Spinoff 1984

National Aeronautics and
Space Administration

Foreword

Two decades ago, NASA pioneered the technology that enabled operation of satellites in geostationary orbit, thereby building a foundation for the space communications networks that followed. Today, more than two-thirds of all overseas communications traffic is relayed by satellite and there are, additionally, a number of domestic communications satellite systems in operation. The commercial space communications industry does more than $3 billion worth of business annually and employs, directly and indirectly, more than one million people—mostly Americans.

The development of space-relayed communications was the first effort to commercialize space and it is so far the most economically successful. In coming years, however, we can expect to see much broader pursuit of commercial space opportunities. Essentially there are three areas of commercial space promise. One is operation of satellites for communications or for a variety of other practical applications involving observation of Earth from orbit. A second is provision of services to satellite operators—building space systems, launching them, or processing and analyzing the data they supply. The third—and perhaps the most exciting—is manufacture in orbit of products that cannot be made on Earth, products that promise societal and economic benefits of immense order.

President Reagan's initiative to build a permanently manned orbital station significantly advances the prospects for space commercialization. It is a plan that builds upon the highly successful policies of earlier years, when the nation expanded and strengthened its economy through publicly-funded development of highways, railroads and airports. Congressional approval of the space station program will assure the U.S. industrial community that the government will create the foundation essential to private sector investment in space. It will enable government and industry to forge a new partnership toward realizing the commercial potential of the space realm.

The space station, however, will be much more than a place to pursue practical applications. It will be an orbital laboratory for advanced scientific and technological research; a base for more efficient operation and servicing of unmanned space systems; a facility for assembling future structures too large to be launched from Earth; and a staging area for the dramatic space ventures contemplated for tomorrow. Most importantly, it will be a symbol of American dedication to maintaining leadership in space.

As we embark on the second quarter-century of American space endeavor, we stand on the threshold of an exciting new era. The space station and the complementary Space Transportation System will enormously broaden our national capability for exploiting space and open new avenues of opportunity for benefit to mankind—not only commercial benefits, but the equally important, if less visible, benefits that will accrue from advanced scientific research in space. To quote the President's summation: "We can follow our dreams to distant stars, living and working in space for peaceful, economic and scientific gain."

James M. Beggs

James M. Beggs
Administrator

National Aeronautics and Space Administration

Spinoff 1984

National Aeronautics and
Space Administration

Office of External Relations

Technology Utilization and
Industry Affairs Division

by James J. Haggerty

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Introduction

By their challenging nature, NASA programs are particularly demanding of technological input. Meeting the aeronautical and space research goals of the past quarter century has necessitated advancements across a diverse spectrum that embraces virtually every scientific and technological discipline. Much of the hardware developed to meet program needs, having served its purpose, is no longer extant—but the technology remains. It is a national resource, a bank of knowledge available for application to new products and processes of benefit to the national economy, industrial efficiency and human welfare.

This ever-expanding storehouse of technical knowledge has been well utilized over the past two decades or more. NASA's own efforts to reapply the technology, and those of imaginative entrepreneurs, have generated thousands of secondary applications—"spinoffs"—spanning a broad range of public needs and conveniences. It is difficult to find a facet of every day life wherein spinoff has not pervaded. NASA techonology has been transferred to the fields of medicine, public safety, transportation, industrial processes, pollution control, energy systems, construction, law enforcement, home appliances, farm machinery, sports and recreation, food products—the list can be expanded to catalog length. Collectively, these innovations represent a valuable contribution to American employment, productivity and lifestyle.

By Congressional mandate, NASA is responsible for promoting further use of the technology. Its instrument is the Technology Utilization Program, which seeks to broaden and accelerate technology transfer in the public interest. The program provides a link between the technology bank and those who might be able to use the technology productively, thereby facilitating the transfer process and spurring expanded national benefit.

This publication, an implement of the Technology Utilization Program, is published under the auspices of NASA's Office of External Relations, which is charged with a broad spectrum of responsibilities related to keeping the general public, industry and other organizations outside the agency informed about NASA and the results of its activities. The Office's efforts to carry out these responsibilities include—in addition to the Technology Utilization Program—daily interaction with news and television media, special programs to enhance space-related educational curricula nationwide, and management of international cooperative programs in space and aeronautical research.

Organized in three sections, *Spinoff 1984* is intended to heighten public awareness of the technology bank's potential and to stimulate interest among prospective users of the technology.

Section 1 summarizes NASA's current mainline programs, which are producing *direct* public benefit and simultaneously contributing to *indirect* benefit by generating new technology that may find secondary application in future years.

Section 2, the focal point of this report, contains a representative selection of spinoff products and processes and describes the NASA technology from which these transfers derived.

Section 3 details the mechanisms NASA employs to foster technology utilization and to strengthen the government/industry partnership for technological progress. It lists, in an appendix, contact sources for further information about the Technology Utilization Program.

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Space Operations: The Next Decade

A maturing Space Transportation System and new technology advancements on the horizon combine to expand opportunities for exploiting the promise of space

On the tenth Space Shuttle mission in February of this year, Mission Specialist Bruce McCandless II made his maiden voyage to orbit. And what a debut! Donning a backpack Manned Maneuvering Unit (MMU) that was similarly making its first appearance in space, McCandless became the first human satellite, flying in formation with the Orbiter *Challenger* through a full circumnavigation of the Earth at a speed of 17,500 miles per hour.

Over the following two days, McCandless and fellow Mission Specialist Robert L. Stewart each made two EVAs (extravehicular activities), moving at times more than 300 feet from the Orbiter without benefit of protective tethers or life support umbilical lines. Their job was to check out the performance of two MMUs and to demonstrate their own abilities to use the systems effectively, an important step in expanding space capability because EVA figures prominently in NASA plans for future space operations. Beginning this year, the MMUs will be employed in missions involving retrieval, repair and servicing of satellites in orbit. Later, NASA will use a combination of EVA and free flying robot vehicles to assemble the manned space station proposed by the Administration for erection early in the 1990s. Still later, space station crews will employ the EVA/robot combination to assemble and deploy space systems too large to be accommodated in the Shuttle Orbiter's payload bay.

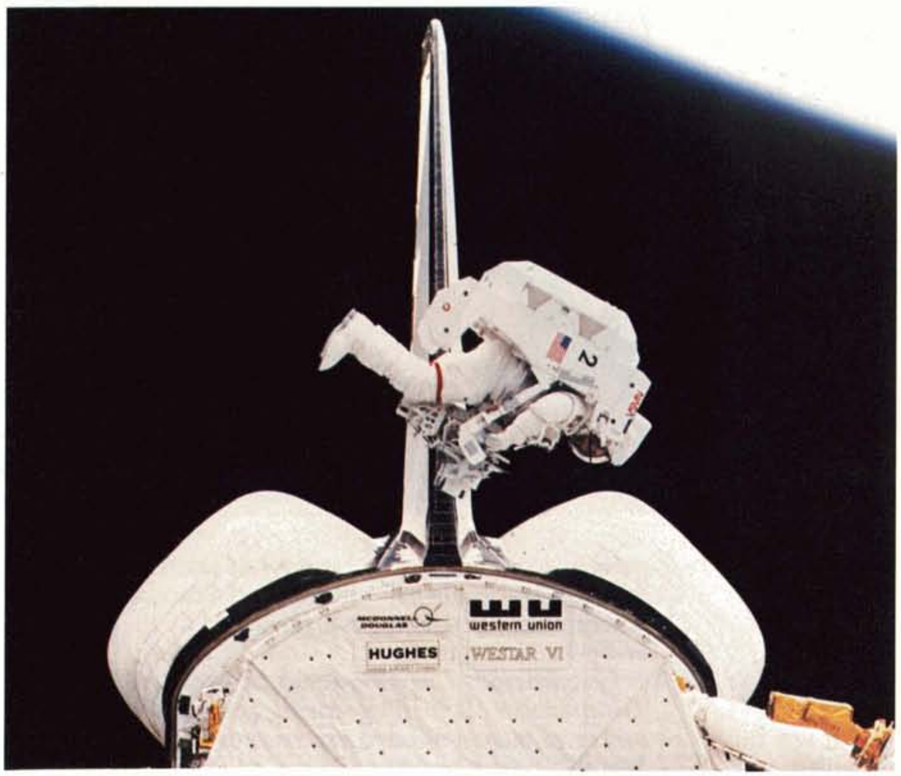
Built by Martin Marietta Aerospace, the MMU is an orbital propulsion system in which 24 small nitrogen gas jets provide thrusting impulses to maneuver an astronaut in a desired direction on command from hand controllers built into the unit's arm rests. The left hand controller governs fore/aft, right/left and up/down translation; the right hand controller handles roll, pitch and yaw motions. Gas is fed to the thrusters from two tanks that hold 13 pounds of nitrogen; the tanks can be recharged in less than 20 minutes at a facility in the Orbiter's bay. The controllers may be used singly or in combination to provide a full range of movement within the operating logic of 729 command combinations, including attitude hold. Two MMU batteries supply enough electrical power for six hours of EVA.

Above, astronaut Bruce McCandless is controlling his Manned Maneuvering Unit (MMU) 170 miles above Earth, untethered to the Shuttle Orbiter some 300 feet distant. McCandless became the first human satellite during the tenth Shuttle flight in February. At right center, McCandless is maneuvering himself into the Orbiter's payload bay for a docking experiment.

The MMU is not by itself a "one-man spacecraft" because it has no life support equipment. Life support is provided by the EVA space suit/ backpack, formally known as the Extravehicular Mobility Unit (EMU). Developed by United Technologies' Hamilton Standard division, the EMU supplies oxygen, removes carbon dioxide, controls temperature and provides protection from meteoroids. The MMU latches to the space suit's backpack.

During the tenth Shuttle flight, McCandless and Stewart executed a number of tasks associated with satellite retrieval, repair and servicing. One, for example, was a test of an assembly known as the TPAD, for Trunnion Pin Attachment Device. The TPAD is a docking mechanism that is affixed to the MMU arm rests. It enables an astronaut, strapped into the MMU, to dock with an orbiting satellite and, in effect, become a part of the satellite; the astronaut can then actuate the MMU thrusters to stabilize the satellite before it is grappled by the Orbiter's Remote Manipulator System and deposited in the payload bay for repair or servicing. McCandless and Stewart used the TPAD to practice several connections with a docking pin on a wall of the payload bay, a simulation

Secured by foot restraints to a work platform, McCandless is using the Orbiter's robot arm as a "cherry picker" to reach and work on a satellite mockup in the Orbiter's bay, simulating an orbital repair operation.

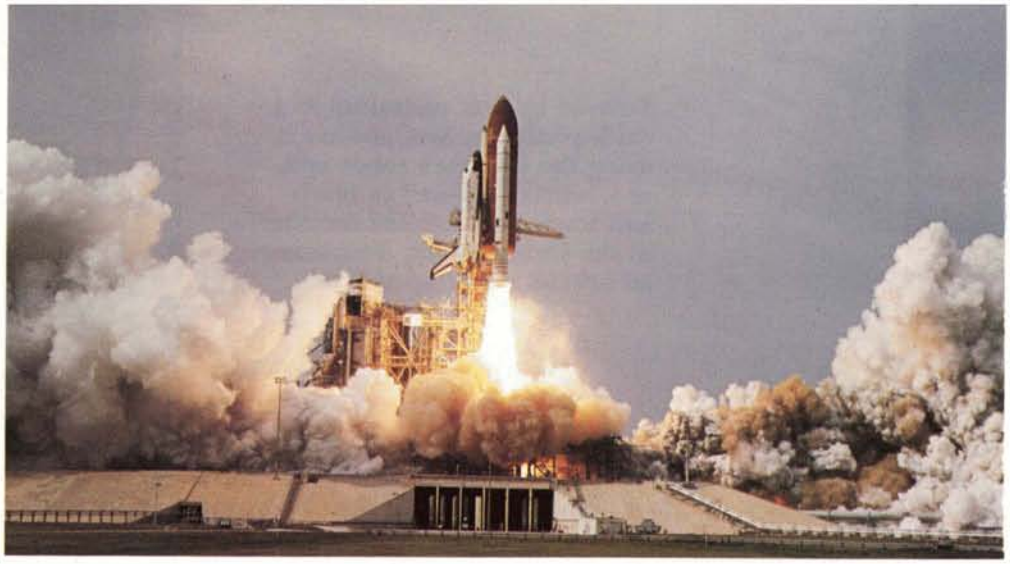


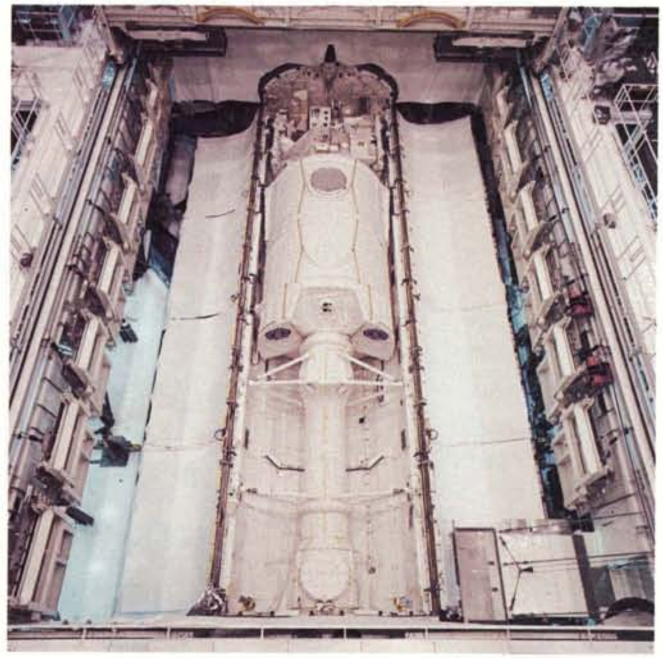
of the docking fixture on a satellite designed for retrievability. Later, the TPAD was used in an actual docking with a satellite, West Germany's SPAS-01 Shuttle Pallet Satellite; the SPAS was not in free flight, but secured in the payload bay.

Flight 10 included a number of other capability demonstrations without the MMU. McCandless performed a checkout of another new device called the Manipulator Foot Restraint (MFR). The MFR is a work platform that attaches to the end of the Remote Manipulator System, the 50-foot-long robot arm developed by the National Research Council of Canada. Foot restraints and a safety tether hold the astronaut in place on the platform, leaving his arms free for work activity. McCandless used the MFR in a simulated repair of a spacecraft's electronics module; the robot arm was operated from the Orbiter's flight deck by the third Mission Specialist, Ronald E. McNair. In another EVA task, Stewart conducted a test of refueling a satellite in orbit; using hand tools, he hooked up a hydrazine fueling line to a fueling port mockup in the payload bay.

There was one other important capability demonstration on Flight 10—the first landing at Kennedy Space Center (KSC) in Florida, where there is less margin for error than at the huge desert landing area of Edwards Air Force Base in California. This was a big step toward the goal of reducing Shuttle turnaround time, because it eliminates the necessity for the Orbiter's transcontinental piggyback trip back to KSC.

Flight 10 was flawed by equipment malfunctions that resulted in improper satellite deployment and forced cancellation of some planned experiments. But the successes outweighed the difficulties and the mission represented a major advance in the growing capability of the Space Transportation System and the people who man it. Among capability expansions planned for the next decade are increasing mission frequencies, improvements in the Shuttle's weightlifting capacity, extension of the Orbiter's stay-time in space, development of new vehicles for moving payloads in orbit, demonstrations of space construction techniques and, eventually, establishment of the manned orbital base that will provide vastly greater operational flexibility. In an on-orbit radio conversation with President Reagan, Bruce McCandless summed up the achievements of Flight 10: "We're literally opening up a new frontier in what man can do in space."





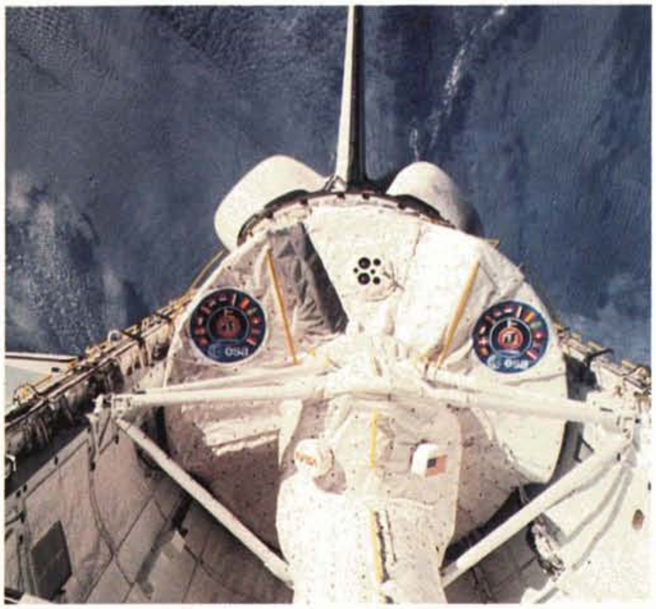
Spacelab 1

On November 28, 1983, NASA launched a milestone mission of the Space Shuttle Program (top photo), the initial flight of the Spacelab orbital laboratory. It was the ninth flight of the Shuttle, the sixth for the Orbiter *Columbia* and it carried the largest crew ever to venture into space aboard a single spacecraft.

