight with a thin shell. In 1989 the company came out with the Air Attack, the lightest and best ventilated of all the Giro models; Gentes' friend Greg LeMond, world renowned cyclist, wore the Air Attack in his successful bid to win the 1989 Tour de France.

Giro helmets have won high acclaim in the U.S. and abroad, and the flow of orders has transformed Gentes' original one-man-in-a-garage business into a 15,000 square foot facility with 95 employees. ●

Traffic Monitor

Below is the Mestech X-15 "Eye in the Sky," a traffic monitoring system developed by Mestech Creation Corporation, Houston, Texas that incorporates NASA imaging and robotic vision technology. The system includes a camera, or "sensor box," mounted in a weather resistant, temperature controlled housing; a portable monitor; and a controller cabinet containing a computer and test switches for on-site set-up and repair. **Below**, a Mestech engineer is conducting circuit board tests on an X-15 prior to shipping.



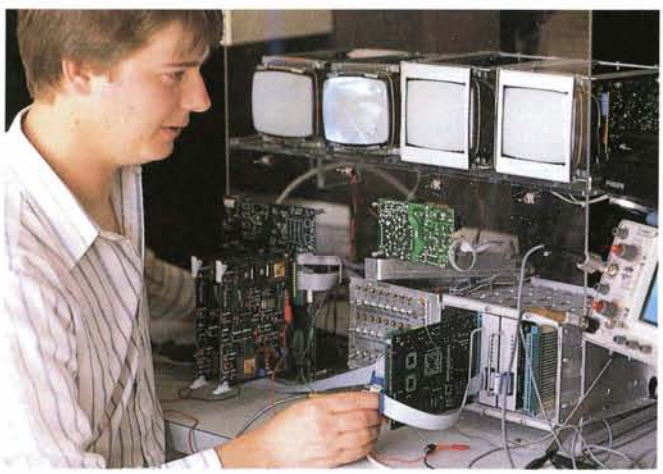
Marketed by SIDS, Tomball, Texas, the X-15 system employs up to four imaging sensors that operate over a wide range of electromagnetic wavelengths and are designed to withstand bad weather, extremes of temperature and street vibrations. At **top right** is a closeup view of the sensor box, which has very low light capability along with high infrared and ultraviolet sensitivity, providing high accuracy for object identification in both high and low contrast lighting.

The key sensor technology was developed with the help of NASA information supplied by Jet Propulsion Laboratory (JPL). In *NASA Tech Briefs*, a publication that lists NASA technologies available for transfer, a Mestech engineer read two articles of interest. One, on high resolution imaging spectrometry, described how a system aboard an imaging satellite separated more than 200 frequencies to form composite color images of Earth scenes. The other article dealt with technical details of robotic vision research.

Mestech requested and received from JPL Technical Support Packages, followup detailed information on each of the subjects described in *Tech Briefs*, and used this information in the company's development of the X-15 system.

A typical X-15 installation consists of a sensor box mounted on a ridge pole or other structure at a traffic intersection. The sensor detects vehicles approaching the intersection from either direction and sends the information to the local (at the intersection) computer, or controller cabinet, which controls the traffic light according to the traffic rate. The system can also send traffic information to a central or regional computer for control of a larger area.

At **bottom right** is a view of the screen detailing the four zones of interest of



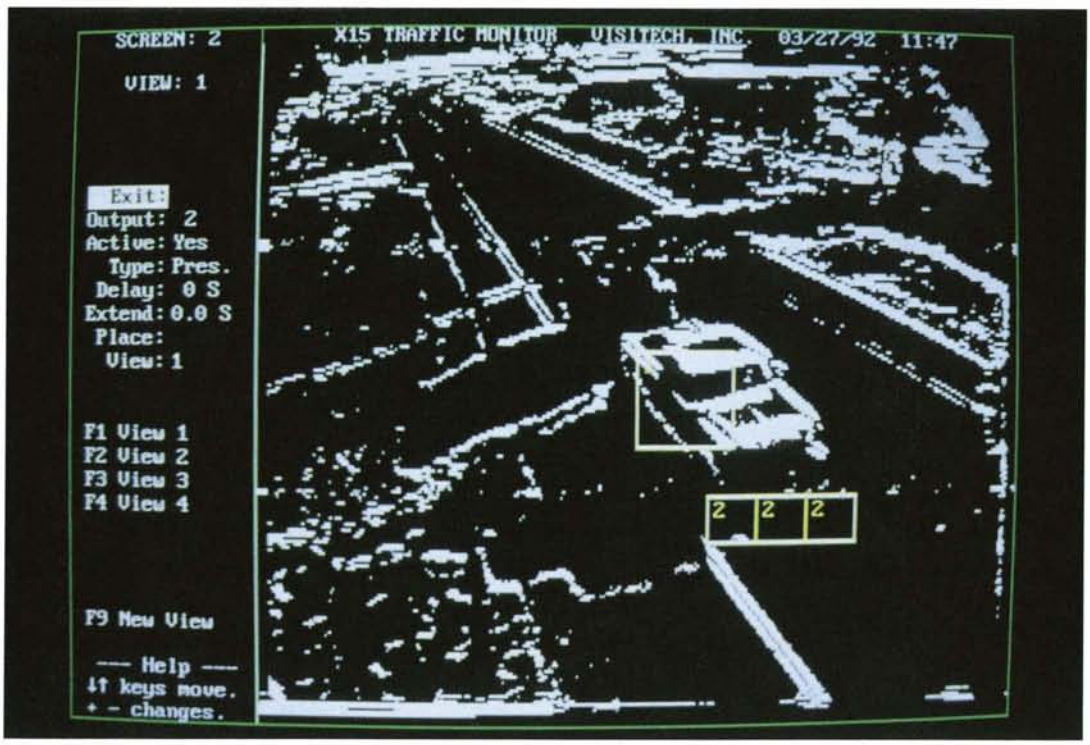
NASA SENSOR TECHNOLOGY AIDED DEVELOPMENT OF A GROUND TRAFFIC CONTROL SYSTEM

the monitoring camera. When a vehicle passes through these areas, the computer processes the sensor's information and signals the controller unit of the vehicle's presence and the zone it occupies; it does this 32 times a second.

An alternative use of the X-15 is its "smart highway" application, in which the system detects, or counts, vehicles on a highway and computes the number of vehicles in each lane and their speeds. Information of this type is important to freeway control engineers when they are required to divert traffic for highway repairs.

The system has additional applications. In airport operations, it can be employed in ground monitoring of runways and taxiways. It can also be used to monitor train yards, parking lots or any large area where an intruder detection system is needed (cost would preclude its use for small area surveillance, home monitoring, for example). Another potential application is its use to monitor robotic assembly lines.

In the traffic monitoring application, the system acquires several images, processes them simultaneously in less than 30 milliseconds, and transmits the results to the controller computer. The sensor's range of detection is nomimally 10 to 200 feet; with optional equipment it can be extended. The system is intended to replace loop-type traffic detectors buried in the road surface; use of the pole-mounted X-15 eliminates the need for cutting the street to install or repair a system. The sensor units weigh less than eight pounds. ●



NASA's Software Bank

A SPECIAL NASA SERVICE CONTRIBUTES TO NATIONAL PRODUCTIVITY BY SUPPLYING INDUSTRY REUSABLE SOFTWARE AT LOW COST

In these days when competition among businesses is at an all-time high, companies throughout the nation are vigorously exploring every possible avenue to cost reductions, in order to increase productivity and competitiveness.

To businesses that are computerized, and today that includes nearly all of them, NASA offers a means of reducing automation costs through a special type of spinoff service operated by the Computer Software Management and Information Center (COSMIC)®. COSMIC supplies to American businesses, at relatively low cost, government-developed computer programs that have secondary utility.

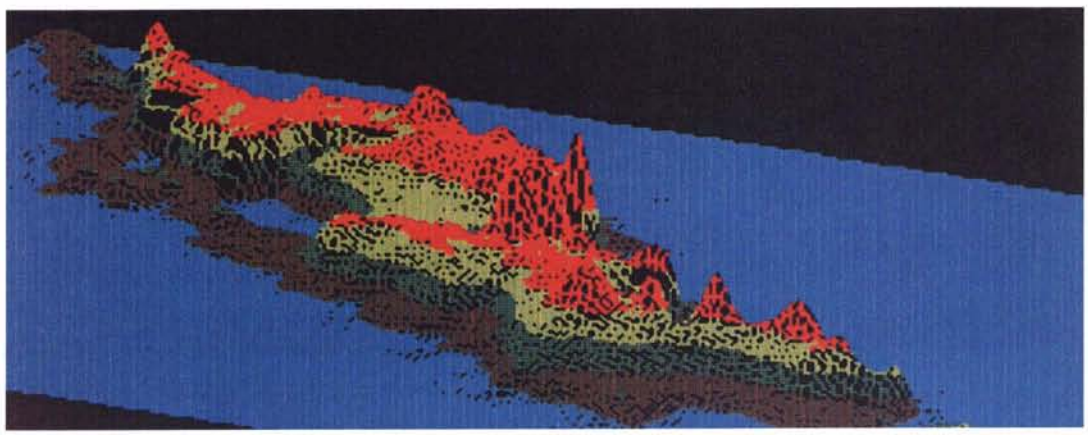
Use of such software obviates the need to develop entirely new programs, which is time consuming and expensive; software costs sometimes amount to 30-40 percent of the total cost of computerizing a business or an industrial process. Thus, business users can realize significant savings by taking advantage of a national resource available to them, the large "bank" of computer programs developed in the course of work for NASA, the Department of Defense and other technology generating agencies of the government.

An example of how secondary use of government-developed software technology aids business and industry is the use of a COSMIC program by The Signal Group, Wake Forest, North Carolina, a company that designs and manufactures radio and data communications systems and equipment.

While much of The Signal Group's work is of a conventional nature, the company does "probe the frontier a bit" to provide some unique approaches to clients' needs — for example, a system that links a desert area that has no communications facilities with civilization. The reason: a hunting/falconry party of wealthy Middle Eastern men

Shown being deployed is a tethered blimp, a key element of a novel system that enables blimp-relayed communications between an isolated Middle Eastern desert and a metropolis. The system was developed by The Signal Group; a COSMIC computer program provided an assist in development of the system's software.

This is a typical 3D graphic depiction of a mountain area used in a radio propagation study of the desert communications system.



must penetrate deep into the desert to the best hunting grounds, yet they must also keep in touch with their businesses and their families in the city.

The Signal Group's answer in that instance was a portable system that includes the latest in two-way radio technology along with a small, inflatable blimp tethered 3,000 feet above the desert floor on a Kevlar line; the blimp serves as a solar-powered relay station for radio communications.

A COSMIC program helped The Signal Group provide this advanced service during the system development phase. The company first had to perform transmission studies to assess the reliability of voice and data communications. An important influence in system performance is how radio waves propagate over the particular terrain in which the system is intended to operate.

In the U.S., these studies could readily be accomplished by computer analysis of digitized terrain data. Satellite derived terrain data has been compiled for most of Earth's land masses, but in some parts of the world governments consider computer records of their geography strategically important. Dissemination of such data, therefore, is severely restricted if not totally prohibited. That rules out computer prediction of RF propagation.

A "BANK" OF GOVERNMENT DEVELOPED COMPUTER PROGRAMS CONSTITUTES A NATIONAL RESOURCE

Since a number of The Signal Group's clients fall under such a restriction, the company undertook development of a process that would use terrain data from available printed maps to create a proprietary analysis of RF propagation.

Topographic maps encompass a wide variety of sometimes outdated projections, spheroid models, and scales. The Signal Group wanted to develop a method that would be essentially universal with respect to input, but during the research phase of the software design effort a number of conflicting aspects of the cartographic process were encountered.

A program obtained from COSMIC offered a solution. Titled *Transverse Mercator Map Projection of the Spheroid Using Transformation of the Elliptic Integral* and originally developed by Jet Propulsion Laboratory, the program not only helped resolve the conflicts encountered, it also provided The Signal Group a capability to perform certain types of analyses not previously possible.

(Continued)

NASA's Software Bank (Continued)

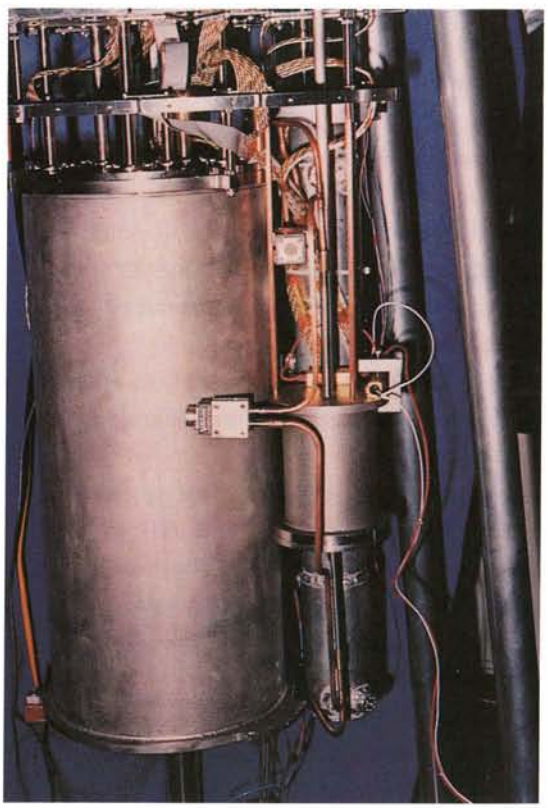
Located at the University of Georgia, COSMIC gets a continual flow of government-developed software and Center personnel identify those programs that can be adapted to secondary usage. Much of the software is directly applicable to secondary application; most of it can be adapted to special purposes at far less than the cost of developing a new program.

The Center stores the programs and informs potential users of their availability through the publication *NASA Tech Briefs* (see page 141).

COSMIC's library numbers more than 1,200 programs applicable to a broad spectrum of business and industrial applications. COSMIC customers can purchase a program for a fraction of its original cost; in most instances, users get a return many times their investment. Industry's acceptance has been extraordinary. The Center has distributed thousands of programs, some of which have made possible savings in the millions. Thus, COSMIC's service represents one of the broadest areas of economic benefit from spinoff technology.

Here are some additional examples of how COSMIC's service aids users:

Astronautics Corporation of America, Madison, Wisconsin designs and manufactures electronic equipment and aerospace systems. Among advanced research and development projects under way at the company's Astronautics Technology Center is an investigation of possible materials and designs for magnetic refrigerators, which operate under the principle that some materials heat up when placed in a magnetic field and cool down when removed from it. Applications of these low temperature (below minus 321 degrees Fahrenheit) refrigerators include cooling superconducting magnets used in magnetic resonance imaging systems at hospitals, in particle accelerators for high energy physics research, and in magnetic containment vessels for fusion energy research.



Astronautics Corporation's Active Magnetic Regenerator proof of principle apparatus, a device used to test different types of materials that might be employed in magnetic refrigerators. The company uses COSMIC software in its research and development on refrigerators that operate below minus 321 degrees Fahrenheit.

In Astronautics Corporation's quest for efficient magnetic refrigerator devices, Technology Center personnel use the COSMIC-supplied SINDA '85/FLUINT, a software system developed by NASA for solving physical problems governed by diffusion-type equations. Initially, engineers employ SINDA '85/FLUINT in the conceptual design process; the various possibilities for a design are modeled with the COSMIC program to allow comparison of relative efficiencies for selection of the best concept. SINDA '85/FLUINT is later used to develop a more complex model for predicting temperature distribution in the refrigerator.

Another example involves use of a COSMIC program called NETS (*A Neural Network Development Tool*) in a university artificial intelligence research program. Originally developed by Johnson Space Center, NETS is a software system for mimicking the human brain. It is designed to help scientists engaged in exploring artificial intelligence solve problems that involve learning and pattern matching.

Dr. Jerry Darsey (standing) shows University of Arkansas at Little Rock student Archie Stone a result of calculations generated by COSMIC's NETS program, a software system for applying artificial intelligence. The pair are part of a University of Arkansas/Oak Ridge National Laboratory team seeking to "train" a computer to recognize pattern relationships in chemical systems.

Dr. Jerry Darsey of the University of Arkansas (UArk) at Little Rock, Dr. Don Noid of Oak Ridge National Laboratory, and students of the UArk Chemistry Department are collaborating on a project to apply NETS to pattern matching of chemical systems. A successful effort could greatly help chemists identify mixtures of compounds without lengthy and sometimes costly separation procedures.

Using NETS as a framework, the group has trained the computer to recognize certain pattern relationships in a known compound and associate the results to an unknown compound. Dr. Darsey terms the research "promising" and adds, "Designing a molecule or compound on a computer before we even go into the laboratory may be possible."

A third COSMIC application exemplifies how use of NASA technology can give a small business a competitive edge over large companies.

Esse Systems, Portland, Oregon is a small consulting company that designs computer programs for regional manufacturers. Typically, Esse's work involves writing custom software that would help a client automate a portion of his operation.

Believing that better information management is the key to helping clients improve productivity, the firm began exploring expert systems, computer programs that make decisions based on what an expert in the field would do if faced with a problem.