At left above is an unusual photograph of the six-man crew posing for a group shot in a circular cluster, an arrangement made possible by their weightlessness. Upside-down in top center is STS-9 Commander John W. Young, who became the first person in the world to make six trips into space. Clockwise from Young are European Space Agency (ESA) Payload Specialist Dr. Ulf Merbold of West Germany's Max Planck Institute; Mission Specialist Dr. Owen K. Garriott; Pilot Brewster H. Shaw, Jr.; Mission Specialist Dr. Robert A. R. Parker; and NASA Payload Specialist Dr. Byron K. Lichtenberg of Massachusetts Institute of Technology. Merbold became the first non-American to fly aboard a U.S. spacecraft. He and Lichtenberg were the first payload specialists, a new category of non-astronaut scientists and engineers who conduct Spacelab experiments but who are not trained to fly the Shuttle or operate its systems.

Spacelab adds a new capability to the Space Transportation System by making possible a broad variety of human-directed experiments in space. The Spacelab system consists of pressurized modules for human habitation and non-pressurized pallets mounted in the Orbiter's payload bay for experiments that require direct exposure to the space environment. These elements can be flown in a number of different combinations, for example, a "short" single-segment pressurized module with up to three pallets; a "long" (two-segment) manned module with one or two pallets; or as many as five pallets without the manned module. The combination for STS-9/Spacelab 1 was a long module with a single pallet.

Shown above is a pre-launch view of Spacelab 1 installed in the bay of the Orbiter *Columbia*. The two segment, 23-foot-long module is in center photo; aft of it (top of photo) is the experiment pallet. In the foreground is an 18.8-foot enclosed passageway called the Spacelab Transfer Tunnel, which connects the

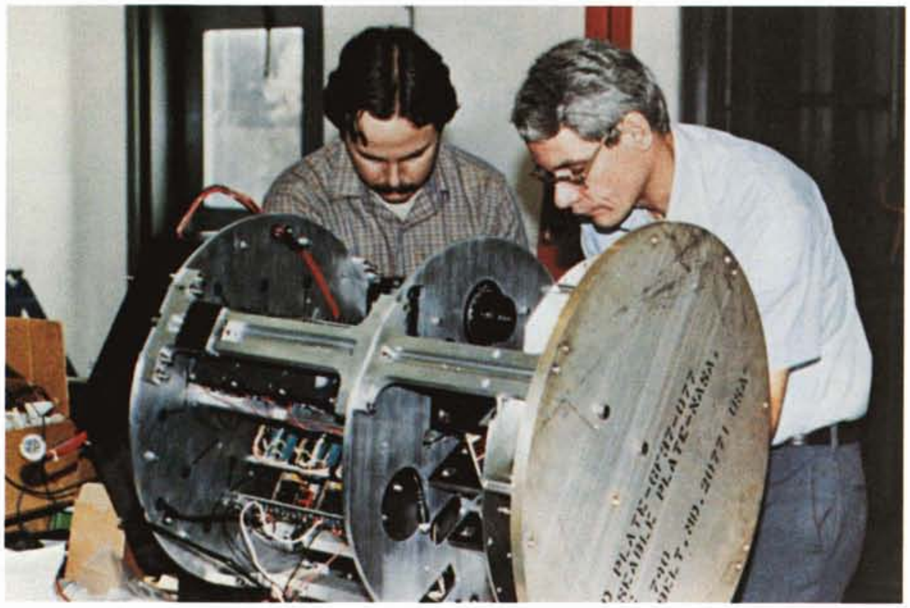


module with the Orbiter's mid-deck. At upper left is an in-flight view of Spacelab, as seen from the Orbiter's flight deck. ESA funded and developed the Spacelab and Marshall Space Flight Center (MSFC) provided U.S. coordination; MSFC also managed development of the tunnel and certain other Spacelab accessories.

The nine-day Spacelab 1 mission was designed to test the laboratory and all its systems and to conduct more than 70 separate investigations in five areas of research: atmospheric physics and Earth observations; astronomy and solar physics; space plasma physics; life sciences; and materials processing in the near-zero gravity environment. It was a joint NASA/ESA mission with each organization sponsoring half of the scientific payload. Experiments were provided and supported by scientists of 11 European nations, the United States, Canada and Japan. MSFC was responsible for the NASA part of the payload and for Spacelab mission coordination; manager for the European portion of the payload was ESA's Spacelab Payload Integration and Coordination in Europe (SPICE) team.

Materials processing experiments; 36 of them, represented the largest category of research activity. On this mission, Spacelab carried a facility known as the Materials Science Double Rack Facility, which includes several furnaces and processing chambers for microgravity studies in such areas as crystal growth, fluid physics, chemistry and metallurgy. The facility is shown at upper right; Ulf Merbold is conducting an experiment in one of the electric furnaces.

The Spacelab 1 team also conducted 16 life sciences experiments, concerned for the most part with the effects of microgravity and radiation on the growth and development of microbial and plant systems. A special group of experiments probed the interaction between man's vestibular system and the brain, for study of the causes of space motion sickness and sensory motor adaptation to weightlessness. An example is shown above where crew members (left to right) Lichtenberg, Merbold, Parker and Garriott appear to be engaged in an orbital card game, using a hatch cover as a table. Actually, they are conducting an "awareness of body position" experiment, in which they view the location of several different "targets" (the cards) then, blindfolded, try to point to and identify a target. The experiment was designed to determine whether the absence of gravity affects one's sense of body position and the ability to locate objects relative to one's body without looking.



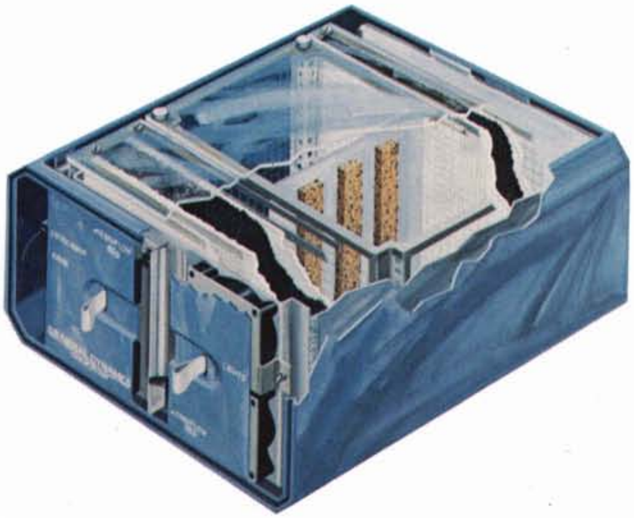
Getaway Specials

Above, engineers of GTE Laboratories, Inc., Waltham, Massachusetts, are preparing a Getaway Special experiment package that was later flown on the 10th Shuttle flight in February of this year. The experiment was study of how the optical and electrical properties of arc discharge lamps change in microgravity when convective effects are eliminated.

Getaway Specials are small, self-contained payloads flown on Shuttle missions when there is leftover space in the Orbiter's bay after primary payloads have been accommodated. This space availability offers low-cost ($3–10,000) opportunities for orbital research projects to experimenters who could not justify or could not afford the expense of a primary payload—industry researchers, research organizations, educational institutions or private individuals. Managed by Goddard Space Flight Center, the Getaway Special Program seeks to stimulate broader interest in space research by the large segment of the scientific community not engaged in development of primary payloads.

Payloads must be of a scientific or industrial research nature. They are exposed to the space environment in the open payload bay, then returned to Earth for analysis. The payloads are housed in NASA-supplied canisters ranging from two and a half to five cubic feet in volume and from 60 to 200 pounds in weight. Shown below is a pre-launch view of Getaway Special packages carried by the Orbiter *Challenger* on the STS-7 mission of June 1983, when a record seven canisters were flown; six are pictured, the seventh was on the opposite side of the payload bay.

The Getaway Special flight program was inaugurated on the fourth Shuttle mission in 1982 with a single payload. Through the 10th Shuttle flight in 1984, 21 payloads had been flown. NASA has several hundred reservations for future flights.



Student Experiments

To stimulate interest in science and engineering among secondary school students, NASA and the National Science Teachers Association jointly sponsor an annual nationwide competition—the Shuttle Student Involvement Project—to select proposals by young scientists for experiments to be flown aboard the Space Shuttle.

Proposals are based primarily on scientific/engineering merit and originality. Each student winner is paired with a corporate sponsor and a NASA scientist or engineer, who work with the student to determine the feasibility of developing the proposal into an actual flight experiment. Where a proposal requires new hardware, corporate sponsors may help develop the equipment. Finalists whose proposals are judged not feasible for flight may be assigned to work as part of a NASA research team on a project in the student's field of interest. In all cases, sponsors and advisors help the student analyze the data and report the results of the experiment in a scientific format.

An example of a winning proposal is an experiment to determine whether weightlessness helps relieve arthritis in laboratory rats. Flown aboard the 10th Shuttle mission in February of this year, the experiment was developed by Daniel J. Weber, then a student at Hunter College High School, New York and now at Cornell University, Ithaca, New York. Three small white rats, injected prior to the flight with arthritis-inducing chemicals, were flown on the Shuttle in the animal enclosure shown at top left; three similarly injected control rats remained on the ground. After the flight, the rats were examined by experienced researchers to compare the arthritic severity of the space rats with those left on Earth. The final report is in preparation. Weber's sponsors were Pfizer, Inc., Groton, Connecticut and General Dynamics Corporation, San Diego, California.

Representative of other winning proposals are two experiments scheduled for Shuttle flight this year. At bottom left, Dan Poskevich, a freshman at Tennessee Tech University, Cookeville, Tennessee, is shown with a bee enclosure module designed to fit in a chamber on the Shuttle Orbiter's mid-deck. The experiment will compare the size, shape, volume and wall thickness of two honeycomb structures, one flown in orbit and the other in a control bee colony on Earth. Poskevich's work is sponsored by Honeywell, Inc., Clearwater, Florida. At bottom right, Shawn P. Murphy of Newbury (Ohio) High School is pictured with the components of his experiment, which is designed to grow a specially-treated gallium crystal in the low-gravity environment of space; the crystal will be compared with one grown in identical fashion on Earth. Murphy's sponsor is Rockwell International, Downey, California.

Shuttle Status

The photo shows the Shuttle Orbiter Discovery on its arrival at Kennedy Space Center (KSC) late last year, where preparations began for its first flight in mid-year 1984. Discovery is the third of the currently authorized fleet of four Orbiters. The fourth—*Atlantis*—is scheduled for delivery to KSC in December and slated for its initial flight in 1985.

Discovery joins the earlier operational Orbiters *Columbia* and *Challenger* in a 1984 flight program that will be the most active in the history of the U.S. manned space flight. Barring schedule changes, NASA will fly nine Shuttle missions this year. The previous record for manned missions in a single year was five; that was accomplished twice—in 1965 and 1966—during the Gemini program.

The 1984 record will be short-lived, because Shuttle mission frequencies will increase sharply in coming years. NASA plans 12 Shuttle flights in 1985 and 16 in 1986. It is estimated that the flight rate will build up to 24 a year by 1988 and in later years to 30–40 flights annually. Beginning in 1986, Shuttle missions will be flown from Vandenberg Air Force Base, California as well as from KSC.

The primary users of the Shuttle system will be NASA and the Department of Defense. Among other major users are the National Oceanic and Atmospheric Administration, the European Space Agency, a number of foreign nations, the operators of commercial satellite systems and industrial sponsors of materials processing experiments. Throughout this decade, the principal activity will be delivery to orbit of commercial and scientific satellites, but the Shuttle will also be increasingly involved in Spacelab flights and on-orbit repair and servicing operations. In the early part of the next decade, the Shuttle will serve as both component delivery vehicle and construction base for assembly of the manned space station. Once the station becomes operational, the Shuttle will be its resupply and crew rotation transport link with Earth.

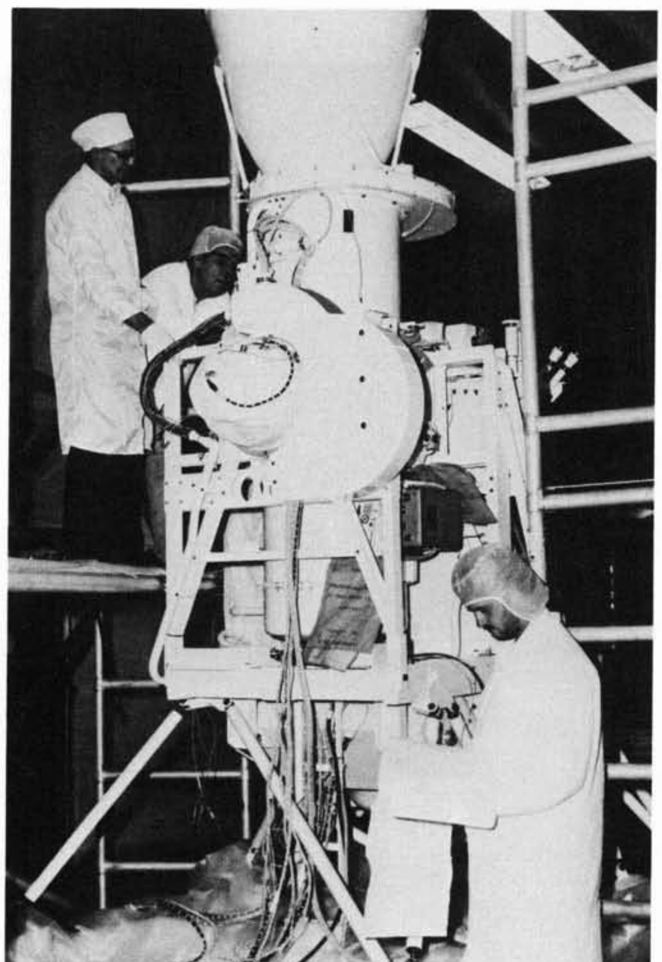
The Next Spacelabs

To be launched late in 1984, the second Spacelab mission will emphasize research in low-gravity materials processing and environmental observations; additionally, it will include investigations in life sciences, astrophysics and technology research. The mission is designated Spacelab 3 although it precedes Spacelab 2; it is NASA practice to retain the original mission designations when circumstances dictate schedule changes. Spacelab 3 will include 15 investigations—12 from the U.S., two from France and one from India—conducted by two payload specialists. Other members of the six-man crew are the commander, pilot and two mission specialists.

For this mission, the laboratory's configuration will be slightly different from that of Spacelab 1, which had a two-segment "long" pressurized module and one instrument pallet. Spacelab 3 will have the long module but a special experiment support structure will replace the instrument pallet. Located aft of the long module in the Orbiter's cargo bay, this structure will house two instrument systems known as ATMOS and IONS. ATMOS is designed to obtain fundamental information related to the chemistry and physics of Earth's upper atmosphere, in particular identification of minor constituents of the atmosphere. The IONS experiment is concerned with direct measurement of the ionization states of heavy nuclei in cosmic rays emanating from the Sun and from galactic space. Ten experiments, three of them involving materials processing research, will be located in the pressurized module. There will also be two life sciences experiments designed to assess certain aspects of weightlessness in animals and humans; one of them, developed by Ames Research Center, will be in the long module, the other, supplied by Johnson Space Center, will be mounted on the Orbiter's mid-deck. Marshall Space Flight Center (MSFC) has management responsibility for Spacelab 3.

Also managed by MSFC and targeted for launch in March 1985, the Spacelab 2 mission will be devoted primarily to astrophysics and solar astronomy. It will be the first Spacelab configuration without the manned module. Equipment in the Orbiter's cargo bay will include three instrument pallets, a special structure supporting a cosmic ray detection experiment, an "igloo," a pressurized container housing the electronics for all Spacelab 2 subsystems and the experiments in the cargo bay, and an Instrument Pointing System developed by the European Space Agency. Ten of the 15 experiments will use equipment in the cargo bay, operated by the mission crew from the Orbiter's aft flight deck, where controls and displays are located. Two life science experiments will be stored in mid-deck lockers and the remaining experiment will rely on ground observations.

One of the major investigations will employ the helium-cooled Infrared Telescope (IRT) shown in the accompanying photo during final assembly at MSFC. A joint project of the Smithsonian Astrophysical Observatory, the University of Arizona and MSFC, the telescope will pick up the work begun by last year's highly successful Infrared Astronomical Satellite (see page 22). The objective of the IRT experiment is to map extended sources of low surface brightness, infrared emissions in and beyond the Milky Way galaxy that cannot be detected by conventional optical telescopes in orbit or based on Earth. Spacelab 2 will also include an x-ray imaging telescope for observing clusters of galaxies and four solar telescopes, the latter mounted on the Instrument Pointing System. They will study small-scale structures on the Sun's surface and measure the abundance of helium in the Sun's corona.