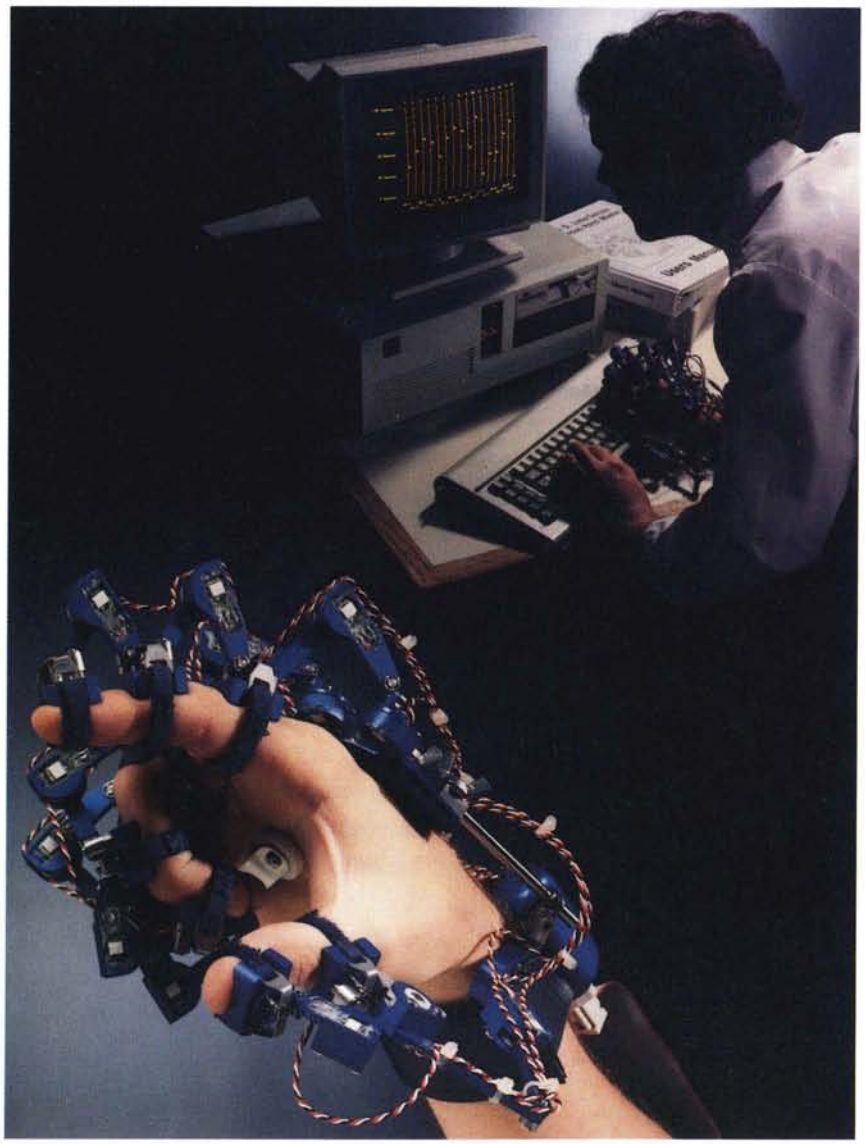
Esse first looked at a number of existing tools for writing expert systems. The firm settled on CLIPS (*C Language Integrated Production System*), a software shell for developing expert systems that originated at Johnson Space Center. With CLIPS, Esse initiated a prototype computer program that would act as a scheduling expert; the company felt that clients could save a great deal of time and use human experts more efficiently by automating many routine, repetitive scheduling decisions, freeing employees to spend time on other matters that required creative thinking.

After developing its prototype expert system and publishing a 32-page *Expert Systems Primer*, Esse Systems is now providing clients service in that area. The company's first contract involves development and implementation of an expert system to schedule reactors for Siltec Silicon, a Salem, Oregon semiconductor manufacturer. The three-phase project promises to provide significant time and cost savings for Siltec.

"We bid the job against some prestigious companies," says Esse Systems software engineer Ken Dellinger. "One reason we got the job was our understanding of the problems and our grasp of the technology available to solve the problem. By capitalizing on NASA technology, we're able to provide our customers with expert systems faster and more economically than we could if we had to start from scratch." ●

Small Business Innovations

A highly productive source of aerospace spinoff applications is the Small Business Innovation Research (SBIR) program, established by the Congress in 1982. In its first decade, it proved eminently successful in accomplishing both of its principal objectives: increasing small business participation in high technology research and development activities, and stimulating conversion of government funded R&D into commercial applications.



NASA and 10 other technology generating government agencies each set aside a percentage of their R&D budgets for SBIR projects, and each agency administers its own program independently under Small Business Administration guidelines.

In NASA's SBIR program, the agency has worked with more than 800 small businesses, who have developed hundreds of new systems and components that advanced NASA's capability for aerospace research and operations. NASA evaluates proposals from small firms from the standpoint of potential usefulness to NASA and the potential for commercial spinoff. The best concepts are awarded six-month contracts under which the company determines the technical feasibility of the innovation it has proposed. The results of Phase I research may lead to follow-on Phase II contracts that can run as long as two years. In Phase III, the small business participant may apply the results of Phase I/II research to development of a product or process for the commercial market, using private capital to do so.

Shown **at left** is an example of a successful NASA SBIR program, the Dexterous Hand Master™(DHM). The DHM is produced by EXOS, Inc., Lexington, Massachusetts, a company formed to manufacture and market products using robotic sensing technologies originally developed under NASA contract by Arthur D. Little's Center for Product Development, Cambridge, Massachusetts.

A 1989 winner of an R&D 100 Award, the DHM is an exoskeleton device for measuring the joints of the human hand with extreme precision. It was developed for NASA's use in controlling robots. In 1990, Exos introduced a commercial version, DHM Series II.

The DHM II is worn on the hand, connected to a computer that records hand motions and transmits that data as control signals to robots and other computers. It is used in such applications as enabling robotic hands to emulate human hand actions through remote operation; controlling and manipulating computer generated images in virtual reality environments; and controlling musical performances by shaping acoustical parameters in real time, on stage, in concert with musicians.

The spinoff DHM inspired two additional spinoffs. In 1990, EXOS introduced to the commercial market the GripMaster™, intended for use in tool design, design of other hand-held objects or design of factory workstations. The GripMaster combines the joint angle sensing technology of the DHM with pressure sensing technology to give measurement of grip strength and wrist position. The primary benefit is reduction of CTD (cumulative trauma disorders) caused by repetitive motions in the work place, a major occupational health risk.

A SPECIAL PROGRAM STIMULATES SMALL BUSINESS PARTICIPATION IN NASA RESEARCH AND DEVELOPMENT

In 1991, EXOS introduced a third product, the Clinical Hand Master System™ (**left**), a product designed for use by hand surgeons, orthopaedic surgeons, physical therapists and occupational therapists.

Another example is QASE® RT, a systems engineering tool for quantitatively evaluating a computer system design — hardware, software and data. Developed by Advanced System Technologies, Inc. (AST), Englewood, Colorado, the commercial QASE RT resulted from two different SBIR projects, one sponsored by the U.S. Navy, the other by Jet Propulsion Laboratory.

The purpose of QASE RT is to enable system analysts and software engineers to evaluate the performance and reliability implications of design alternatives. QASE RT evaluates system timing, capacity and availability. The user describes his system architecture and workload using direct manipulation graphics. QASE RT translates the system description into analytic and discrete event simulation models and executes them.

Analytics rapidly evaluate the feasibility of a wide range of system configuration alternatives. Simulation provides detailed performance evaluation. The results of the evaluations are service and response times, offered load and device utilizations, and functional availability.

AST, a computer performance engineering firm founded in 1984 as a research and development company, has been engaged in 16 SBIR contracts for various agencies. QASE RT, introduced in 1991, was the company's first commercial product line.

(Continued)

™Dexterous Hand Manipulator, GripMaster and Clinical Hand Master System are trademarks of EXOS, Inc.

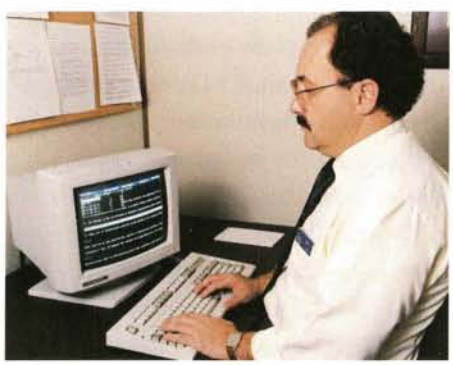
®QASE is a registered trademark of Advanced System Technologies, Inc.

Small Business Innovations (Continued)

Since 1983, when NASA initiated its SBIR program, the agency has sponsored some 1,500 Phase I projects and more than 40 percent of them have progressed through Phase II. Roughly a third of the latter have generated spinoff commercial applications.

Among additional examples of spinoff developments that emerged from the NASA SBIR program is Document Director™, a software system of innovative powerful tools for automating the requirements process in large programs.

Document Director was developed for NASA by Bruce G. Jackson & Associates, Inc. (BGJ&A), Houston, Texas, a consulting firm serving NASA and NASA contractors in requirements development, analysis, management and control. In 1986, BGJ&A started development of an automated tool that combined word processing and database management technologies. The resulting successful development became Document Director, a family of software packages intended to improve the quality of requirements/specifications and provide effective control throughout the life cycle of the program. Its key advantage is the integration of word processor and database manager, which offers the flexibility and convenience of text processing capability together with the linking capability of database management.

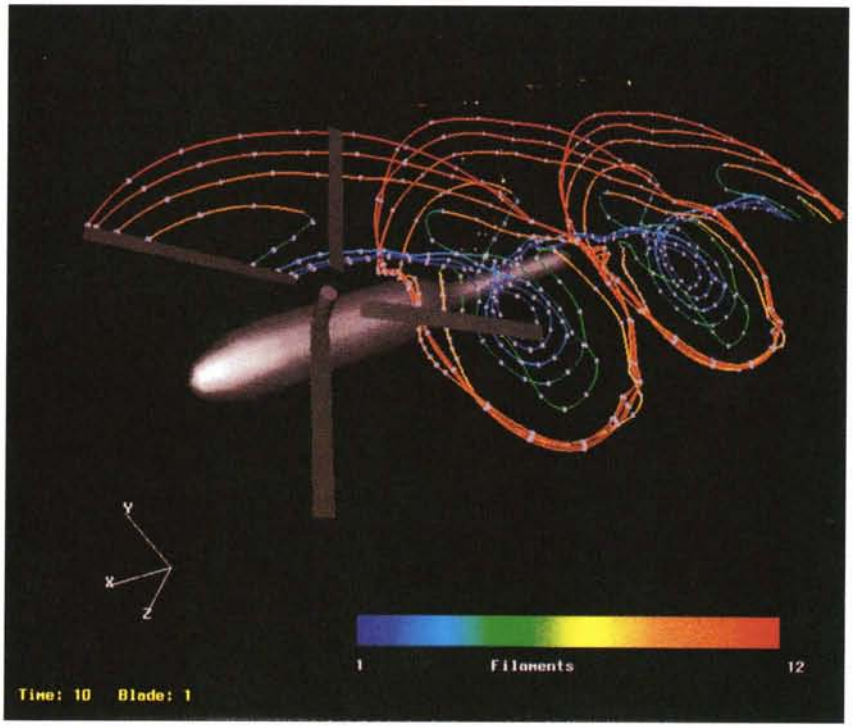


Since problems associated with requirements induce program cost overruns and schedule delays, Document Director also offers potential for improved control of costs and schedules. Document Director says BGJ&A, "provides a means to collect and manage all information associated with requirements development and to access the information in the manner that best supports the user."

Document Director was used by NASA in its program to design the Assured Crew Return Vehicle intended to return astronauts from the Space Station in an emergency; significant time savings were realized during the planning process. The first version of Document Director was released in 1988 and since then there have been three major upgrades. The software system is used by several government and industry organizations in addition to NASA. **At left**, Randolph W. Folck, quality assurance engineer at Southwest Research Institute (SwRI), San Antonio, Texas is pictured working with Document Director; SwRI uses the system regularly in managing research projects for the electric power industry and other clients.

Another outgrowth of the NASA SBIR program is a software package to facilitate development of interfaces between resident and host data base management systems. The software package was developed for Goddard Space Flight Center by Ken Wanderman & Associates, Inc., (KWAI), Staten Island, New York; Ken Wanderman and associate Dr. Marsha Moroh, vice president and head of software research development, are pictured at **bottom left**. This was one of several SBIR projects associated with a Goddard-developed system known as DAVID (*Distributed Access View Integrated Database*).

DAVID was developed as a solution to a problem associated with the diversity of NASA information systems. There are many database formats; there are a variety of com-



mercial and in-house database management systems supporting a number of databases; and there are large quantities of data stored in sequential files, data that can only be accessed by specially written programs. This situation led to difficulties for scientists trying to access information stored in a different format from their own. DAVID was developed to act, in part, as a central database management system.

The contribution of KWAI involved development of software tools that facilitate uniform access to databases, either commercial database management systems or arbitrary file formats. The KWAI software is divided into two parts: a number of interfaces, or bridges, between DAVID and commercial database management systems; and artificial intelligence programs that interact with a human data engineer to solicit information and automatically generate DAVID interfaces to their data. The software has been installed at a number of data centers, including the National Space Science Data Center.

Software innovations developed under Ames Research Center's SBIR program include two helicopter codes developed by Continuum Dynamics, Inc. (CDI), Princeton, New Jersey.

One is EHPIC (*Evaluation of Hover Performance Using Influence Coefficients*), a program used in helicopter design to predict the engine power required for a helicopter to hover. Such prediction is important, but difficult. The primary complication is calculating the effect of the wake of disturbed air trailed by a rotor blade on its neighboring blade (**left**). The EHPIC free wake model produces converged, freely distorted wake geometries that generate very accurate analysis of wake-induced downwash; this, in turn, allows good predictions of rotor thrust and power requirements. CDI has licensed the EHPIC code to three of the four major U.S. rotorcraft manufacturers.

A second CDI product is RotorCRAFT, a program for analysis of aerodynamic loading of helicopter blades in forward flight, a major concern in helicopter design. In particular, an accurate model of unsteady aerodynamic loading is required to understand and alleviate the sources of vibration in helicopters. Using some of the wake modeling tools developed for EHPIC, CDI developed the RotorCRAFT code, which has demonstrated good correlation of measured rotor airloads, an important part of vibration prediction. The code has been licensed to Sikorsky Aircraft Division of United Technologies. ●

Network Software

NASA and other research organizations employ extra-fast supercomputers that generate billions of bytes of data in seconds. This data must be moved by networks from the supercomputers to the workstations where researchers can study it. But until recently the transfer time to move the mountains of data sometimes ran into hours.

Among the solutions to that problem is UltraNet®, a family of products designed to transfer billions of bits per second. Manufactured by Ultra Network Technologies, San Jose, California, UltraNet exemplifies the personnel type of technology transfer, wherein government or contractor employees move to other occupations, bringing with them aerospace technology and skills that can be reapplied in the commercial marketplace.

The central figure in this case is James "Newt" Perdue, a computer engineer at Ames Research Center in the mid-1980s, when Ames was planning to upgrade its supercomputer-based Numerical Aerodynamic Simulation (NAS) program. Although NAS was already employing the fastest supercomputer designed until then, Ames officials saw a need to quadruple computing power — and therefore to upgrade the entire network to support a more advanced NAS.

Perdue and others at Ames worked to define a concept that would solve the problems of networking and access to mass storage systems. Extensive surveys of networking vendors, however, turned up no existing or planned networking products to meet NASA's projected requirements. Perdue took advantage of the opportunity to fill a need; he resigned from NASA in 1985 and founded Ultra Network Technologies.

Within 14 months, working with the NAS program to refine the requirements, the new company had developed prototype examples of gigabit/second networking technology. Today the company offers a full range of products to speed transfer of information among supercomputers, mainframe servers, workstations and other local area networks. The key technology is intelligent network processing to speed the flow of data without stopping, using special networking hardware and standard protocols.

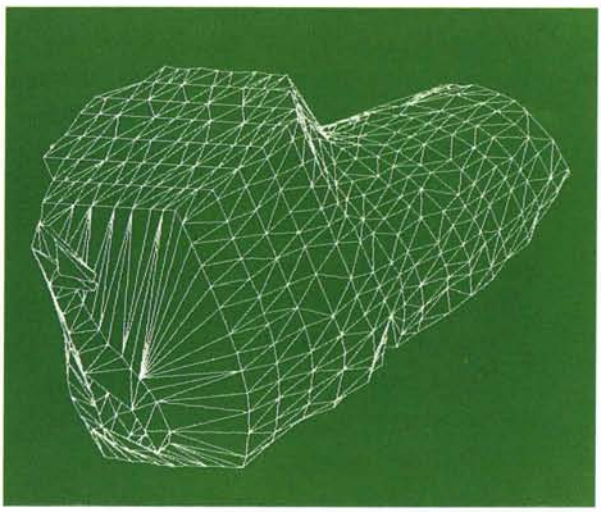
Now in its seventh year, Ultra Network Technologies has expanded its sales base to more than 100 customers worldwide and is designing a new generation of products for a wider market. **At left**, company founder and vice president Newt Purdue is shown with an UltraNet workstation used in a medical application; **below**, an engineer is conducting a pre-shipment check of three UltraNet Model 1000 systems. ●

®UltraNet is a registered trademark of Ultra Network Technologies.

Orthopaedic Footwear Design

About 10 million pairs of orthopaedic shoes are manufactured annually in the U.S. But they can cost as much as $800 and delivery may take several months. The reason: the number of skilled custom shoemakers is declining rapidly while the need for orthopaedic shoes is increasing.

To alleviate the manpower shortage and technical problems associated with manual design and fabrication of orthopaedic/ custom footwear, researchers at North Carolina State University (NCSU) have developed a Computer-Aided Design/ Computer-Aided Manufacture (CAD/CAM) system called CUSTOMLAST™. The system employs several task-specific computer programs, among them the NASA-developed RIM database management system, which is used as a central repository for system-wide information storage. RIM is supplied by NASA's Computer Software Management and Information Center.



The CUSTOMLAST system is comprised of several modules. LASTMOD™ is a CAD package to allow a custom footwear specialist to modify a digitized three-dimensional image of a foot or commercial shoe last to produce a last that can be cut on a milling machine. TORIM™ permits transfer of data from a geometric module to the centralized relational database management system. LASTCUT™ generates the tool path information to machine the shoe. LASTCHEQ™ checks the last against the digitized image generated by LASTMOD. In-addition, the University of Missouri-Columbia has developed three associated modules. Both universities offer licenses for the software at a fee.