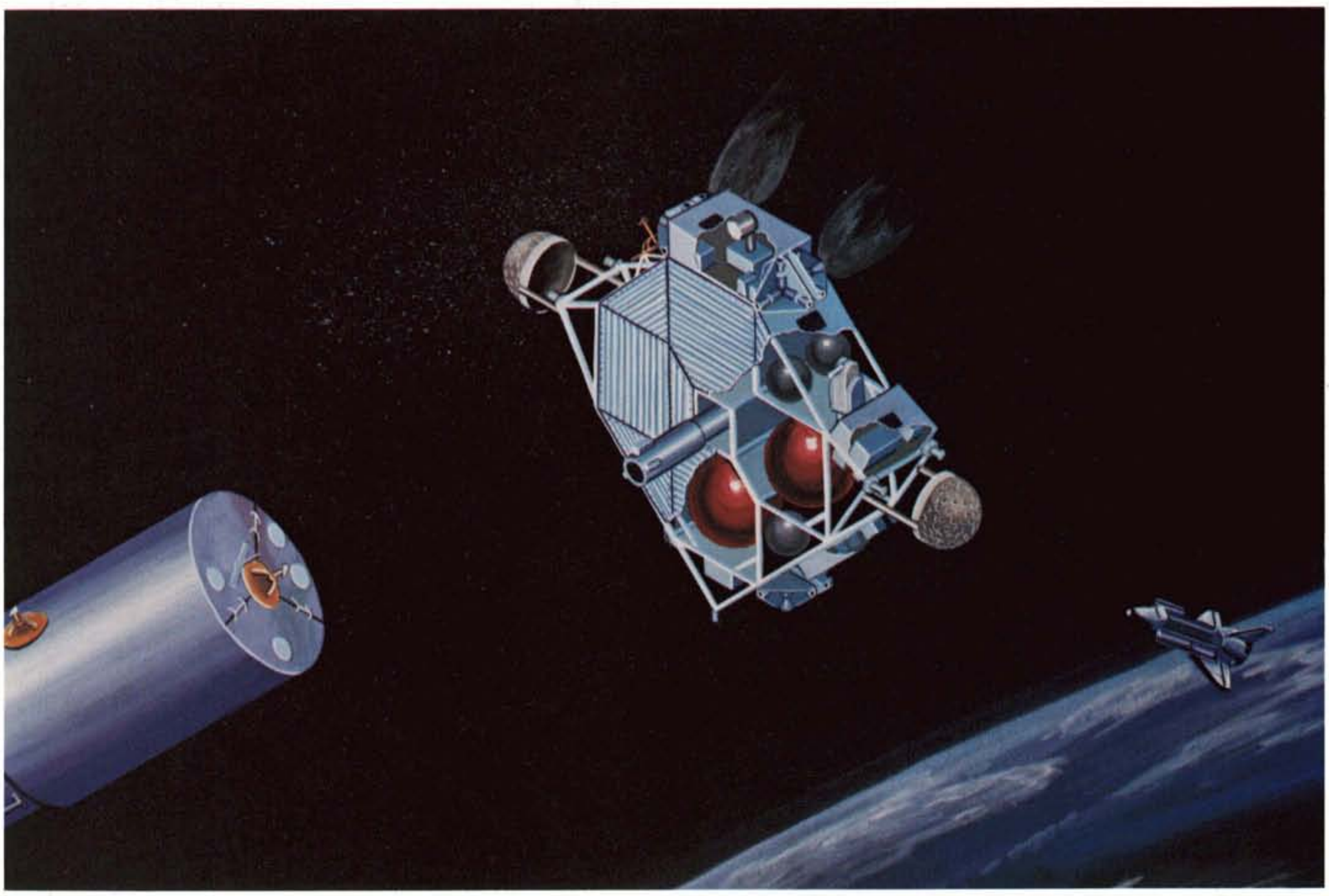
Orbital Maneuvering Vehicle

The accompanying illustration is an artist's concept of a versatile unmanned spacecraft known as the Orbital Maneuvering Vehicle (OMV). Still in the conceptual stage, the OMV would be a "smart space tug" capable of moving satellites and other objects in space from one orbit to another. It would be used in conjunction with the Space Shuttle and the planned manned space station, its operation human-controlled—with the help of television and other sensors—from an Earth station, the Shuttle Orbiter or the space station.

As a supplementary vehicle of the Space Transportation System, the OMV would extend the Shuttle Orbiter's altitude capability. The Shuttle is limited by its design to altitudes below 700 miles, but in practical use it operates at altitudes in the 150–300 mile range. The OMV, with an altitude capability approximately twice that of the Shuttle, would be able to deliver payloads several hundred miles beyond the Shuttle's reach. It would also retrieve satellites from orbits not attainable by the Shuttle and maneuver them to a rendezvous with the Orbiter for repair and servicing. Additionally, it would serve as a means of extending the useful lives of satellites whose orbits were decaying, by reboosting them to stable orbits; this would obviate the far more extensive use of the Shuttle for such missions.

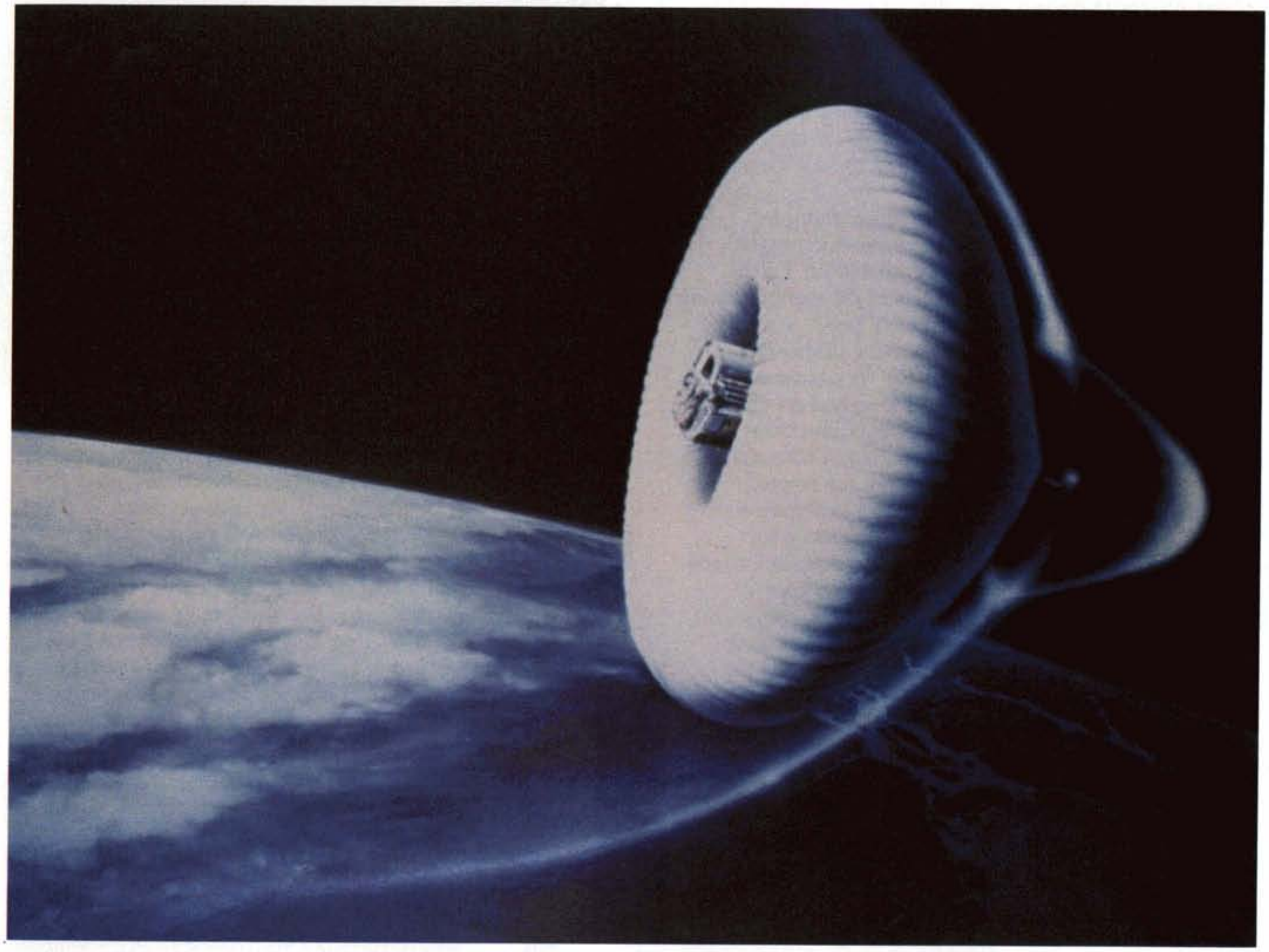
The OMV would play a key role in assembly of the manned space station, maneuvering into position the various modules and segments of the station brought to orbit by the Shuttle. Later, it would become a space station-based work vehicle for such operations as satellite deployment and retrieval, positioning Shuttle-delivered resupply modules, adding new modules to the space station, safely deorbiting satellites no longer useful and collecting space debris.

In its initial concept, developed by Marshall Space Flight Center, the OMV is essentially a propulsion unit—15 feet in diameter and three feet long—incorporating remotely-operated guidance equipment and provisions for docking with other spacecraft. Marshall is selecting contractors to conduct OMV definition studies to be completed next year. One of the companies involved in the definition studies will be chosen to build the vehicle if it is approved for hardware development. Target for its initial use with the Space Shuttle is 1990.



Orbital Transfer Vehicle

Some types of spacecraft—commercial communications satellites, for example—are designed to operate 22,300 miles high in geosynchronous orbit (GEO), where they are figuratively stationary with respect to a point on Earth. Sending spacecraft to GEO, or into interplanetary trajectory, is currently a two-phase operation in which



the payload is deployed from the Shuttle Orbiter in low Earth orbit (LEO), then boosted to higher altitude by unmanned upper stage propulsion units. Existing upper stages, however, are not reusable, nor can they retrieve satellites from GEO.

Looking to the future, NASA is studying an advanced upper stage known as the Orbital Transfer Vehicle (OTV), a reusable system that would be permanently based at the planned space station. The OTV would add a new dimension of space capability by retrieving satellites from GEO and returning them to the space station for repair or servicing, or to the Shuttle Orbiter for return to Earth and refurbishment. In later years, the OTV could become a manned vehicle, allowing on-orbit servicing in GEO.

A major consideration in designing such a spacecraft is that an OTV returning from GEO to LEO must have provisions for decelerating, in order to slow it to the requisite velocity for low orbit. That could be accomplished by retrofiring the OTV's rocket engine, but only with great fuel expenditure and, therefore, sharp limitation of the system's payload handling capability. NASA currently favors an alternative "aeroassisted braking" concept developed by Marshall Space Flight Center. Depicted in the accompanying illustration, this concept involves incorporation of an inflatable device that would decelerate the OTV by using the atmosphere as a brake. En route from GEO to LEO, the OTV would deploy the balloon-like system as it dipped into Earth's upper atmosphere; the resulting drag would slow the craft sufficiently for return to LEO. Under contract with Marshall, Boeing Aerospace Company and General Electric Reentry Systems are conducting studies of this type of OTV.

Space Station

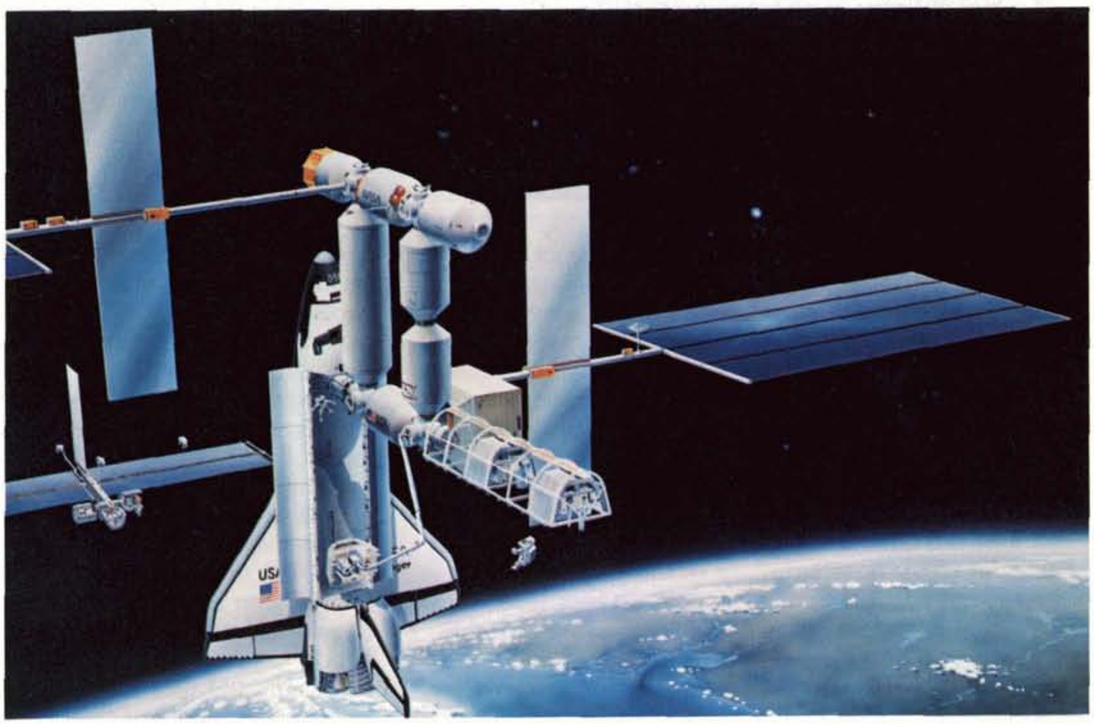
In his January 1984 "State of the Union" address, President Reagan directed NASA to develop a permanently-manned space station, a facility in low Earth orbit that will serve as a base for scientific, technological and commercial advances. The President called for government/industry partnership in development and utilization of the space station, he invited America's friends and allies to participate in the program, and he stated the goal of station occupancy "within a decade."

With the Space Shuttle in operational status, the space station is the next logical step in expanding the U.S. space capability. Its development will assure continued U.S. space leadership in the decade of the 1990s and beyond.

The space station is intended to serve multiple functions. It will enable commercial production, in quantity, of critical materials not available on Earth, where gravity exerts adverse influences on manufacturing processes—materials such as extremely pure pharmaceuticals for improved treatment of disease; ultra-pure semiconductor crystals for very advanced computers and other electronic devices; and metallic superalloys much lighter yet far stronger and more temperature-resistant than existing alloys. The station will also serve as a scientific laboratory for research in such fields as astrophysics, solar system exploration, Earth science and life sciences; as a laboratory for developing technology in such areas as communications and Earth applications; and as a facility for further research in materials processing. It will be a permanent base for tending, servicing and repairing unmanned platforms and satellites, extending the useful lives of these expensive space assets, offering the flexibility to upgrade systems as technology advances. It will provide

a new level of efficiency for operations in space because servicing equipment will be station-based and need not be brought up by the Shuttle for each servicing mission.

Additionally, the space station will permit on-orbit assembly of structures larger than the Orbiter's payload bay, future structures such as large antennas, telescopes and experiment platforms. For the longer term, the space station will offer a staging area for contemplated 21st century missions, such as a permanent lunar base, an unmanned sample-return mission to Mars or a manned mission to Mars, a manned survey of the asteroids, a



human-habitable facility in geosynchronous orbit, or a large complex of scientific/industrial facilities in low Earth orbit.

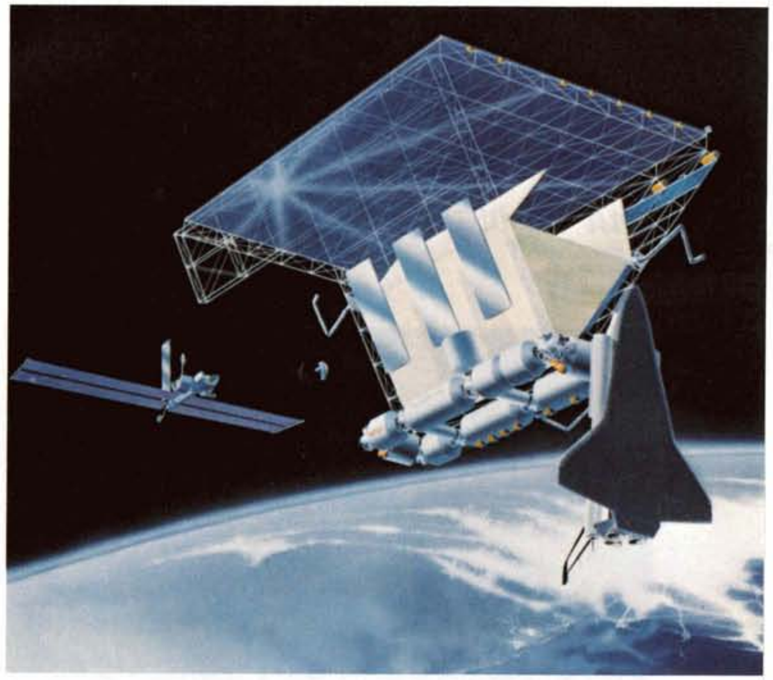
The space station's configuration has not yet been defined; that will happen during a two-year definition effort intended to minimize risk and maximize station capabilities. However, NASA has conducted, over the past two years, a preliminary planning program that included a variety of studies of the functions to be performed at the space station and of the general architecture that may accommodate those functions.