The software development is part of a NASA technology utilization project initiated by Langley Research Center in 1986, in cooperation with Research Triangle Institute, Research Triangle Park, North Carolina, the Veterans Administration and the National Institute for Disability and Rehabilitation Research. ●

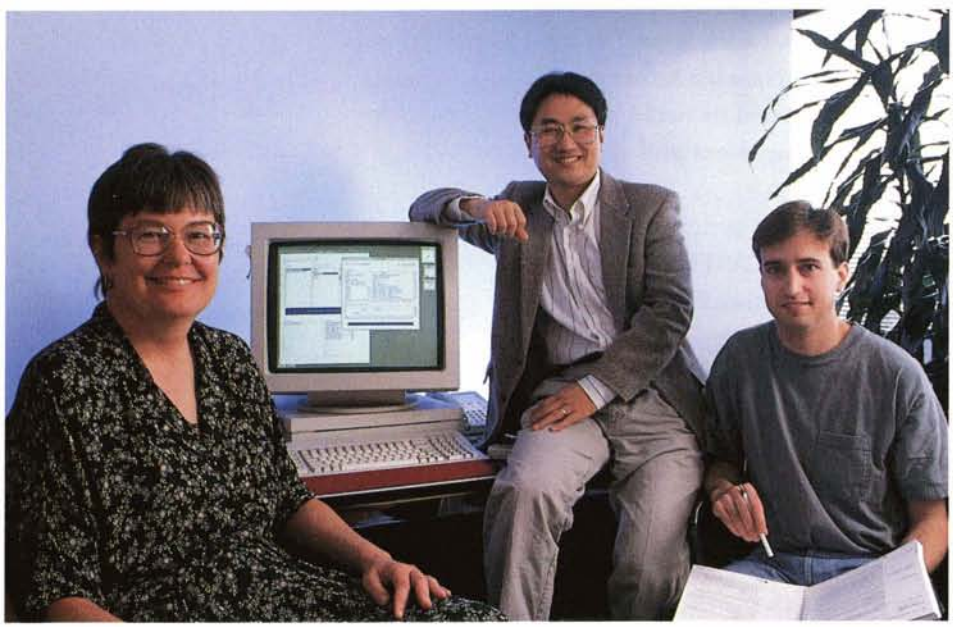
Problem-solving Software

Case-based reasoning (CBR) is defined as "a problem-solving paradigm that adapts stored problem solutions — or cases — to solve new problems specified by a user." CBR is applicable to a wide range of classification and construction tasks. It is particularly useful in tasks where a formal set of rules for generating solutions is difficult to obtain, but examples of correct solutions to similar problems are readily available.

Inference Corporation, El Segundo, California has introduced a stand-alone commercial software product based on CBR.

A COMMERCIAL PROBLEM-SOLVING PRODUCT EMERGED FROM NASA SOFTWARE DEVELOPMENT

Known as CBR Express™, it incorporates technology originally developed by Inference in work on the Advanced Software Development Workstation (ASDW) for Johnson Space Center (JSC). Shown **below** are the three members of the company's original CBR design team, from left, Elizabeth Ralston, Daniel Lee and David Lee.



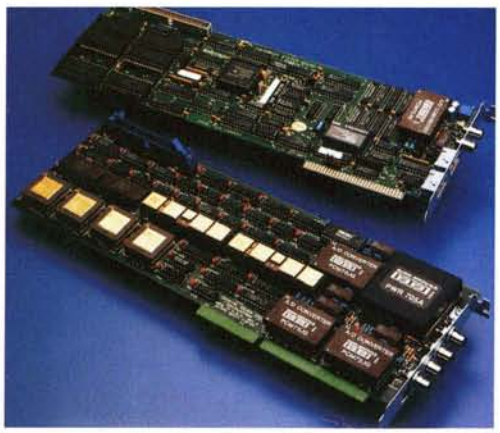
The JSC project focused on reuse of software designs and software components as a means of reducing costs and relieving a bottleneck in software development and in maintenance of deployed systems. Software reuse involves the retrieval and modification of existing software components. The method used was a knowledge-based system that provided a software parts composition system, which consists of a language for modeling software parts and their interfaces; a catalog of existing parts; an editor for combining parts; and a code generator that takes a specification and generates code for that application in the target language.

In the ASDW project, Inference Corporation employed CBR in the reuse process as part of the ACCESS prototype software. ACCESS is a knowledge-based software information system designed to assist the user in modifying or configuring retrieved software or design objects to the user's specifications.

The commercial CBR Express that emerged as a spinoff from the ASDW project is used as a "help desk" for customer support, enabling reuse of existing information when necessary. It has been adopted by a number of companies, among them American Airlines, GTE Corporation and Nippon Steel. An example of its utility: if American Airlines' reservation system software did not work, CBR Express would solve the problem by identifying similar problems in its database; essentially it classifies a given problem situation on the basis of past problems. ●

3D Audio System

Shown **below** is the Convolvotron, a very high speed digital audio processing system that delivers three-dimensional sound over headphones. Marketed by Crystal River Engineering, Inc., Groveland, California, the signal processor was designed by the company's president, Scott H. Foster, as part of an auditory research program conducted by Elizabeth Wenzel of Ames Research Center's Human Factors Division.



The Convolvotron consists of a two-card set designed for use with a personal computer. The system's 128 parallel processors make the Convolvotron 20 times faster than ordinary digital signal processing systems, the company states.

Programmed for a variety of signal processing tasks, the Convolvotron's primary application is presentation of 3D audio signals over headphones. In this application, four independent sound sources are filtered with large, time-varying filters that compensate for the head motion of the listener or the motion of audio sources. As the listener's head changes position, the perceived location of the sound source remains constant — for example, sound perceived to come from in front of the listener will change smoothly to the right side when the listener turns 90 degrees to the left.

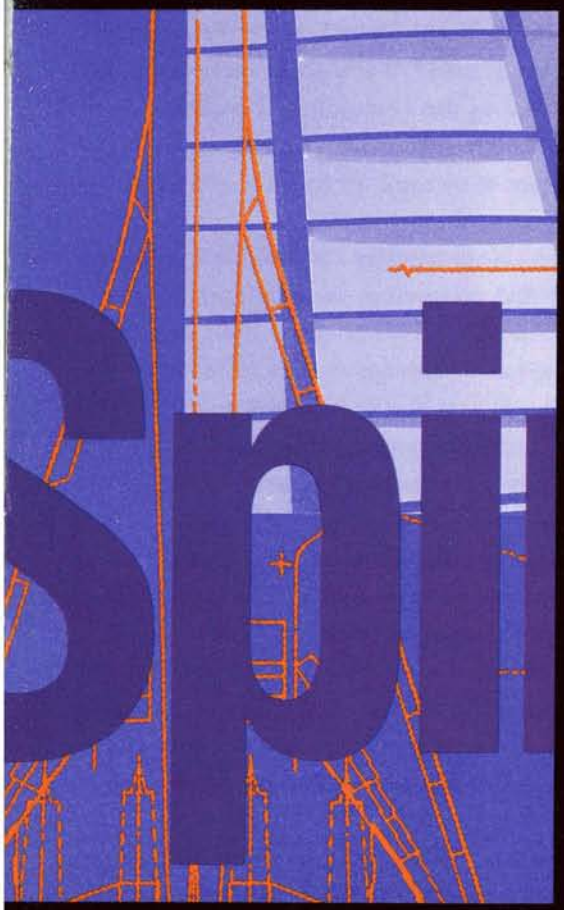
The Convolvotron was developed for Ames' research on virtual acoustic displays, part of the center's broader research into virtual reality, or artificial reality, displays. Ames is investigating the possibilities of combining a 3D auditory system with visual virtual displays **below**.

The primary advantage of the Convolvotron is that it allows monitoring and identifying sources of information from all possible locations, not just "direction of gaze." This feature could be useful in an application such as an air traffic control display in control towers or airplane cockpits. A further advantage is that the 3D system improves the intelligibility of sounds and assists in the segregation of multiple sound sources. A combined visual/auditory system can reinforce the information content of the display and provide a greater sense of realism than either modality alone.

Although the Convolvotron is used mostly by government agencies and their contractors, it is also being sold commercially. It is used in research on hearing and perception; customers include Boston University, Massachusetts Institute of Technology and the University of Wisconsin. Additionally, it is used by virtual reality researchers and systems developers; customers include Fujitsu, Autodesk and Disney Imagineering. The system is also used by aircraft manufacturers; Lockheed Corporation is using it in development of an advanced aircraft cockpit. ●

Technology Transfer

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



Putting Technology to Work

A NATIONWIDE TECHNOLOGY TRANSFER NETWORK SEEKS TO BROADEN AND ACCELERATE SECONDARY APPLICATION OF NASA TECHNOLOGY

By their challenging nature, NASA programs are especially productive of advanced technology. This wealth of technology is a national asset in that it can be reused to develop new products and processes to the benefit of the U.S. economy and expanded industrial productivity.

Such "spinoff" applications, however, do not happen automatically. It takes a well-organized effort to put the technology to work in new ways and to reap thereby a dividend on the national investment in aerospace research.

NASA accomplishes that objective by means of its Technology Transfer Program, which employs a variety of mechanisms to stimulate the transfer of aerospace technology to other sectors of the economy. The program is managed by the Technology Transfer 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.