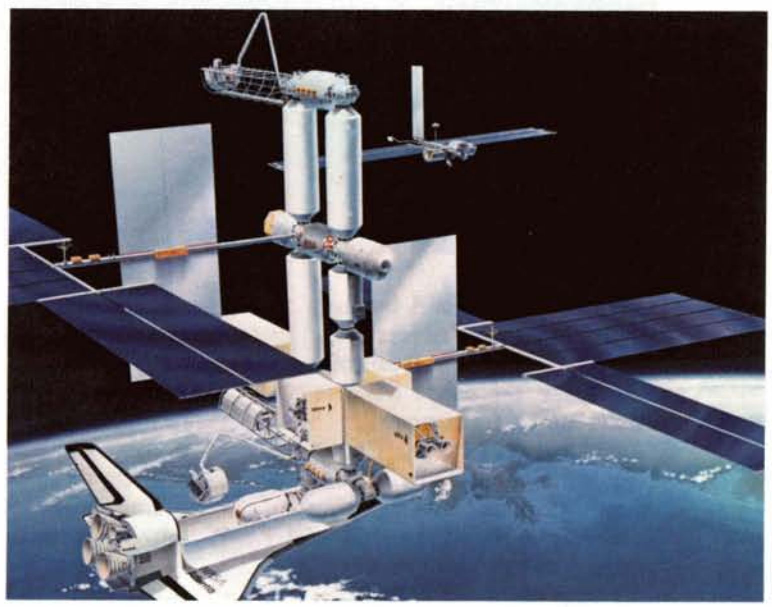
The accompanying illustrations show four reference configurations based on those studies. The artwork at left shows a group of pressurized modules and a port for Shuttle docking which, of course, will be a feature of any configuration selected; the rectangular blue structure adjacent to the modules is a radiator for dissipating excess heat and the robot arm projecting above the radiator is for use in on-orbit assembly work. At lower left, the open rack-like structure in center foreground is a place for mounting experiments that require direct exposure to the space environment; in this illustration, the Shuttle Orbiter's Remote Manipulator System is delivering a new experiment pallet. The concept at right shows several habitable, logistics and utility modules mounted on a triangular open framework that affords a large surface area for solar cell panels or experiment pallets. The bottom illustration depicts a later growth version of the initial station which, designed in modular fashion, can be expanded to increase station capability by Shuttle delivery of add-on modules. This concept has two solar arrays arranged in "split-level" fashion, two large radiators, multiple habitable/logistics/utility modules, two structures for placement of experiment pallets, and hangars (center foreground) for Orbital Maneuvering Vehicles and Orbital Transfer Vehicles.

All four illustrations show an unmanned free-flying co-orbiting platform as part of the space station. NASA's experience shows that manned and unmanned modes of flight each have certain advantages. Both will be utilized in space station design and operation; the challenge for NASA will be to find the proper mix of men and machines.

The current concept of the initial space station contemplates two unmanned platforms. One of them, carrying instruments and experiments for scientific, technological and product research, will operate in the same orbit as the main base, but some distance removed from it to avoid disturbance or contamination from main station activities; the second platform will operate in a different orbit. The co-orbiting platform can be visited by astronauts equipped with maneuvering units for routine inspection and maintenance; for payload changeout, the platform can be retrieved by an Orbital Maneuvering Vehicle and brought to the main base.

The central station will have a large solar power system generating 75 kilowatts and each of the platforms will have solar arrays providing 25 to 35 kilowatts. The manned base will have four or more pressurized modules wherein a crew of six to eight will live and work, plus the docking hub for the Shuttle Orbiter and a utilities system supplying electrical power, thermal control, attitude control and data processing facilities. The Space Shuttle will be the station's link to Earth, resupplying it and rotating crews at intervals of three to six months.





Exploring the Universe

Study of the solar system and the distant galaxies is producing a wealth of knowledge about Earth and its place in the universe.

Operated for NASA by the Association of Universities for Research in Astronomy, the Space Telescope Science Institute in Baltimore, Maryland will be the Earth link with the Edwin P. Hubble Space Telescope, an orbiting observatory that will expand man's view of the universe some 350 times.

Perched on a hillside at the Homewood campus of Johns Hopkins University in Baltimore, Maryland is a new NASA facility, one that may in future years become the Mecca of astronomical science, the focal point of man's dramatically expanding quest for knowledge of the universe.

Known as the Space Telescope Science Institute, it is operated for NASA by the 17-member Association of Universities for Research in Astronomy. It will be the center for collection and distribution of data from NASA's Edwin P. Hubble Space Telescope, named for the American scientist whose discoveries and theories of the 1920s revolutionized the study of astronomy. To be Shuttle-launched in 1986, this orbital observatory will operate at least until the end of the century, periodically serviced by Space Shuttle crews.

The Space Telescope is potentially the most dramatic advance in astronomy since the invention of the telescope in 1610, because it will expand man's view of the universe some 350 times. Even the most powerful ground-based telescopes in use today can "see" only a small portion of the cosmos; a major limiting factor is Earth's veil of atmosphere, which filters out most of the light and other radiations coming from deep space. Free of such distorting effects because it will operate *above* the atmosphere at 370 miles altitude, the Space Telescope will be able to peer seven times farther into space than the largest Earth telescopes, to pick up objects 50 times fainter and to return images with at least 10 times better clarity.

Because light from distant galaxies takes so long to reach us, the Space Telescope will literally allow scientists to look back into time—back as far as 14 billion years ago. Estimates as to the age of the universe range from 12 to 20 billion years; thus, when observing the most distant celestial objects, the Space Telescope will capture light that began its cosmic journey when the universe was in its infancy. This extraordinary capability should provide immensely important clues to the origin and history of the universe.

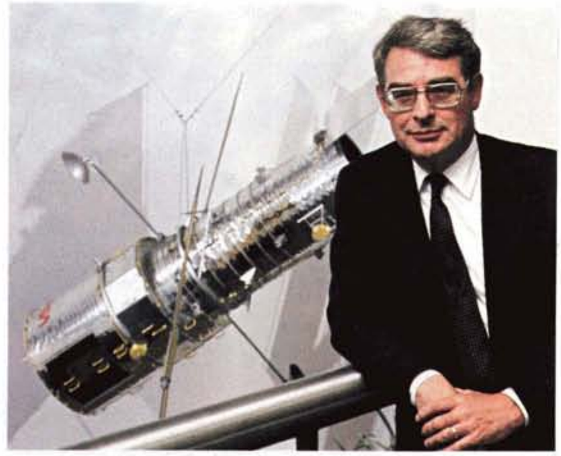
By far the largest astronomical system ever sent into orbit, the 12 ton, 43-foot Space Telescope is being developed—under Marshall Space Flight Center management—by Perkin-Elmer Corporation, Danbury, Connecticut and Lockheed Missiles & Space Company, Sunnyvale, California. Perkin-Elmer is producing the Optical Telescope Assembly, heart of the system, and Lockheed is building the Support Systems Module, which houses the optics and the associated scientific instruments and also provides electrical power, communications and data management. The European Space Agency will furnish one of the five major instruments and the electricity generating solar array.

The Space Telescope is similar in principle to some of the larger Earth telescopes, which literally "do it with mirrors." Starlight entering the open end of the observatory is reflected from a large primary mirror to a smaller secondary mirror, magnified and sharply focused, then directed to an instrument section. There the images the telescope acquires are photographed and analyzed. Major instruments include two cameras, one a wide field system, the other a Faint Object Camera to photograph stars so dim it will take hours of exposure to produce an image. There are also two spectrographs for analyzing the characteristics of the radiations received and a high-speed photometer for precise measurement of the radiation's intensity. Analysis of the visible light and other radiations provides information on the chemical and physical composition of the objects viewed.

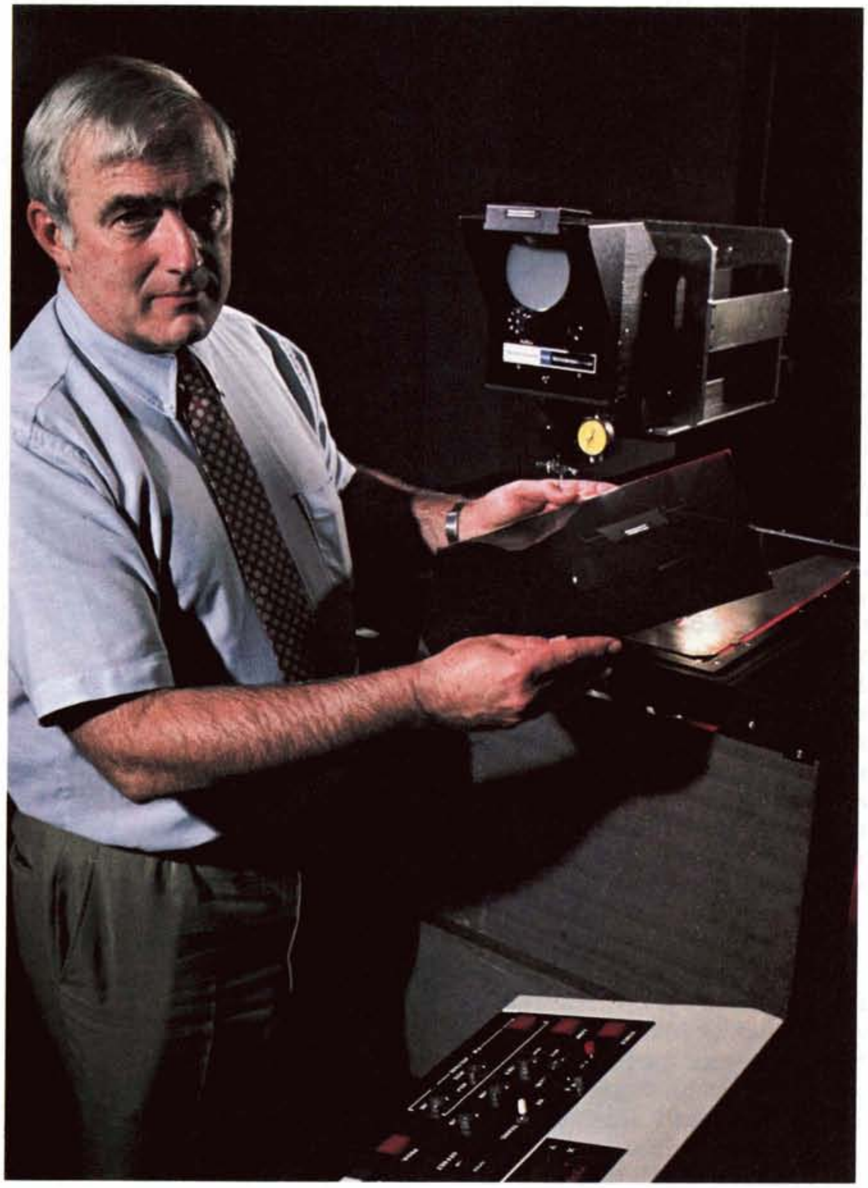
When the system goes into operation, images and instrument data will be relayed—via communications satellite—to Goddard Space Flight Center, Greenbelt, Maryland, which will have responsibility for controlling the telescope, processing the data it returns and forwarding it over land lines to the Space Telescope Science Institute 30 miles away. At a series of consoles in the observation room of the Institute, astronomers will view the images sent by the telescope and get visual and printed readouts of the data flowing from the observatory's instrument module.

Opened last year, the Institute now has about 135 people engaged in a number of preliminary activities that will occupy them right up to the Space Telescope's launch time in 1986. By then, the number will increase to about 200, including some 35 scientists. This latter group will serve as "hosts" to the visiting U.S. and foreign astronomers selected to conduct research programs after a lengthy process of reviewing astronomers' proposals, their scientific importance and their technical feasibility. The host scientists will instruct the visiting astronomers in the use of the Space Telescope and assist them in analyzing the data it provides.

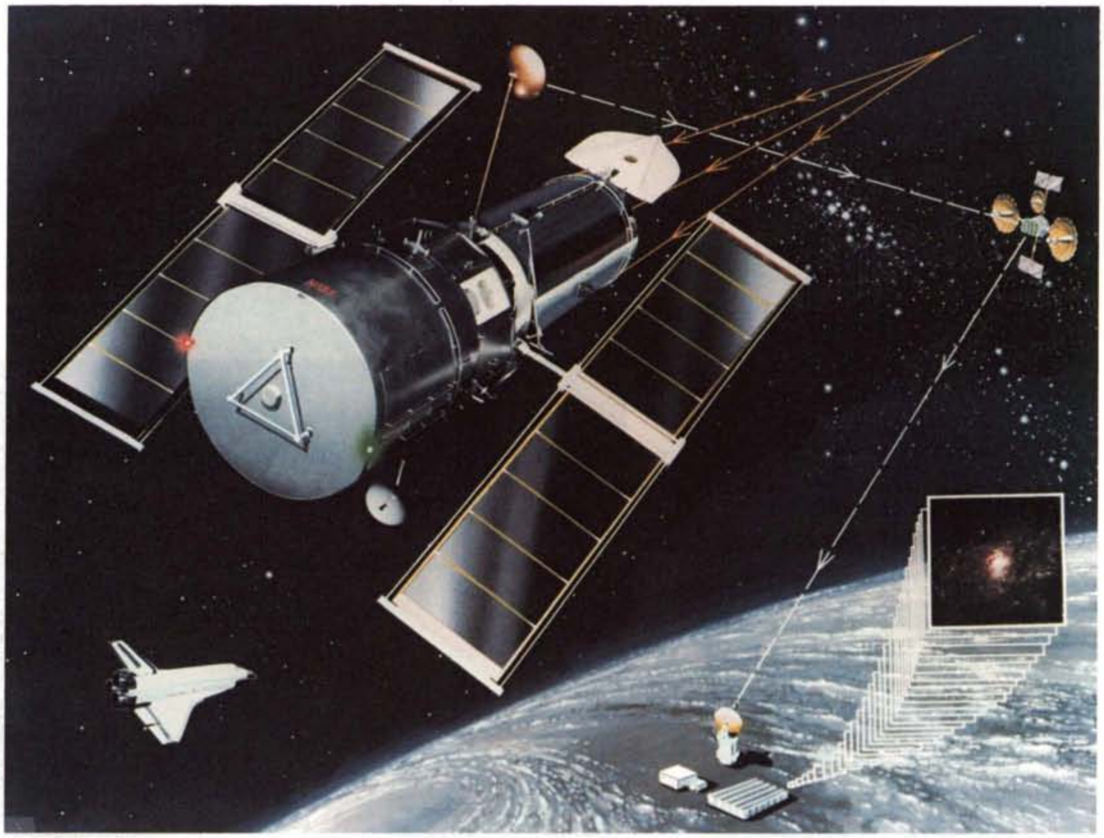
The Space Telescope project exemplifies one aspect of NASA's four-pronged space science program: astrophysics, or the study of distant stars and galaxies. The other areas of activity include solar system exploration, or investigation of the planets, moons, comets, asteroids, and other phenomena within our solar system; solar terrestrial research, which encompasses study of the Sun's energy processes and their interactions with Earth's environment; and life sciences research, aimed at understanding the origin and distribution of life in the universe and at utilizing the space medium to improve knowledge in medicine and biology. The essential goal of this comprehensive effort is fitting Earth into the cosmic picture—the origin, evolution and structure of the universe—and thus learning more about our planet and the complex forces that govern it.



Dr. Riccardo Giacconi, director of the Space Telescope Science Institute, with a model of the Hubble Space Telescope that will begin service in 1986.



Two more years will elapse before the Space Telescope goes into service, but the staff of the Space Telescope Science Institute will need every minute of it for the extensive preparations required. The principal preliminary is cataloging some 20 million stars that will serve as "guide stars," reference points in the sky for aiming the telescope in the desired direction. For this monumental survey, the Institute is being assisted by astronomers at Palomar Observatory in California and Sidings Springs Observatory in Australia. Using ground telescopes and imaging equipment, they photograph segments of the northern (Palomar) and southern (Sidings Springs) skies and record the images on 14-inch square plates; above left, senior engineering physicist Jim Kinsey is examining one such plate. Each of about 1,700 plates is electronically scanned by a computerized microdensitometer, above right, which measures the intensity of light from each star on the plate and stores the information. This catalog will serve as the basis for selecting guide stars for particular observations; appropriate guide stars are those of medium intensity—neither too bright nor too dim—best located with respect to the celestial target.

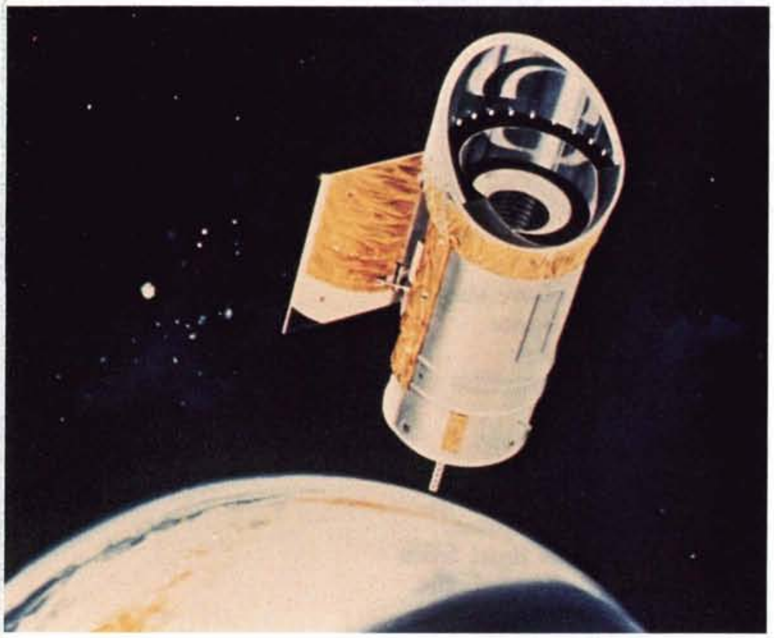


The illustration above shows how the Hubble Space Telescope will gather astronomical information and relay it to Earth for processing and analysis. Pointed with exquisite accuracy at a celestial body, the telescope will acquire, magnify and focus light from the star and photograph the resulting image. Images and instrument data will be converted to electronic signals, sent to one of NASA's Tracking and Data Relay Satellites, thence to Goddard Space Flight Center, Greenbelt, Maryland for computer processing. Over land lines, Goddard will forward the processed data and reconstructed images to the Space Telescope Science Institute in Baltimore, 30 miles away. There astronomers will view the images (left) and get visual and printed readouts of the data sent by the orbiting observatory.

Infrared Observatory

Stars being born, or stars in their death throes, do not "shine" in visible light because shine requires temperature upwards of 5,000 degrees Fahrenheit, generated by nuclear activity. In the very young star, nuclear ignition has not yet occurred; in the dying star, nuclear activity has all but ceased. Thus, these and other non-luminous, low temperature celestial bodies cannot be seen by optical telescopes on Earth or in orbit.

Such cool and cold objects do, however, emit some heat in the form of infrared radiation; therefore, they can be detected by an orbiting telescope capable of sensing infrared emissions, a basis for creating images of otherwise invisible bodies in space. Such a system, the Infrared Astronomical Satellite (IRAS) was launched in January 1983 and operated for 10 months. Shown



above, IRAS made enormous contributions to astronomical science in its brief period of existence. Its array of 62 infrared sensors detected never-before-seen infant stars and moribund stars, found five new comets and a mysterious dark object near our solar system, perhaps a part of it, and discovered distant galaxies not earlier mapped.

Perhaps IRAS' most dramatic finding was last summer's discovery of particles orbiting the star Vega and extending about 7.4 billion miles from the star. Although superbright Vega, 60 times as luminous as the Sun, is one of the most studied stars in the sky, the orbiting material had never been seen; IRAS' discovery was the first evidence that solid bodies exist within the gravitational field of a star other than the Sun. Scientists think that the objects may be similar to the particles and meteoroids that abound in our solar system. Since Vega is an adolescent star, less than a billion years old—compared with our Sun's 4.6 billion years—it is possible that this orbiting material may someday coalesce into planetary bodies to create a solar system like our own.

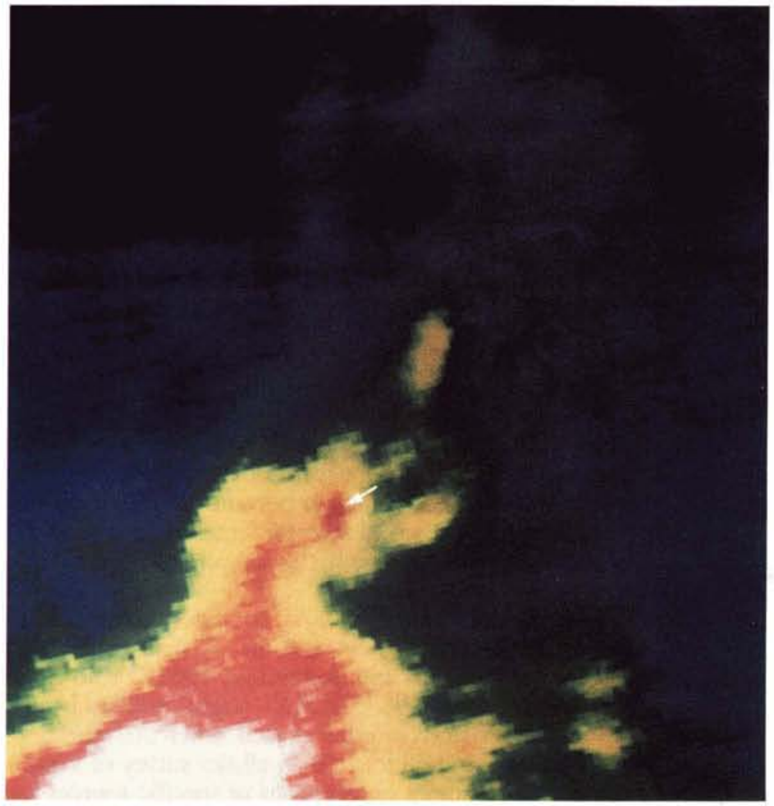
The Vega observation underscores the exceptional utility of the IRAS system. Operating in one of the least explored regions of the spectrum, it gave scientists an instrument for charting the universe in an entirely different and immensely important perspective.

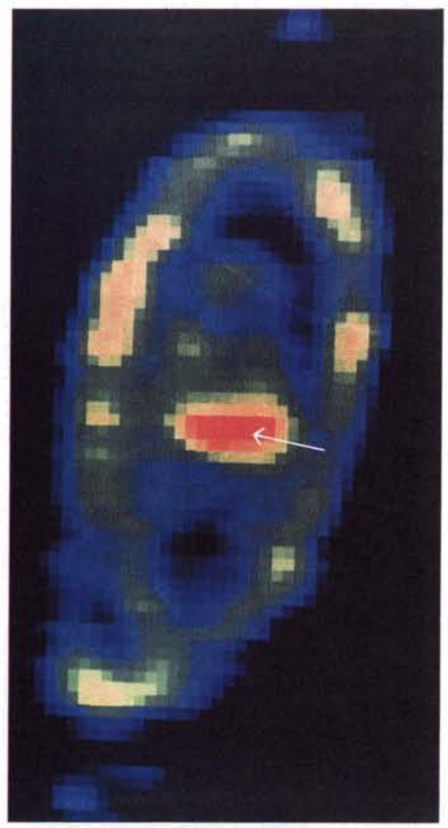
The accompanying photos illustrate what IRAS "saw" in comparison with an Earth telescope. At left is a view of the Andromeda Galaxy—a neighbor of our Milky Way only two million light years distant—as seen by the 200-inch optical telescope at Palomar Observatory in California. At right is IRAS' view of Andromeda, computer-colored to delineate the intensities of infrared radiation sensed: blue is very faint radiation, while green, yellow, orange and red indicate progressively more intense infrared emissions. The yellow, orange and red areas, not defined at all in the Earth view, identify regions where young stars are probably forming.

An isolated view of a newborn star is shown at bottom right as a red spot (arrow) within a huge gas and dust cloud that is part of the Milky Way. Named B5-IRS 1, the infant star is no more than 100,000 years old and its energy output suggests that it is a low mass star like our Sun; in fact, it is probably much like the Sun was four and a half billion years ago.

B5-IRS 1 is one of thousands of infrared objects detected by IRAS. The telescope mapped about 100,000 infrared sources for future study; its findings may answer many fundamental questions about energy radiations from distant galaxies. IRAS was a three-nation project in which the U.S. (NASA) provided the telescope and launch services, the Netherlands the spacecraft and the United Kingdom the control center. Development of the 24-inch telescope was managed by Ames Research Center; Ball Aerospace Systems built the instrument. Jet Propulsion Laboratory is overall manager for the U.S. portion of the project.

IRAS' sensors were cooled by superfluid helium to a few degrees above absolute zero (theoretically the lowest temperature possible) in order to detect cool and cold objects in space. The supply of helium was thus a limiting factor that made IRAS a short-life satellite. However, NASA intends to continue infrared astronomy—next year with a small helium-cooled Infrared Telescope and later with an advanced observatory called the Shuttle Infrared Telescope Facility (SIRTF). Supercooled like IRAS, but with even more sensitive instruments, SIRTF will study the very cold regions of galactic space and investigate low temperature objects within our solar system, such as planets, moons and asteroids; it will also conduct detailed spectrographic analyses of the infrared sources discovered by IRAS.





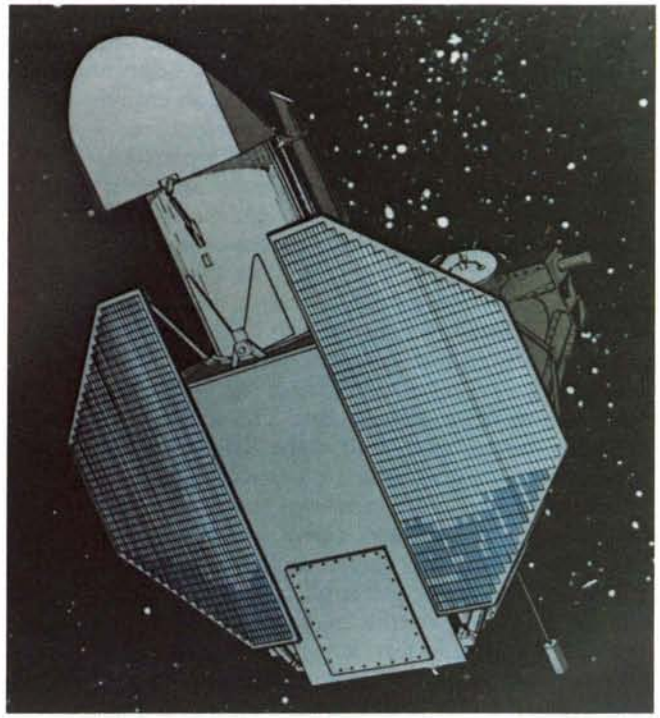
X-ray Astronomy

Confirmed only 22 years ago, the existence of x-ray sources in space prompted NASA development of a series of satellites to explore these non-luminous radiations, which—like ultraviolet, infrared and gamma radiations—are absorbed or filtered by Earth's atmosphere, hence are largely invisible to ground observatories.

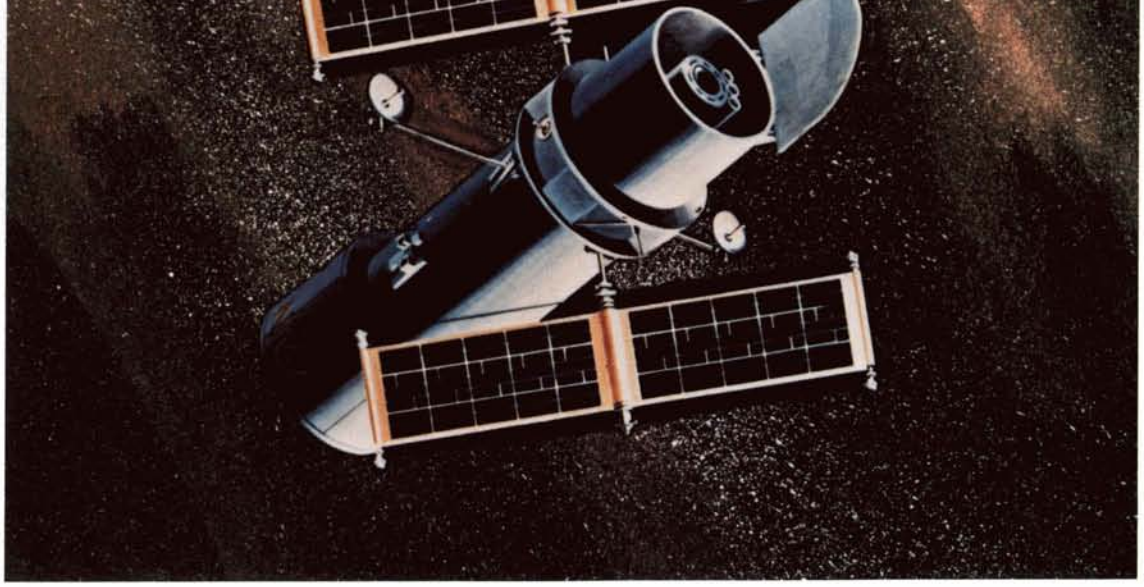
The work of such NASA satellites as Uhuru (1970) and HEAO-2 (1978), the second High Energy Astronomical Observatory, provided a base of knowledge about x-ray emissions from a wide variety of objects, including stars, pulsars and galaxies. This radiation represents the predominant form of energy released by these objects and thus offers important clues to their nature. Heightened world scientific interest in cosmic x-rays led to plans for two highly advanced x-ray observatories.

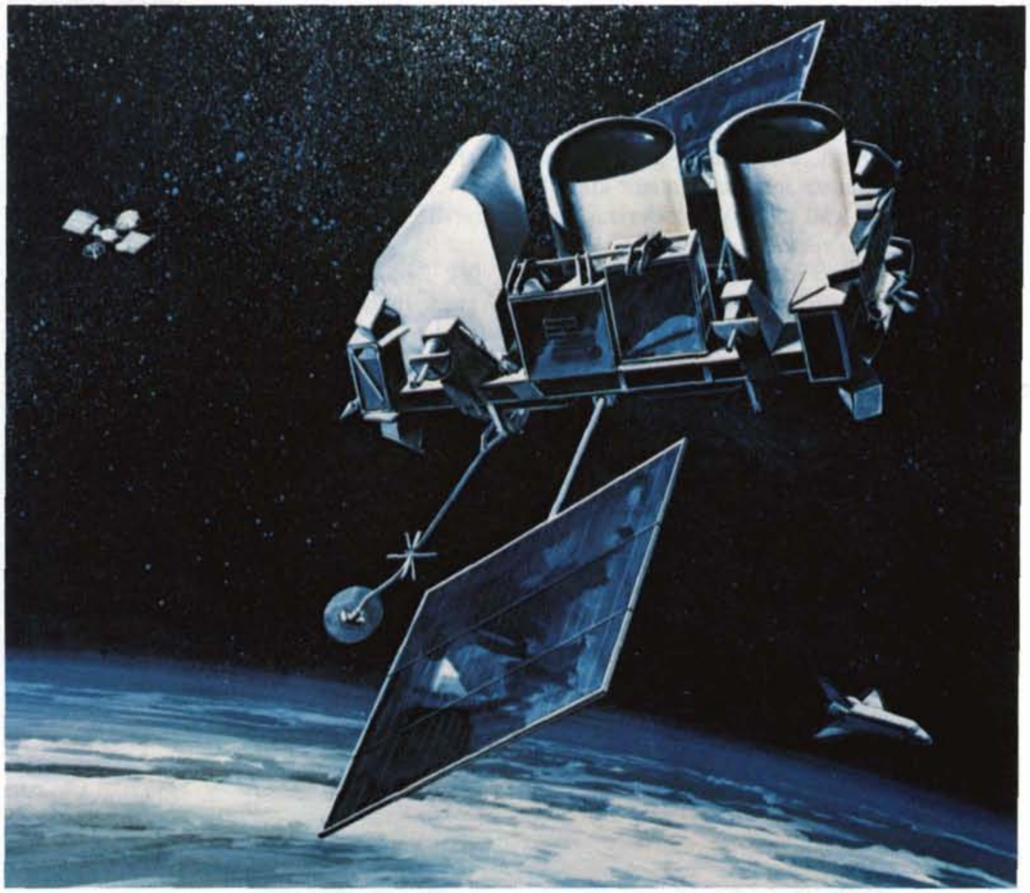
The first is designated ROSAT, for Roentgensatellit, a joint development of NASA and the German Federal Ministry for Research and Technology (BMFT). To be Shuttle-launched in 1987, ROSAT (right) will study x-ray emissions from celestial objects other than the Sun. The mission will include an all-sky survey of x-ray sources and dedicated observations of specific sources for extended periods of time. It will allow astronomers to investigate in greater detail many of the phenomena discovered by HEAO-2, including the scientifically intriguing question of why some stars apparently nearly identical to our Sun have surprisingly higher x-ray luminosity levels.

NASA will provide a high-resolution imaging system for ROSAT, along with launch services; BMFT will build the spacecraft and the x-ray telescope. Goddard Space Flight Center is NASA's program manager; the German Aerospace Research Establishment is managing the BMFT portion of the program.



NASA contemplates an even more advanced x-ray observatory for the 1990s. Managed by Marshall Space Flight Center, the planned Advanced x-ray Astrophysics Facility (AXAF) shown below will be a 10-ton, 43-foot spacecraft with instruments about 100 times more sensitive than those of HEAO-2. Intended to operate for at least 15 years by means of on-orbit servicing by the Space Shuttle, AXAF will study x-ray emissions from virtually all known astronomical objects, ranging from nearby stars to quasars at the edge of the universe.





Orbiting Observatories

In addition to X-ray astronomy (see opposite page) and infrared observations (page 22), NASA is investigating other types of non-visible radiations from space, because each area of the electromagnetic spectrum offers a different set of clues to the origin and evolution of the universe.

Development started this year on a spacecraft called EUVE (above), for Extreme Ultraviolet Explorer. Extreme ultraviolet refers to a certain wavelength range within the ultraviolet region of the spectrum, a range that has never had an astronomical survey. Objects in this range are generally stars at highly advanced stages of their evolution. EUVE will make an all-sky survey of the extreme ultraviolet range. Observation of a large number of mature stars—complementing studies by other spacecraft of young and dying stars—is expected to provide better understanding of star evolution. Planned for launch in 1987, EUVE is managed by Jet Propulsion Laboratory.

Another major astrophysics project is the Cosmic Background Explorer (COBE) planned for 1988 launch. Being developed by Goddard Space Flight Center, COBE will be the first satellite designed specifically to observe details of the "Big Bang," the monumental explosion believed to have marked the beginning of the universe. It will survey cosmic background radiation at many different wavelengths; believed to be a remnant of the Big Bang, this background radiation offers clues to the nature of the great explosion and the formation of the first galaxies.