A relatively new mechanism is an annual technology transfer conference and exposition designed to promote greater awareness of the NASA technology bank among the nation's non-aerospace industrial community. This program is intended to show companies how to tap into the great technology storehouse to increase their productivity and competitiveness; to acquaint industrial firms with potential opportunities for NASA/industry cooperative research and development; and to emphasize to the non-aerospace community the technology advancement benefit to the nation accruing from space programs.

NATIONAL CONFERENCES HIGHLIGHT NASA MECHANISMS FOR STIMULATING TECHNOLOGY TRANSFER

The program is aimed primarily at such company officials as top management, research directors, scientists, engineers and small business entrepreneurs. The exposition features wide-ranging exhibits by federal laboratories, their prime contractors, other high technology firms and universities with cutting-edge inventions available for license or sale.

The conference includes scores of symposium presentations spotlighting advances in critical areas of technology. Technical sessions deal with such matters as advanced manufacturing, biotechnology, communications, electronics, materials science, computers in medicine, software engineering, electro-optics and life sciences.

A series of government/industry workshops cover such subjects as patent licensing, cooperative R&D, and Small Business Innovation Research opportunities. A highlight of the conference is an annual Technology Transfer Awards Dinner recognizing outstanding achievement in the field of technology transfer. The conference is jointly sponsored by NASA, the Technology Utilization Foundation, and Associated Business Publications of New York City, publisher of *NASA Tech Briefs*.

The initial conference, titled *Technology 2000*, was held in Washington, D.C. on November 27-28, 1990. It was an immediate success, drawing more than 2,000 attendees. The great interest aroused prompted the sponsors to expand the conference significantly and, at the urging of Dr. D. Allan Bromley, science advisor to President Bush, to include other technology generating agencies of the government.

Technology 2001, the second annual conference, was held in the San Jose (California)

Technology 2001, the second national technology transfer conference and exposition, drew 3,900 industry leaders and 220 exhibitors to the San Jose (California) Convention Center.

Convention Center on December 3-5, 1991. The expanded three-day meeting drew almost 4,000 attendees and 220 exhibitors occupying 50,000 square feet of exhibit space.

More than 120 technical papers were presented. Participation included 50 government laboratories representing NASA, the Environmental Protection Agency and the Departments of Defense, Energy, Transportation, Agriculture, Commerce, Health and Human Services, Interior and Veterans Affairs, who detailed their latest technologies available for transfer.

Indications are that further expansion of both the exhibits and the technical presentations will be necessary for the third annual conference, *Technology 2002*, to be held in the Baltimore (Maryland) Convention Center on December 1-3, 1992.

In addition to the conferences, other mechanisms employed in the Technology Transfer Program include applications engineering projects, in which NASA collaborates with public sector or industrial organizations to develop innovative solutions to major problems through redesign or reengineering of NASA technology; technical assistance centers that provide, for industrial and government clients, access to a great national data bank; a software center that offers computer programs applicable to secondary use; Technology Transfer Officers, located at each of NASA's field centers, who serve as regional managers for the program; and publications that inform potential users of technology available for transfer. These mechanisms are amplified in the following pages.

Technology Transfer Network

To promote technology utilization, NASA operates a number of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government clients.

In order to better meet the technological needs of American industry and enhance U.S. competitiveness in the 1990s and beyond, NASA has upgraded and restructured those centers into a National Technology Transfer Network composed of a National Technology Transfer Center (NTTC) and six Regional Technology Transfer Centers (RTTCs).

The RTTCs replace the prior network of 10 Industrial Applications Centers, a move designed to streamline NASA's technology transfer operations and at the same time provide a more equal distribution of services throughout the country. The regional deployment of the centers, and their alignment with the six Federal Laboratory Consortium regions, allows the RTTCs to work closely with federal, state and local programs in serving the technology-related needs of business and industry.

The RTTCs began operation in January 1992, providing value-added services to meet the needs of clients, including:

- Information services: computerized searches of federal technology databases and other technology sources.
- Technical services: assessment of technology requirements, analysis of technology applications, and engineering reports.
- Commercialization services: technology brokering, business analyses and venture capital sourcing.

Other elements of the National Technology Transfer Network include:

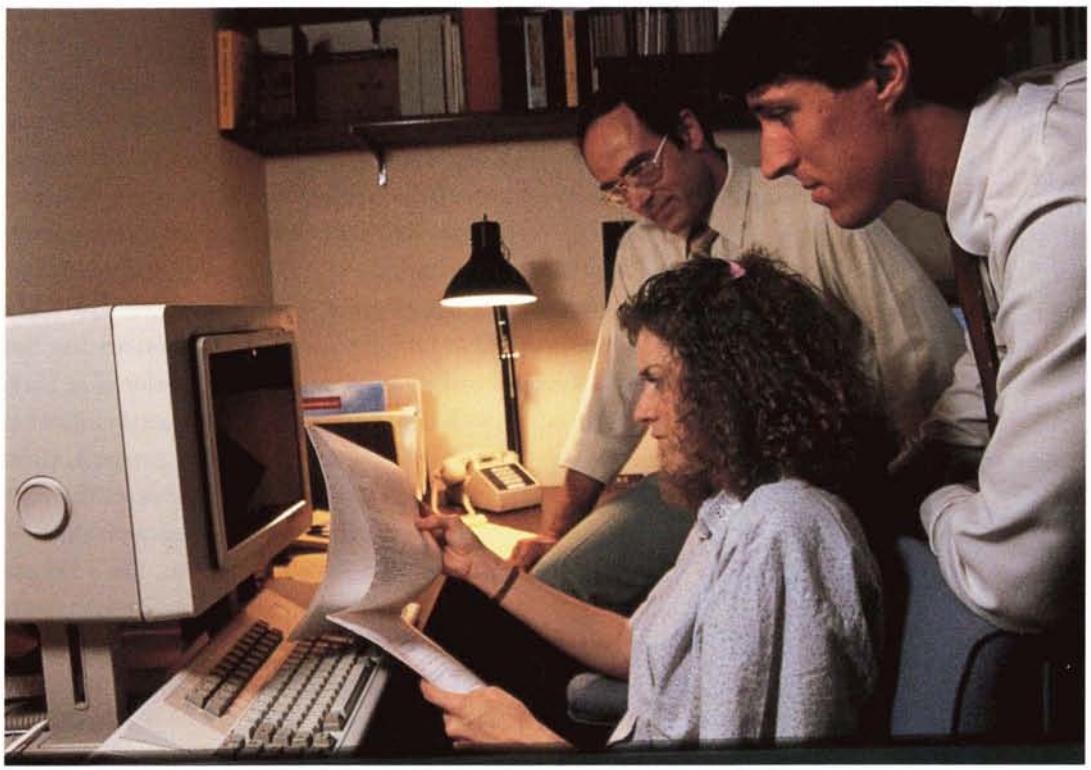
- Federal agency technology transfer program and activities;
- State and local agencies and their programs, such as technology centers and business/technical assistance services; and
- Business and industry consortia, associations and communities.

The National Technology Transfer Network is designed to provide an effective, market-oriented means of transferring technologies from the more than 600 laboratories in the federal R&D base to the private sector.

Now in the initial phase of a five-year development program, the NTTC will serve as the hub of the national network. Located at Wheeling Jesuit College, Wheeling, West Virginia, it will serve as the national clearinghouse for federal technology transfer, linking U.S. firms with federal agencies and laboratories, the RTTCs and state/local agencies.

The NTTC will also provide training and educational services to government and industry to develop the skills essential to effective technology transfer. Additionally, the center will conduct outreach and promotional activities to improve private sector awareness of technology transfer opportunities.

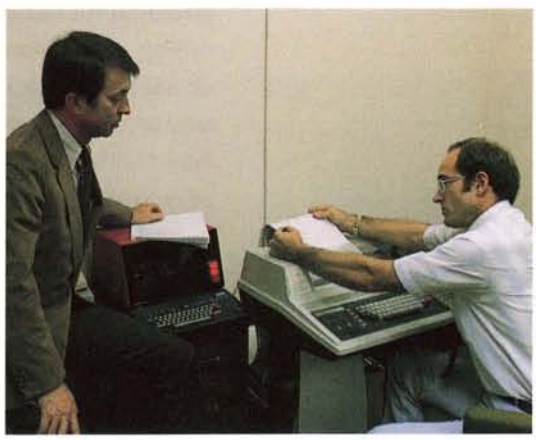
A typical regional center is the Southeast RTTC, also known as the Southern Technology Application Center



(**left**), which is located at the College of Engineering, University of Florida, Alachua, Florida. Formerly one of NASA's Industrial Applications Centers, the center covers a nine state area that includes Florida, Louisiana, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Tennessee and Kentucky. The organization is a technology transfer component of the State University System (SUS) of Florida and it has offices at five other SUS institutions in addition to the headquarters office.

The Southwest RTTC offers a wide range of services in four major categories: business and operations management; research planning and development; commercialization; education and training. Examples of specific services include information retrieval (**above**); expert referral and organizational networking; marketing assistance, business and product development; technology assessment, matching and brokering; capital sourcing; training programs; and project management. Shown **below** are the center's director, Ron Thornton (standing) and information research director Lynn Heer.