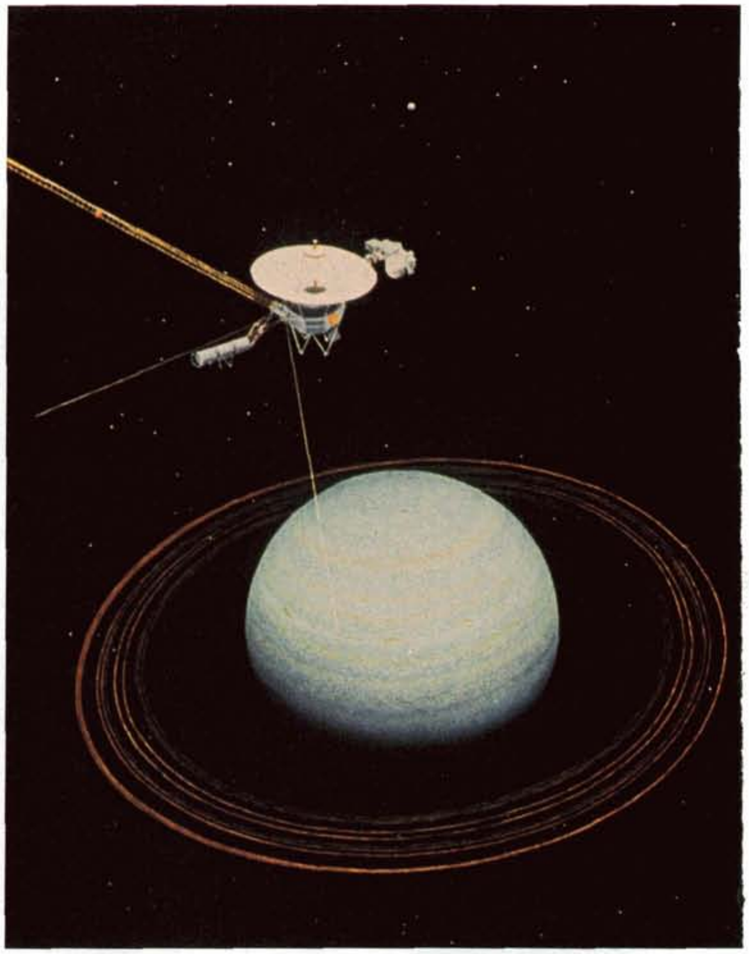
Gamma rays are the most energetic form of radiation known. As such, they offer insight into the violent aspects of the space medium—explosive, high-energy and nuclear phenomena—and how these processes influence such puzzling objects as pulsars, quasars, black holes and the ultrabright stars called supernovae. To investigate this area of cosmic radiation, NASA is developing—jointly with Germany, The Netherlands and the United Kingdom—a spacecraft called the Gamma Ray Observatory (GRO). To be launched late in 1988, GRO (above right) will give scientists an opportunity to study a broad range of cosmic phenomena of particular importance, such as the origins of extremely high energy gamma ray bursts, the nuclear processes occurring near neutron stars and black holes, and the nature of recently discovered gamma ray sources in our own Milky Way galaxy. Goddard Space Flight Center is NASA's manager for the project.

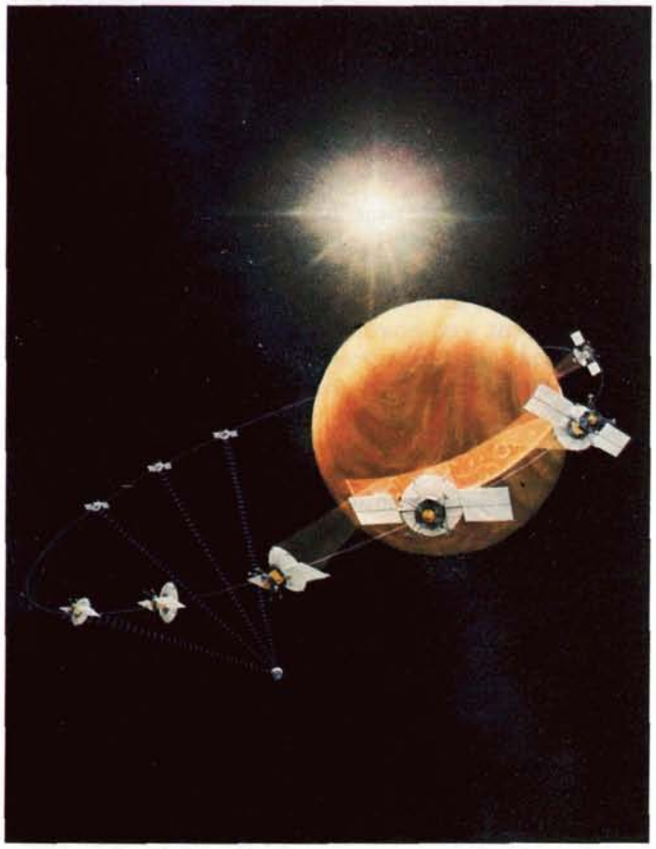
Planetary Exploration

The planet Venus approximates Earth in age, size, density and orbital distance from the Sun. Yet in many other respects the two planets differ markedly; Venus, for example, has a surface temperature of about 900 degrees Fahrenheit, an atmosphere almost entirely carbon dioxide and an atmospheric pressure 100 times greater than Earth's. A prime science objective is to learn why two planets so much alike evolved in such dissimilar fashion. There is a practical aspect to this research: scientists feel that greater knowledge of Venus' history will lead to better understanding of Earth's complex environment.

The Pioneer Venus mission of the late 1970s provided immensely valuable information on Venus, including the first look at the planet's surface, obscured from Earth based telescopes by permanent cloud cover; radar measurements taken by the Pioneer Venus Orbiter produced data for contour maps covering more than 90 percent of the surface. Important as a departure point, these maps lack the clarity of detail essential to further study. They emphasized the need for a follow-up mission by a spacecraft equipped with a higher-resolution radar.

Such a program was initiated last year. Targeted for launch in 1988, the Venus Radar Mapper (below) will use an advanced type of radar to map—over a span of eight months—virtually all of Venus' surface with resolutions more than 10 times better than were





obtained by Pioneer Venus. Where the maps generated by the latter spacecraft show only large-scale features, the greater resolution of the Venus Radar Mapper will enable identification of such small-scale features as volcanos, impact craters, lava flows, tectonic faults, erosion channels and possibly the remnant shorelines of long-ago oceans. That kind of information will represent a big step toward determining the geological history of Venus. The Venus Radar Mapper program is managed by Ames Research Center.

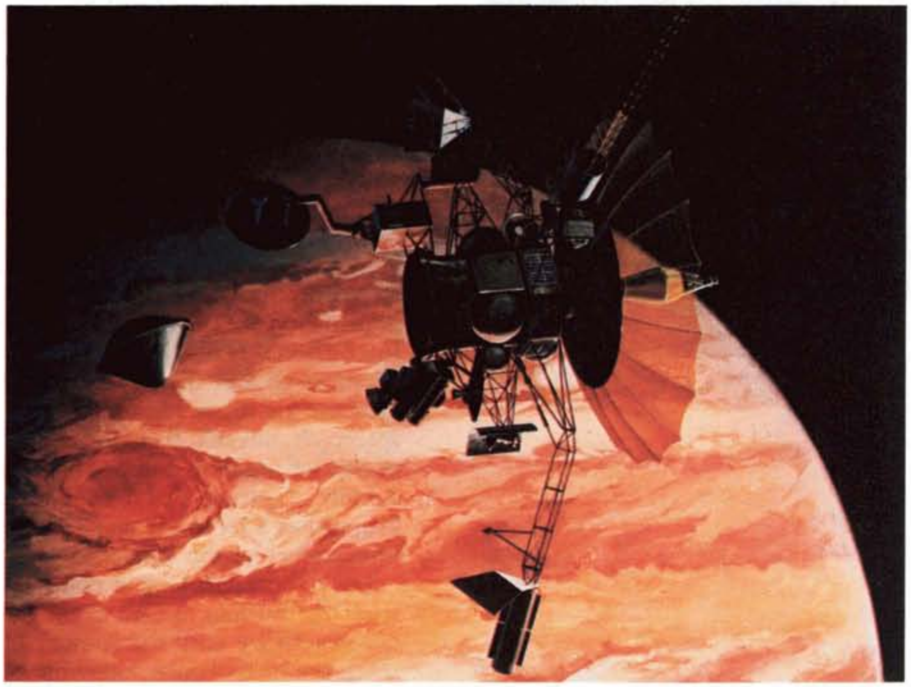
The mapping mission is one of two major programs planned for the 1980s that involve further exploration of the inner planets, the group nearest the Sun—Mercury, Venus and Mars, in addition to Earth. The other, still in study status, is the Mars Geochemical/Climatology Orbiter, designed to amplify knowledge of the Red Planet acquired in earlier missions; it will address such matters as the Martian atmosphere, climate, minerals and water distribution.

Among planetary programs started earlier, the Voyager 2 spacecraft continues its journey through the solar system toward a 1986 encounter with distant Uranus (above), the seventh planet, which orbits the Sun at a distance of two billion miles. If all goes well, Voyager 2 will continue its odyssey with a 1989 flyby of

Neptune, the eighth planet, a billion miles farther from the Sun than Uranus. These encounters are of utmost scientific importance, because neither Uranus nor Neptune has been visited by spacecraft and they have been observed only dimly by Earth telescopes. NASA's manager for the Voyager project is Jet Propulsion Laboratory.

A major step in NASA's exploration of the outer planets will be the 1986 launch of Galileo to amplify earlier findings about Jupiter. The artist's concept at right shows the Shuttle Orbiter launching the two-element Galileo spacecraft affixed to a Centaur upper stage that will boost Galileo toward a 1988 encounter with Jupiter. On arrival, the spacecraft will release its entry probe (below), which will descend by parachute into Jupiter's gas atmosphere; protected by a heat shield from temperatures expected to reach 14,000 degrees Fahrenheit, the probe will report data on temperature, pressure, and atmospheric composition for about an hour. The primary element of Galileo will then swing into orbit about the giant planet, relaying high quality images and instrument data on Jupiter and its moons. Galileo is a cooperative program with the Federal Republic of Germany. Jet Propulsion Laboratory is project manager and builder of the orbiter; Ames Research Center has responsibility for the probe, which is being built by Hughes Aircraft Company and General Electric Company.

Successful development of the Jupiter probe will enable use of similar probe equipment for advanced exploration of the outer planets. Among missions in planning status is the Titan Probe/Radar Mapper to investigate Saturn's largest moon; knowledge of Titan's atmosphere is scientifically very important because it is the only other atmosphere in the solar system that may be like Earth's before life evolved on our planet. Also under consideration for the 1990s and beyond are probe missions to Saturn, Uranus and Neptune, and a flyby reconnaissance of Pluto which, after this decade, will be the only known planet not visited by spacecraft.



Comets and Asteroids

In addition to the planets and moons, the solar system contains a great many "small bodies"—comets and asteroids. Comets are chunks of ice and cosmic dust orbiting the Sun and occasionally—in some cases rarely—making approaches to the Sun/Earth vicinity. Composed mostly of rock or metals, asteroids are believed to be fragments of long-ago collisions between larger objects, or "planetesimals" that never aggregated into planets; they range in size up to several hundred miles and most of them reside in an orbital "Mainbelt" that lies between Mars and Jupiter.

Because they are small and cold, comets and most asteroids failed to evolve as did other solar system bodies; thus, they remain largely unchanged since their formation four and a half billion years ago and investigation of their chemical and elemental composition offers an opportunity to observe material as it existed when the solar system was created. Comets and asteroids have never been observed up close, but missions to these small bodies have now become a high priority space science objective.

The first closeup observation of a comet will occur in September 1985 when NASA's International Cometary Explorer (ICE) encounters Comet Giacobini-Zinner as it approaches the Sun. Built by Goddard Space Flight Center, ICE was designed for another purpose, hence has no imaging equipment for closeup pictures. However, its instruments can provide important data as they probe directly into the comet's tail and report on temperatures, gases, particles and magnetic forces.

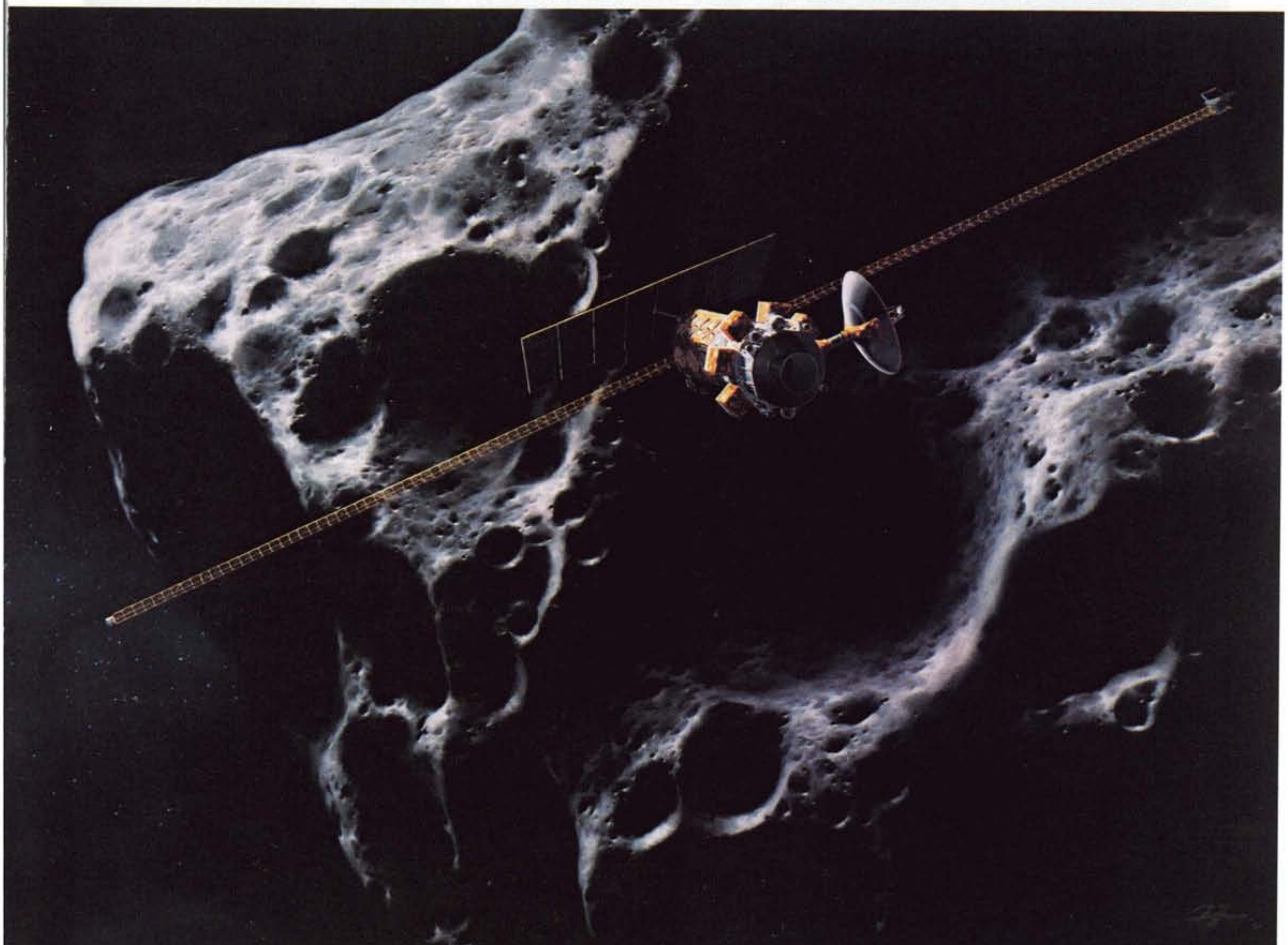
Early in 1986, Comet Halley will make its once-every-76-years close approach to the Sun and it will be encountered by spacecraft from the Soviet Union, Japan and the European Space Agency (ESA). NASA will send no close encounter spacecraft, but the U.S. will participate in Halley observations in a number of ways. ICE will provide solar wind and other information to complement data reported by other spacecraft. In March 1986, when Halley is closest to Earth, NASA will fly a Shuttleborne payload—called Astro—for a look at Halley. Astro (upper left) consists of three wide-field ultraviolet telescopes mounted on a Spacelab pallet. The U.S. will also be represented in the ESA Halley mission, called Giotto; there will be American co-investigators for nine of the 10 instruments that make up the Giotto payload.

In addition to these flight activities, NASA will play an important role in coordinating the flow of information about Halley. The NASA-sponsored International Halley Watch (IHW) is composed of scientists all over the world, who will analyze data and monitor the many Halley-watching instruments aboard spacecraft, aircraft, balloons and at ground facilities. All of this information will be channeled to a central Halley Archive. Co-leaders of the IHW are NASA's Jet Propulsion Laboratory and Germany's Remeis Observatory of the University of Erlangen-Nurnberg.

For a thorough look at comets, scientists want to study the nucleus as well as the tail (the long tail does not materialize until the comet comes close to the Sun, when the heat of solar radiation initiates its buildup).

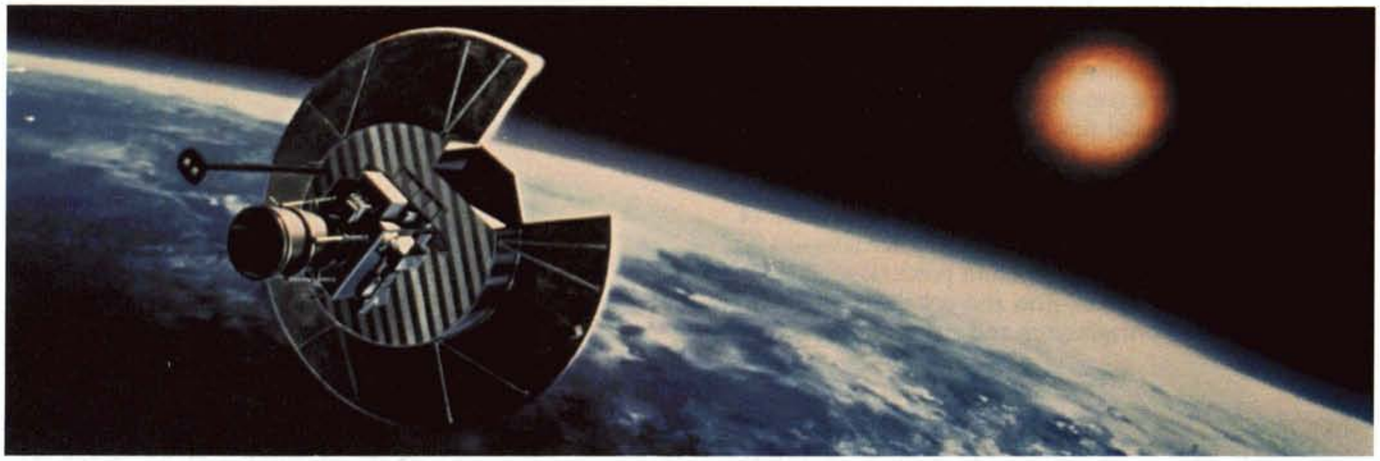
This demands a mission in which a spacecraft meets the comet far from the Sun and maintains rendezvous with it for a long period of time, to observe the nucleus and the rapid changes caused by solar heating. Such a mission is contemplated for the 1990s. It will require a new type of spacecraft, the Mariner Mark II (lower left) designed by Jet Propulsion Laboratory, a multipurpose vehicle whose configuration can be changed by adding different modules for different assignments; it could be used for flyby, orbiting and probe releasing missions to planets, comets and asteroids. It could also be used for a later mission involving return to Earth of a sample of cometary gases and particles.

A flyby look at an asteroid (below) is also planned for the 1990s, possibly a two-part mission in which a Mariner Mark II would first encounter a Mainbelt asteroid, then proceed to a cometary rendezvous. Aside from scientific interest, asteroids offer valuable resources that could be mined in the 21st century. Examination of meteorites—which probably came from asteroids—indicates that some asteroids contain precious metals along with alloys of nickel, iron and cobalt, others may be rich in titanium, magnesium and other metals.



Near-Earth Environment

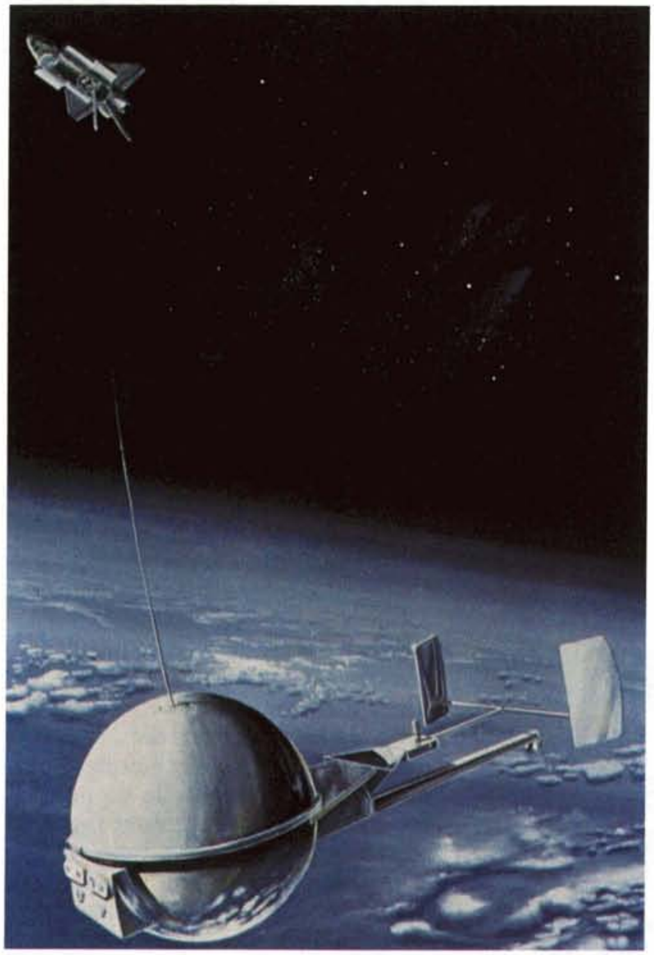
The planet that is still getting most attention in NASA's space science program is Earth. A quarter century of Earth study by spacecraft has produced an immense volume of information, but it has also underlined the fact that there is a great deal still to be learned about the near-Earth environment. Scientists want to know more



about how energy from the Sun is transported to Earth. They want to expand their knowledge of the electrified gas known as the solar wind, which transfers energy through a chain of complex reactions with Earth's magnetic fields and its upper atmosphere. They are interested in Earth's layer of ozone and how it is affected by human activities. They want to learn more about the chemical composition of the atmosphere, in particular the increasing level of carbon dioxide and what causes it. These and other scientific goals have practical implications, since they affect such matters as weather, climate, communications, power transmission, air quality, even human and plant life.

Among satellites already studying these areas are the Solar Mesosphere Explorer (SME), shown above, and two Dynamics Explorers, all launched in 1981. The latter spacecraft are investigating the massive transfer of energy from the Sun to the Earth's magnetosphere and upper atmosphere. SME is studying how Earth's ozone layer is affected by solar energy transfer and by natural and man-made contaminants. The SME project is managed by Jet Propulsion Laboratory; Ball Aerospace Systems built the spacecraft. RCA Astro-Electronics built the Dynamics Explorers; Goddard Space Flight Center is project manager.

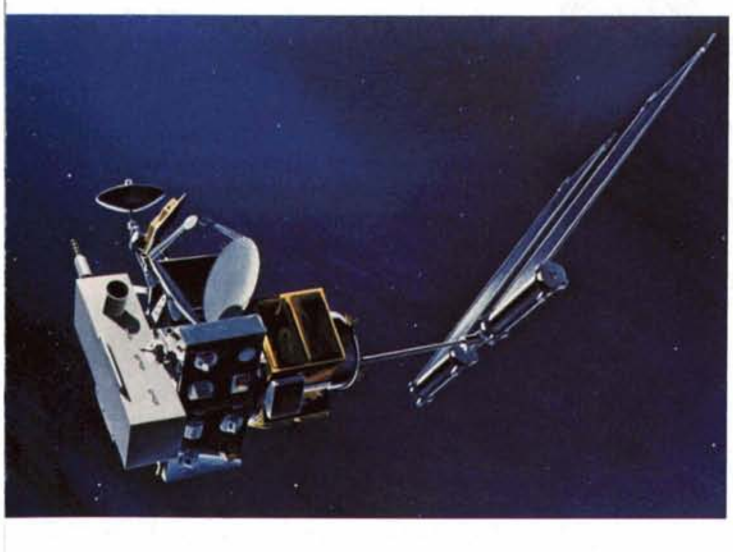
A new program begun last year is the Global Tropospheric Experiment. Managed by Langley Research Center, it involves—initially—development and test of instruments and techniques for measuring the constituents of the lower atmosphere, in particular the "trace species" that exist in very low concentrations and thus demand instruments of special sensitivity. Instrument tests started with a series of airborne evaluations over the Caribbean. Long range plans call for global atmospheric sampling by aircraft in the late 1980s, followed by measurements with space-based instrumentation in the 1990s.



New spacecraft joining the near-Earth environment investigating team this year are two Active Magnetospheric Trace Particles Explorers (AMPTE), one supplied by NASA and the other by Germany, and the Earth Radiation Budget Explorer (ERBE). The AMPTE spacecraft study how plasma—electrified gas—is transported through the magnetosphere. ERBE (lower illustration, opposite page) investigates how solar energy is distributed through Earth's environment, a step toward understanding the mechanisms that determine Earth's climate. Goddard Space Flight Center manages both projects; Ball Aerospace built the ERBE spacecraft.

Under study for possible service late in this decade is a joint U.S./Italy program called the Tethered Satellite (left), in which a spacecraft would be suspended from the Shuttle Orbiter by a tether line up to 60 miles long. This system has a number of applications, one of them being exploration of the upper atmosphere, roughly 60 to 90 miles above Earth's surface. This is a relatively unexplored region, because aircraft and balloons cannot operate at those altitudes, nor do spacecraft, because there is a slight air drag at such levels that would slow a spacecraft and sharply limit its time in orbit. Marshall Space Flight Center is NASA's manager for the Tethered Satellite program.

Planned for launch in 1989 is a highly advanced environmental observatory called the Upper Atmosphere Research Satellite (UARS). UARS (left below) will conduct a very comprehensive survey of the upper atmosphere, aggregating in a single large spacecraft instrumentation to build on the work of several prior satellites. It will have 11 major remote sensing instruments for precisely measuring ozone and other chemical species, solar radiation, winds, temperatures and the dynamics of the upper atmosphere on a global scale. UARS will sense atmospheric data from an altitude of 375 miles, well above the air drag level, so it can report continuously for several years. Goddard Space Flight Center is project manager.



In planning status is a program called OPEN, for Origin of Plasmas in Earth's Neighborhood. This would be a total study of the many components of the entire "geospace," which embraces the whole near-Earth environment—magnetosphere, ionosphere, upper atmosphere, near-Earth interplanetary space—and the complex reactions and interactions that occur in those zones. Because the investigation is so broad and complex, OPEN would require four separate spacecraft working as a team, each studying certain components in a common time frame. Goddard Space Flight Center is managing the project.

Trailblazing Future Flight

Tomorrow's airplanes are taking shape today in NASA's aeronautical research facilities

Research on powered flight has been going on for more than eight decades, so one might think that man has learned just about all there is to know. Not by a long shot. He has acquired sufficient knowledge to cope with the forces of nature in building safe and productive flying machines. But to develop the superefficient airplanes envisioned for tomorrow, scientists must gain far greater understanding of the manner in which air flows and burbles and twists and swirls about a body in motion through the atmosphere, and how the shape of the body affects the many forces acting upon it.

It is a subject of infinite complexity and its study requires a broad array of special facilities, some of them as complex as the end product—facilities for creating new aircraft designs, predicting the airflow patterns the design will encounter, verifying or correcting the predictions and, finally, testing the design in actual flight. To support the endless quest for greater flight efficiency, these facilities must be continually updated and improved to keep pace with advancing technology.

An example of a highly advanced facility is a supercapable wind tunnel, dedicated last year at Langley Research Center, known as the National Transonic Facility (NTF). As its name indicates, it operates in the transonic speed range—near the speed of sound. This is an area of particular importance in designing both commercial transports and military aircraft; it is also an area of special complexity, because an airplane's approach to the speed of sound creates airflow patterns very different from those encountered at lower speeds.

The NTF offers a significant advance in wind tunnel capability in that it is able to correlate more closely the results of tunnel-testing small models and the flow patterns that will actually occur as the full scale airplane flies at transonic speed. The correlation factor is called the Reynolds Number, which ties together velocity, air density, air viscosity and model size; the higher the Reynolds Number, the better the comparison between wind tunnel values and actual flight. In the past it has been very difficult to get high Reynolds Numbers because of the many differences between tunnel conditions and free flight conditions, but the NTF will provide a substantially improved approximation of the real flight environment. Blowing supercooled nitrogen gas instead of air, operating at pressures several times the outside atmospheric pressure, it will develop the highest Reynolds Numbers ever attained in ground facilities at transonic speeds.

Before it gets to the wind tunnel stage, an aircraft design goes through a computer phase. For many years, researchers have employed computer design techniques in aircraft development, creating mathematical airplane models and flying them by computer simulation; this enables study of the performance and structural behavior of a number of different designs before settling on one configuration. In recent years, computational simulation has expanded enormously to embrace calculations of many types of forces acting on airplane and engine components, including phenomena that cannot be realistically simulated in a wind tunnel.

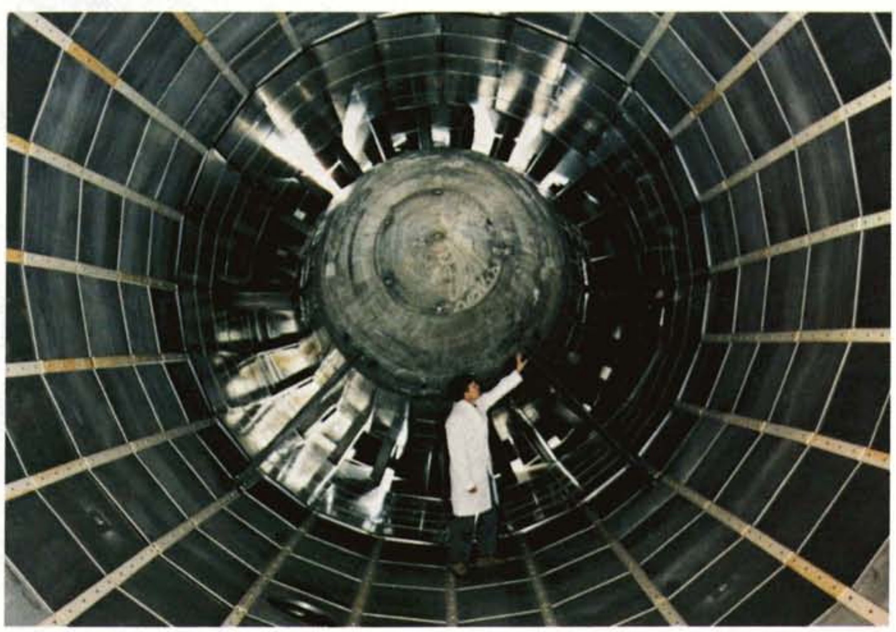
Looking to tomorrow, aeronautical scientists see as the next major goal the ability to simulate, rapidly and routinely, the immeasurably complex three-dimensional flow about a complete airplane. That will take a lot more computer capability than is currently available to NASA and industry; it will require data storage capacity of 250 million words and the ability to process as many as one billion computer operations each *second*. Toward that end, NASA initiated last year a Numerical Aerodynamic Simulation (NAS) program, an effort to develop the world's fastest aerodynamic analysis computerized facility.

Located at Ames Research Center, the NAS will be developed in phases, beginning with an initial single processor capability of 64 million words of memory and 250 million operations a second by early 1986; with the addition of a second, more advanced processor and other equipment, Ames hopes to reach the billion-operation-per-second goal by late 1987. The NAS facility will allow solution of many previously intractable problems; it will make possible performance of most of the calculations required to design a new airplane with increased accuracy and reliability. NAS will improve the efficiency of the design process and reduce the long and expensive process of wind tunnel and flight testing now necessary.

The National Transonic Facility and the Numerical Aerodynamic Simulation program are representative of the broad range of facilities operated by NASA's principal aeronautical research complexes: Ames, Langley and Lewis Research Centers. Built and upgraded over several decades—one tunnel is more than half a century old—these facilities represent an investment of several billion dollars. They are *national* resources, for use by NASA, other government agencies, industry and universities, intended to benefit the American economy and national security by maintaining U.S. leadership in development of aeronautical systems.

Operation of these facilities is one facet of NASA's comprehensive aeronautical research program. While the agency devotes a substantial part of its effort to solution of current and predictable problems—curbing jetliner fuel consumption, for example—most of the program's objectives relate to anticipating the long range needs of future flight and developing applicable technology. This involves, on the one hand, research of a general nature aimed at advancing aerodynamics, propulsion, materials and structures, aviation electronics and knowledge of the human factors in flight operations. Additionally, it includes research toward improving the performance, safety, efficiency and environmental acceptability of specific types of flight vehicles, such as tomorrow's general aviation planes, rotorcraft, short-haul transports, advanced jetliners and high performance military aircraft.

NASA's new National Transonic Facility at Langley Research Center (left) represents a significant advance in wind tunnel research capability. Blowing supercooled nitrogen gas and operating at several times the outside atmospheric pressure, it provides a much improved simulation of the real flight environment. The large fan compressor at right generates flows equivalent to airspeeds ranging up to 850 miles per hour.

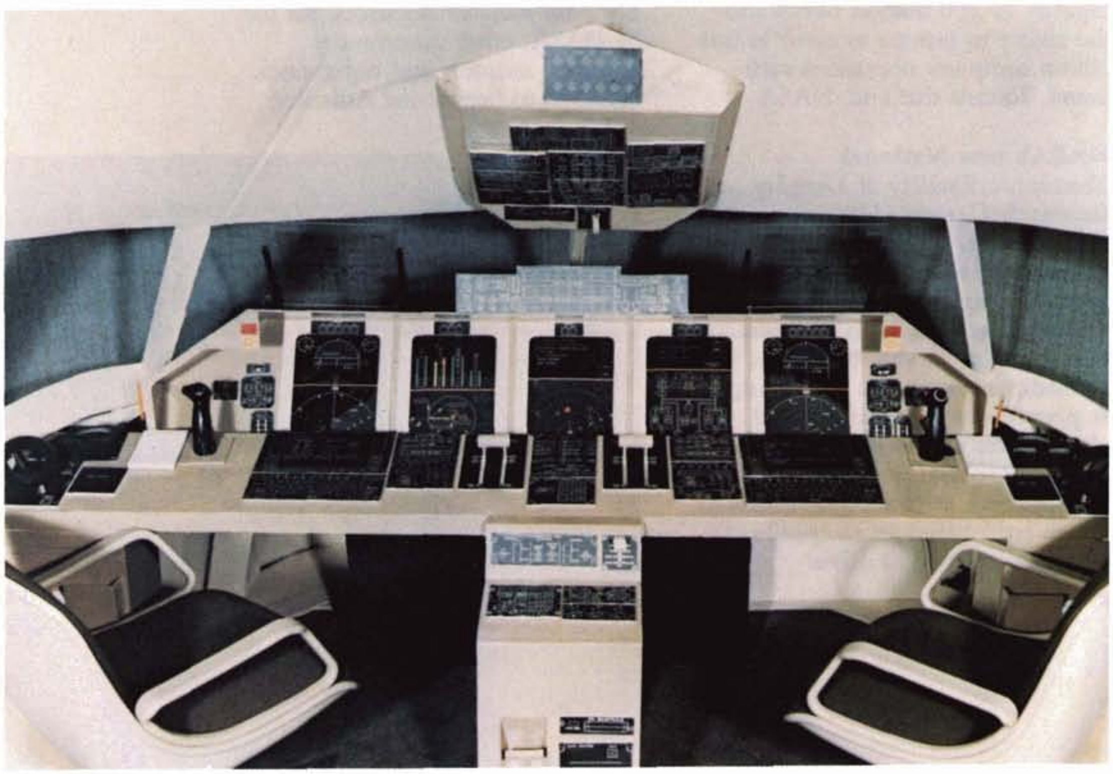


Human Factors Research

Ames Research Center operates more than a score of facilities that simulate flight conditions in aircraft, rotorcraft and space vehicles to aid technology development in those areas. A recently completed addition to the simulation complex is the Man-Vehicle Systems Research Facility, which will enable scientists to study the relationships between aircraft crews, the airplanes they fly and the air traffic environment in which they operate. This type of investigation, called human factors research, is aimed at greater understanding of aircrew capabilities and limitations in order to enhance safety, improve flight deck instrumentation, and solve other human-related problems that affect aviation growth and efficiency.