The locations of the regional centers and their areas of coverage are detailed on page 142. ●



Technololgy Utilization Officers

An important element among the NASA mechanisms for accelerating and broadening aerospace technology transfer is the Technology Transfer Officer, or TTO. TTOs are technology transfer experts at each of NASA's nine field centers who serve as regional managers for the Technology Transfer Program.

Representative of the group is Norman L. Chalfin, TTO at Jet Propulsion Laboratory, California Institute of Technology, one of NASA's field centers.

Chalfin (second from right) is shown **at left** manning a booth at a tradeshow with Jean Fradet of his office. In the photo **below**, Jo Fitzsimmons, another member of the JPL technology transfer staff, is preparing a computer program for submission to the Computer Software Management and Information Center (see page 140).

The TTO's basic responsibility is to stay abreast of research and engineering activities at his center that have significant potential for generating transferrable 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 NASA 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 technology bank available for secondary application.

To advise potential users of the technology's availability, the TTO evaluates and processes selected new technology reports for announcement in NASA publications and other dissemination media. Prospective users are informed that more detailed information is available in the form of a Technical Support Package (TSP).

The TTO also serves as a point of liaison among industry representatives and personnel at his center, and between center personnel involved in applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology. On such projects, the TTO 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 TTO 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 — indus-

try participants seek to follow up with visits to the center, he serves as the contact point.

Support for the TTOs — and for all other elements of the NASA technology transfer network — is provided by the Technology Transfer Office at the Center for AeroSpace Information (CASI). This office executes a wide variety of tasks, among them maintenance of the subscription list for *NASA Tech Briefs*, the principal tool for advising potential users of technologies available for transfer; maintenance and mailout of TSPs, 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 60,000 letters and other inquiries and mailout of more than 300,000 documents a year. The office additionally serves as a "help desk," channeling information seekers to the proper agency or organization when the information is not available at CASI. **Above**, technology associate Jeff Beck is abstracting *Tech Briefs* articles; **at right**, Bobbi Ebberts (standing) and LaDonna Jenkins are processing requests for TSPs.

The Technology Transfer Office/CASI is also responsible for research, analysis and other work associated with this annual Spinoff volume; for distribution of technology transfer publications; for retrieval of technical information and referral of highly detailed technical requests to appropriate offices; for developing reference and bibliographical data; and for public relations activities connected with media, industry and trade show interest in technology transfer matters. ●

Technology Applications

Applications engineering projects are efforts in which NASA seeks to solve significant public sector or industrial problems through redesign or reengineering of existing technology. They originate in various ways. Some stem from requests for 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 also employs an applications team composed of scientists and engineers representing different areas of expertise, who identify problems, submit them to NASA centers for review, then assist the centers in adapting solutions.

An example of an ongoing applications engineering project is an effort at Marshall Space Flight Center (MSFC) to develop a new type of microscope that could have a profound impact on cell biology and genetic engineering; it could revolutionize the search for the human genetic code and lead to cures for currently incurable diseases, such as cancer and AIDS.

This effort, spearheaded by astrophysicist Richard B. Hoover of MSFC's Space Science Laboratory, involves transferring to the world of medicine technology originally developed for space based studies of the Sun. Hoover is pictured **at left** with the Water Window Imaging X-Ray Microscope. This MSFC development borrows technologies employed in a spaceborne telescope known as the Rocket X-Ray Spectroheliograph and a later advancement known as the Multi-Spectral Solar Telescope Array; both were cooperative projects of MSFC, Stanford University, and the Department of Energy's Lawrence Livermore National Laboratory.

The "water window" is a narrow band of the x-ray spectrum where water is relatively transparent and carbon is highly absorptive. Operating within that wavelength regime, the Water Window Imaging X-Ray Microscope will make it possible to investigate carbon structures (and possibly even note the motions of these structures) within the aqueous environment of living cells.

The microscope offers potential for revolutionary advances in genetic research. Where such research is currently based on indirect techniques, the water window microscope would allow scientists to study cells while they are alive and to get actual images of DNA molecules. Such a development has enormous implications for medical researchers; it would permit, for example, direct study of malignant tumors, design of advanced drugs, and study of genetic mutations that cause birth defects.

Another example is a Direction Discriminating Hearing Aid System being developed by Muray Jhahvala at Goddard Space Flight Center (GSFC), who is employ ing a number of microelectronics and micro-miniaturization techniques. The device is intended to help people who have substantial hearing loss in one or both ears and who, as a result, have difficulty discerning the directions from which sounds originate. In some cases — sound of street traffic, loading dock horns, sirens, etc. — the problem poses a serious hazard.

GSFC's corrective system centers on a device, mounted on an eyeglass assembly, that measures the intensity of sounds and indicates the directions from which they come. The device includes a microchip, batteries, light-emitting diodes and two mini-microphones. The microchip determines the strength of a noise signal received by each of the two microphones and decides which received the stronger signal. The diodes, mounted on the lenses of the eyeglasses, flash a colored-dot signal to the wearer informing him of the direction and volume of the sound.

The system has two other components: a stationary alarm and a noise-seeking wand. The stationary alarm is a free-standing, portable, high intensity xenon flash tube; placed near a door, for example, it flashes a visual signal that there is a knock or a bell ring at the door. The noise-seeker wand is used in conjunction with the stationary alarm; the rotating wand displays a visual signal that is most intense when aimed directly at the noise source, weaker when the wand is rotating away from the noise source, thus providing a directional indication. The hearing aid system, a cooperative effort of GSFC, the University of Maryland, other government agencies and private sector organizations, has been commercially prototyped.

A third applications engineering example involves adaptation of NASA sensor technology to a portable fetal heart rate monitor that will help spot prenatal problems and enable a mother to keep track of her developing baby's health at home each day. Shown **above** undergoing test at Eastern Virginia Medical School, the device was developed by a Langley Research Center team headed by electronics engineer Dr. Allan J. Zuckerwar in collaboration with the concept originator, Dr. Donald A. Baker of Spokane, Washington.

Zuckerwar adapted passive, film-type acoustical sensors normally used by Langley researchers to measure surface pressures on aircraft or wind tunnel models of aircraft. His seven-sensor monitor, mounted on a belt worn by the mother, detects pulses from the mother's abdomen and recognizes and isolates the fetal heartbeat. Since the baby's heartbeat changes measurably under adverse influences, the monitor can determine when the heartbeat goes outside certain limits. In the final commercial version, an abnormal signal will trigger an alarm telling the mother to seek assistance. Langley's Technology Transfer Office provided funding for development of the monitor and is supporting Dr. Baker's effort to market the system commercially. ●

Software Center

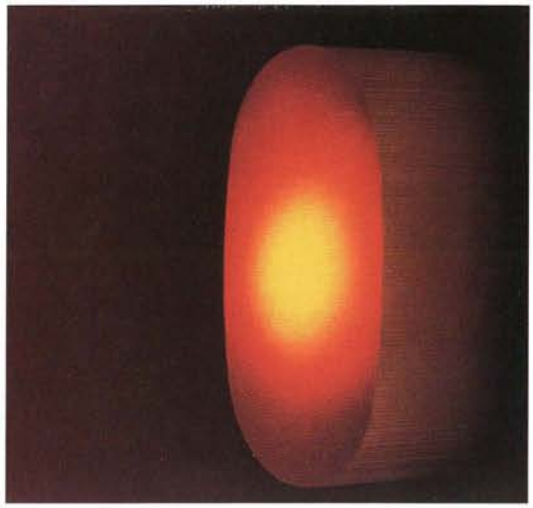
In the course of its varied activities, NASA makes extensive use of computer programs, as do other technology generating agencies of the government. To meet their software requirements, these agencies have of necessity developed many types of new computer programs.

These programs 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 time and money by taking advantage of a special NASA service that offers software capable of being adapted to new uses. NASA's mechanism for making such programs available is the Computer Software Management 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 that 1,200 programs for such purposes as structural analysis, artificial intelligence, computational fluid dynamics, thermal analysis, image processing, project management and a great variety of other functions. COSMIC customers can purchase a program for a fraction of the original cost and get a return many times the investment, even when the cost of adapting a program to a new use is included.

An example of how this service aids industry is the use of COSMIC-supplied



software by a division of Smiths Industries, Grand Rapids, Michigan, which designs navigational aids and other avionics for aircraft. Smiths packaging engineers avoid unnecessary and costly redesign of a product through the use of the SINDA '85/FLUINT software system for predicting thermal performance.

SINDA '85/FLUINT is a program for solving the physical problems governed by flow and diffusion type equations and is most widely used as a general thermal analyzer. A 20-year user of COSMIC's service, Smiths has applied the SINDA design tool to an Integrated Display Computer (**left**) for a Navy aircraft. By applying finite modeling techniques to develop a model of the structure, engineers can get thermal predictions typically within two degrees Centigrade of measured values. When an abnormality — such as a hot spot — is predicted, a change in the product design can be made early to eliminate potential problems.

Another SINDA user is Corning, Inc., Corning, New York, a specialty glass and ceramics firm. One application of the program is modeling the heat flow in catalytic converters; shown **above** is a catalytic converter during heat-up. A SINDA'85/FLUINT thermodynamic model can be used to predict the time necessary for the converter to heat up to optimum performance during a standard Environmental Protection Agency test cycle. ●

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

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 and innovations developed in the course of work for NASA. These reports provide the input for *Tech Briefs*. Issued monthly, the publication is a current awareness medium and a problem solving tool for more than 200,000 government and industry readers. It is a joint publishing venture of NASA and Associated Business Publications, Ltd. of New York City.

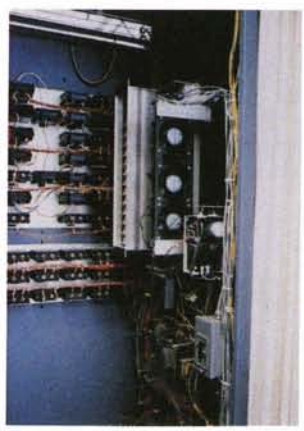
Each issue contains information on newly developed products and processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs, and other innovations originating at NASA field centers or at the facilities of NASA contractors. Firms interested in a particular innovation may get more detailed information by requesting a Technical Support Package; (TSP); more than 130,000 such requests are generated annually.

An example of how *Tech Briefs* inspires secondary applications of NASA technology is the experience of the Water Division of the Utility Department, City of Dubuque (Iowa). The division was operating a computer system that gathered data, both analog and digital, from remote tanks, pumping stations, wells and the division's main plant.

Shortly after the computer system became operational, the division began experiencing failures of the analog inputs, ranging from signals out of tolerance by more than 30 percent to intermittent — and sometimes complete — loss of signals. Investigation traced the problem to lack of signal isolation on the analog input cards, which made the input vulnerable to interference from storms and machinery. Most of the problems originated in the main plant pump room shown **at left**; the pumps have thermocouples mounted on their bearings and their signals are not isolated from the computer inputs.

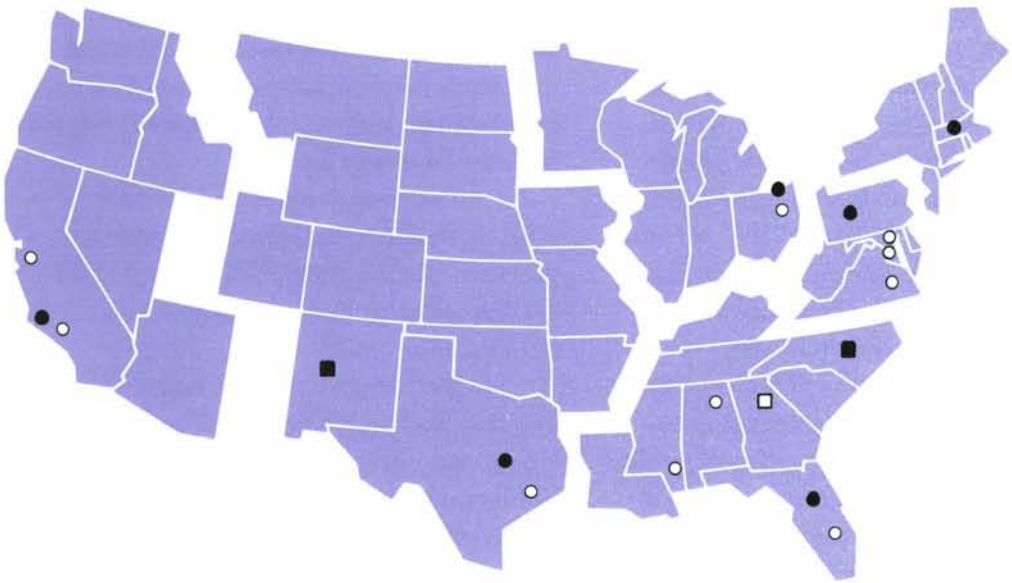
The division purchased commercial isolation modules that solved the immediate problem. But the Water Division's tight budget demanded a more cost effective long term solution.

Division electronic technician Bob Ervolino read an article in *Tech Briefs* describing an Ames Research Center solution to a similar problem. He sent for the TSP, studied details of the Ames invention, and learned the name of the vendor supplying the isolation circuit described in the article. The vendor suggested devices the Water Division might use and they were installed. Ervolino reports that *Tech Briefs* information solved the problem and saved the Water Division more than 50 percent of the cost of commercial signal isolators. The solution — the signal isolators — is pictured **at left.** ●



NASA's Technology Transfer Network

THE NASA SYSTEM OF TECHNOLOGY TRANSFER PERSONNEL AND FACILITIES EXTENDS FROM COAST TO COAST. FOR SPECIFIC INFORMATION CONCERNING THE ACTIVITIES DESCRIBED BELOW, CONTACT THE APPROPRIATE TECHNOLOGY TRANSFER PERSONNEL AT THE ADDRESSES LISTED, OR ADDRESS INQUIRIES TO THE MANAGER, TECHNOLOGY TRANSFER OFFICE, CENTER FOR AEROSPACE INFORMATION, POST OFFICE BOX 8757, BALTIMORE, MARYLAND 21240.



○ ***Field Center Technology Transfer Officers:*** manage center participation in regional technology utilization activities.

● ***Regional Technology Transfer Centers:*** information, technical and commercialization services.

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

□ ***Application Teams:*** assist agencies and private institutions in applying aerospace technology to solution of public problems.

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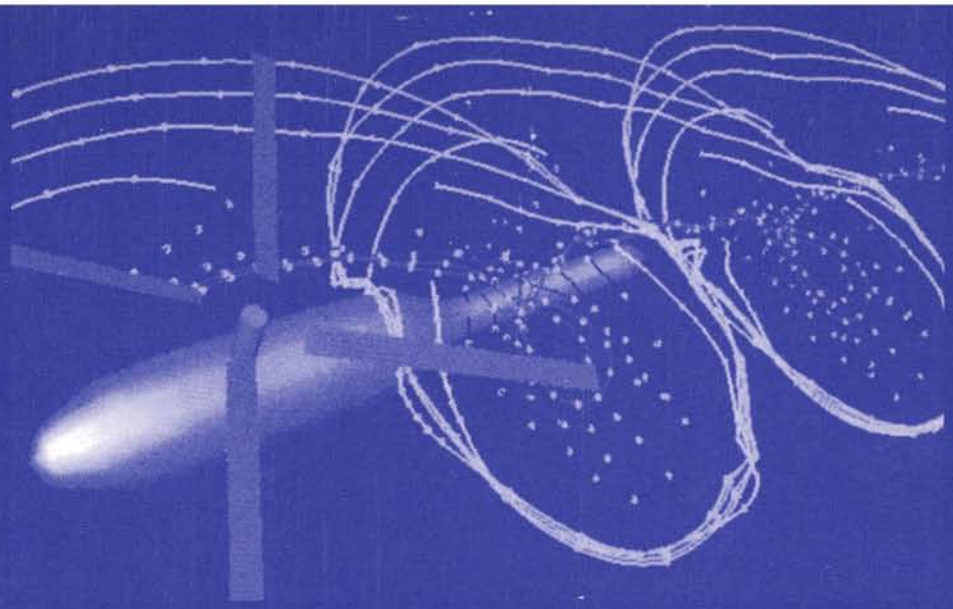

Transportation

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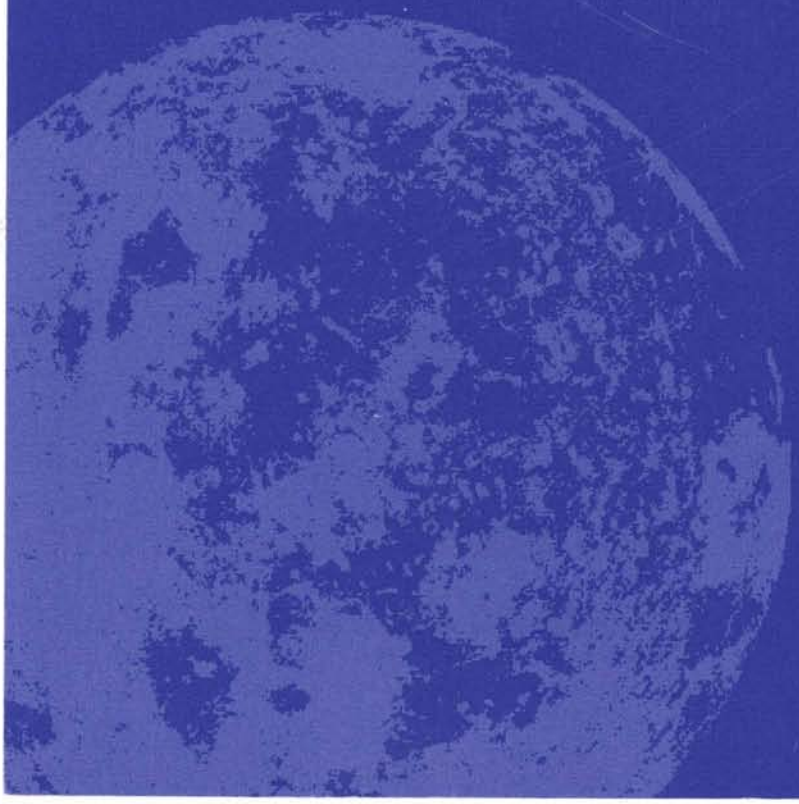

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