The Man-Vehicle facility includes three advanced simulators, two of them representing the "cabs" (cockpits) of commercial transport aircraft. One (right) replicates the cockpit of a current technology jetliner, the Boeing 727. Developed by Ames in cooperation with Langley Research Center and Lockheed Georgia Company, the other cab (below) represents the flight deck of a commercial transport that might be in service in the 1990s; it has a variety of advanced informational displays, voice command and response equipment, and new types of flight and engine control simulations. Using either cab, Ames can run realistic full-mission, full-crew simulations of transport operations. The results of such tests will provide industry, the military services and the Federal Aviation Administration (FAA) guidelines for further development and certification of advanced automated cockpit systems.

The Man-Vehicle facility also includes a computerized representation of the air traffic environment, simulating large numbers of interactive aircraft in a given airspace on different headings and at different speeds and altitudes. This simulation permits evaluation of new three-dimensional cockpit displays of traffic information (CDTI) jointly developed by NASA and the FAA. Tests are aimed at determining how quickly and accurately aircrews respond to CDTI displays and what improvements might be incorporated in the displays.



Airflow Control

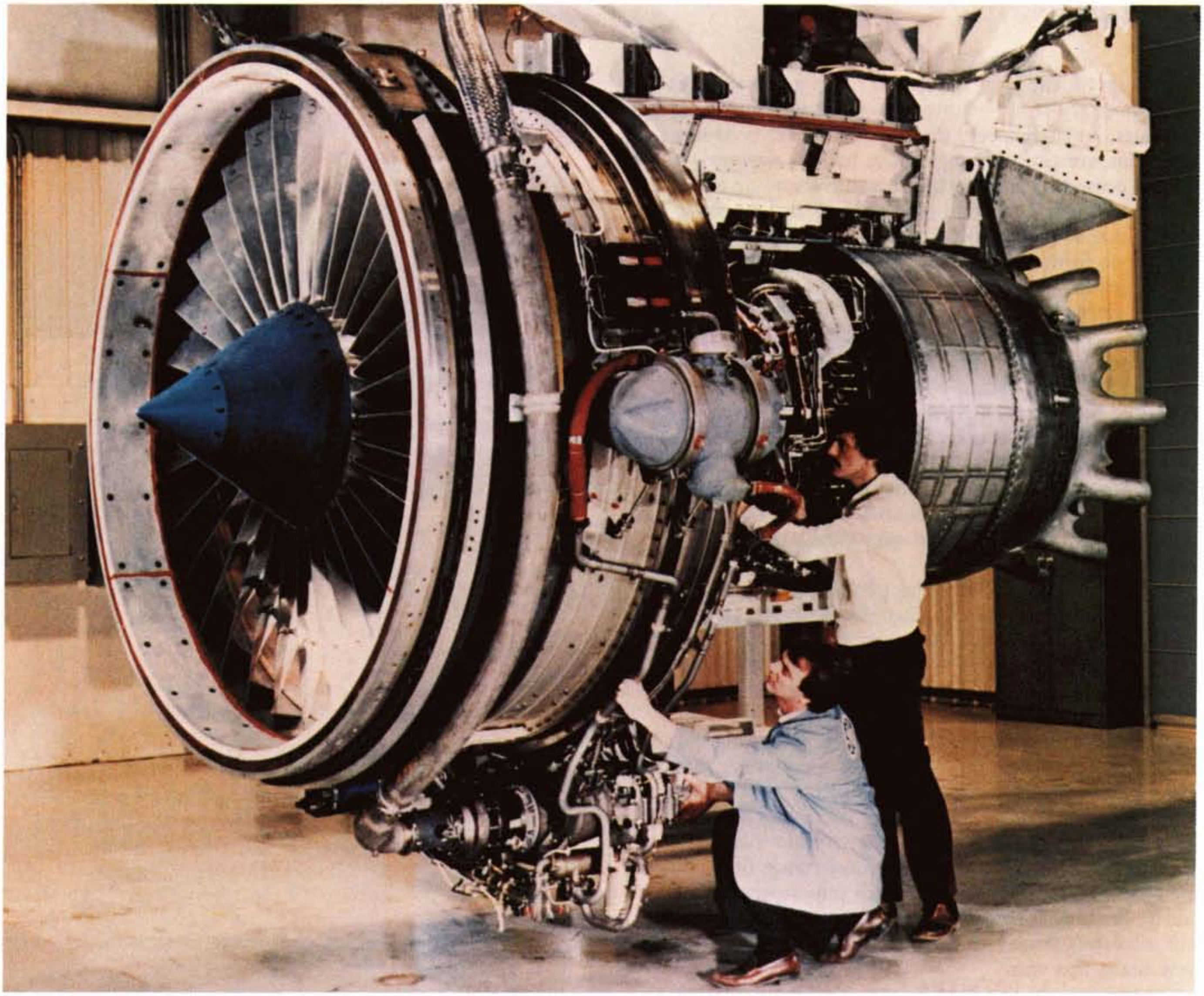
At low speed, the layer of air next to an airplane's skin—the "boundary layer"—flows smoothly over the plane's contours. At high speed, the boundary layer becomes turbulent, creating air drag; about half an airplane's total drag is caused by friction between turbulent air and the airplane skin. If a smooth, or "laminar" airflow could be maintained at higher speeds, large-scale improvements in aircraft performance could be realized—in particular, greatly increased range or sharply reduced fuel burn.

Ever since the 1930s, aerodynamicists have sought to devise practical laminar flow control (LFC) systems, but the technology has proved elusive. Some systems have reached flight test status, but they were not sufficiently advanced for operational service. A major problem has been buildup of insects or ice on the wings, which changes wing contours and promotes turbulence. Other problems included the inability to manufacture sufficiently smooth wings within acceptable costs, and maintaining the required smoothness during regular operational service.

For the past several years, as part of NASA's Aircraft Energy Efficiency program, Langley Research Center and industry contractors have been developing technology for advanced systems that could lead to the first operational use of LFC in the 1990s. Exploiting new materials, fabrication methods, analysis techniques and design concepts, they have been investigating two different approaches. One, called natural laminar flow, involves coating an airplane with a plastic substance that smoothes airflow by reducing friction. The other approach, potentially far more effective but also more technologically challenging, is active laminar flow control by means of suction pumps, which remove the turbulent air by drawing it through microscopic holes or slots in the airplane's skin. This latter technology reached flight test status this year.

At upper right is a NASA JetStar twin-engine light transport modified by Dryden Flight Research Facility to incorporate two contractor-designed active LFC systems. The systems are located on the leading edge of each wing; they are encased by the gray-colored "gloves" at mid-wing. At right is a close-up view of the glove covering Lockheed Georgia Company's system. Although the glove appears solid, it is actually perforated by hundreds of tiny suction holes. The other system, located on the opposite wing, was developed by McDonnell Douglas Corporation.

Although different in technical detail, both systems use suction to draw boundary layer air into the wing; both also employ methods of dispensing a solvent onto the wing leading edge to dispose of insects and prevent ice accumulation that could create turbulence and block suction holes. Successful test of these systems could provide a means of saving up to 40 percent of the fuel consumed by present day commercial jetliners. Dryden will conduct an extensive flight test program, simulating typical airline operations into a number of different airports under varying weather conditions to evaluate each LFC concept in a realistic flight environment.



Energy Efficient Engine

Although airline fuel costs have declined somewhat from the 1980–81 peak, they still represent about 30 percent of a carrier's total operating cost. A reduction of only one percent in annual fuel usage would save the financially pressed U.S. airlines about $100 million. That's why airline operators are looking with real interest at a NASA/industry research program that offers a reduction of *15 percent* in aircraft engine specific fuel consumption, compared with engines in current jetliners. Such an engine could be in airline service in the late 1980s.

Started in 1978, NASA's Energy Efficient Engine (E^3) program, managed by Lewis Research Center, culminated last year with ground testing of an experimental engine that incorporates a number of new component technologies. Both General Electric Company and United Technologies' Pratt & Whitney Aircraft division participated in E^3 on a cost-sharing basis, each independently developing advanced technology. Pratt & Whitney concentrated on technologies for a wide range of engine components and individual testing of each component. GE assembled its advanced components for testing as a complete engine.

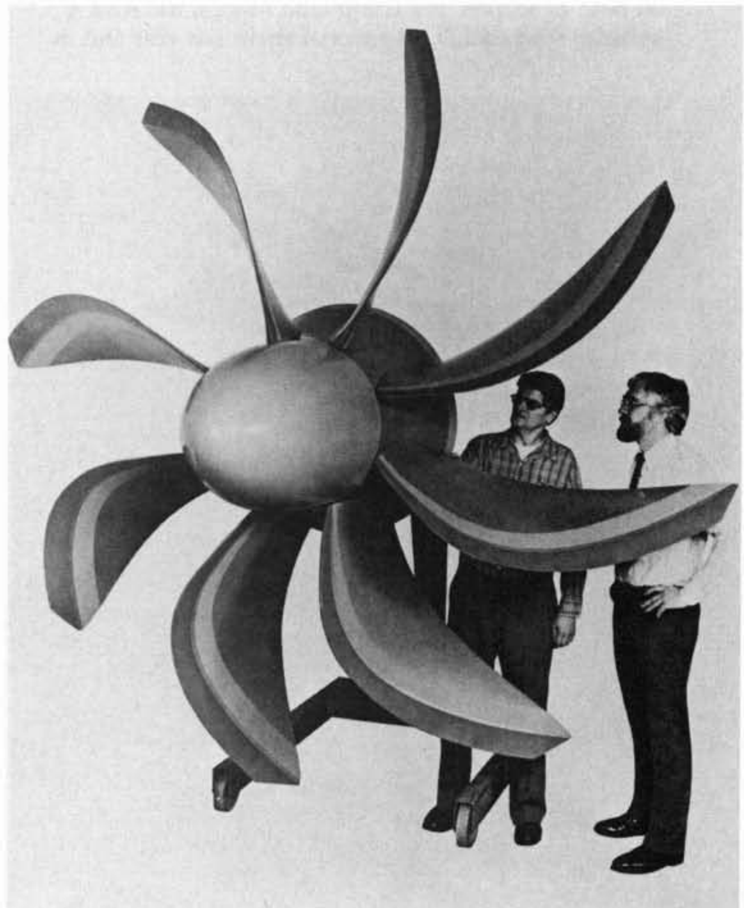
Shown in the accompanying photo, the GE engine completed 65 hours of operational testing at the company's Peebles, Ohio test facility. The tests showed that the engine's specific fuel consumption would be about 13½ percent better than a current GE engine; improvements already identified would boost the reduction to at least 15 percent. The technologies from the E^3 program are applicable not only to turbofan (jetliner) engines, but also to advanced turboprops and helicopter engines for commercial and military aircraft. Both GE and Pratt & Whitney have incorporated some of the technologies in engines planned for production.

Advanced Turboprop

When the turbojet engine was introduced to commercial air service a quarter century ago, the propeller lost favor among airline operators because propeller tip speed limitations restricted airplane speed. Although turbine propeller engines offered inherently better fuel consumption than the jet, fuel then cost only about one fifth what it does today and airlines were willing to burn more fuel to get the greater speed of jet transportation. Today, with fuel costs high and future prices uncertain, there is a revival of interest in the turboprop engine. NASA research has shown that advanced technology multibladed, swept-tip, turbine-driven propellers can provide jetlike speed with fuel economy about 20 percent better than equally advanced turbofans—and perhaps 40 percent better than some older jet engines in service today.

In the Advanced Turboprop Program—part of NASA's broader Aircraft Energy Efficiency program—NASA is pursuing the promise of new propeller technology. Over a period of several years, Lewis Research Center and its principal contractor for turboprop research—United Technologies' Hamilton Standard division—have conducted wind tunnel tests of propeller/nacelle/wing models and flight tests of a small-scale version of a swept-tip propeller assembly. These tests confirmed the fuel-saving potential of the advanced turboprop and indicated that ancillary problems—for example, higher noise levels—can be overcome.

The program has moved into a new phase with Hamilton Standard's fabrication of three large-scale (nine-foot diameter) propeller assemblies (right) for further static and wind tunnel testing. Lewis is directing a project combining the advanced propeller system, an existing engine, a modified gearbox and a new-design engine nacelle into a test assembly for exploring the structural and dynamic characteristics of the advanced turboprop. After a full range of ground tests, NASA plans to test the assembly in flight, beginning in 1987.



X-wing Aircraft

In the photo below is the Rotor Systems Research Aircraft (RSRA), one of two built by Sikorsky Aircraft for a joint NASA/Army research program. A heavily instrumented flying laboratory that can accommodate different rotor systems, the RSRA is used to investigate promising rotorcraft concepts with future commercial or military potential. The RSRA operates either as a pure helicopter or as a compound helicopter, a hybrid system that combines the helicopter's vertical flight characteristics with the greater speed of the fixed-wing airplane.

Having completed extensive ground and flight testing in both helicopter and compound modes, the RSRA vehicles reached full operational status last year and in 1984 they are starting new research programs. One RSRA is assigned to the flight investigation of a new rotor concept called the X-wing. The X-wing (above) is a four-bladed, extremely stiff rotor that is stoppable in forward flight. In hover and low speed flight the rotor functions as a helicopter rotor. At a speed of about 200 knots, the rotor is stopped to become two forward swept and two aft swept fixed wings in an "X" configuration. In this mode, design speeds of 450 knots are envisioned. A possible use for the X-wing would be a high-speed, vertical lift aircraft for civil or military service about the end of the century.

The U.S. Navy David Taylor Ship Research and Development Center (DTNSRDC) initially investigated this concept in a series of wind tunnel model tests. The Defense Advanced Research Projects Agency and NASA are jointly conducting the advanced X-wing flight test program with the RSRA. Flight testing will involve a lengthy series of translations from vertical to forward flight involving rotor starts and stops at 230 knots. Ames Research Center is managing the project, with rotor system technical support from DTNSRDC.

The other RSRA is assigned to developing a much needed data base for modern technology four-bladed rotors. This effort will aid helicopter designers in providing quieter, more efficient rotor designs.

Tilt Rotor Aircraft

Among candidates for tomorrow's short-haul air transportation system is the tilt rotor aircraft, which combines the vertical lift advantages of the helicopter with the greater forward speed of the fixed-wing airplane. The feasibility of this concept has been demonstrated by five years of successful flight testing of the XV-15 Tilt Rotor Research Aircraft (above). Managed by Ames Research Center, the XV-15 program is a joint NASA/Army effort; Bell Helicopter Textron built the two XV-15 experimental vehicles.

Success of the XV-15 led to a Department of Defense design and development program for an advanced tilt rotor aircraft, based on the XV-15 but considerably larger and heavier. Bell Helicopter Textron has teamed with Boeing Vertol Company for development of the military tilt rotor, which is known as JVX; first flight is targeted for 1987 and operational service for 1991. Both contractors are also exploring the potential of the tilt rotor as a short-haul civil airliner.

Ames Research Center is continuing flight tests of one XV-15 to provide an expanded data base in support of the military JVX program. Additionally, NASA is using XV-15 technology as a base for investigating advanced tilt rotor concepts that might evolve into civil commuter aircraft operating from small, close-to-city heliports in the 1990s.

High Performance Aircraft

NASA's High Performance Aircraft Research Program is directed toward development of advanced technologies that offer future benefit for civil aircraft and more immediate application in military aircraft. Most of these activities are cooperative ventures with industry or with such Department of Defense agencies as the Air Force, Navy and the Defense Advanced Research Projects Agency (DARPA).

An example of NASA/industry collaboration is a project wherein Langley Research Center and Ames Research Center teamed with General Dynamics Corporation's Fort Worth Division in redesign of an Air Force production airplane to increase its range and payload. In this project, NASA applied its "cranked arrow wing" technology, originally developed for advanced supersonic civil transports, to a company funded modification of the F-16 fighter known as the F-16XL (right). In addition to substantially improved aerodynamic performance, the arrow wing more than doubles the area of the standard F-16 wing, adding space for 82 percent more fuel internally; this eliminates the need for external fuel tanks on most missions. With only internal fuel, the F-16XL will have a combat radius some 40 percent greater than the production F-16 and it will carry twice the payload. NASA's input included computer design work, wind tunnel and simulator testing at Langley and Ames, and flight testing at the Air Force Flight Test Center, Edwards, California. Two prototype F-16XLs are in their second year of flight test.

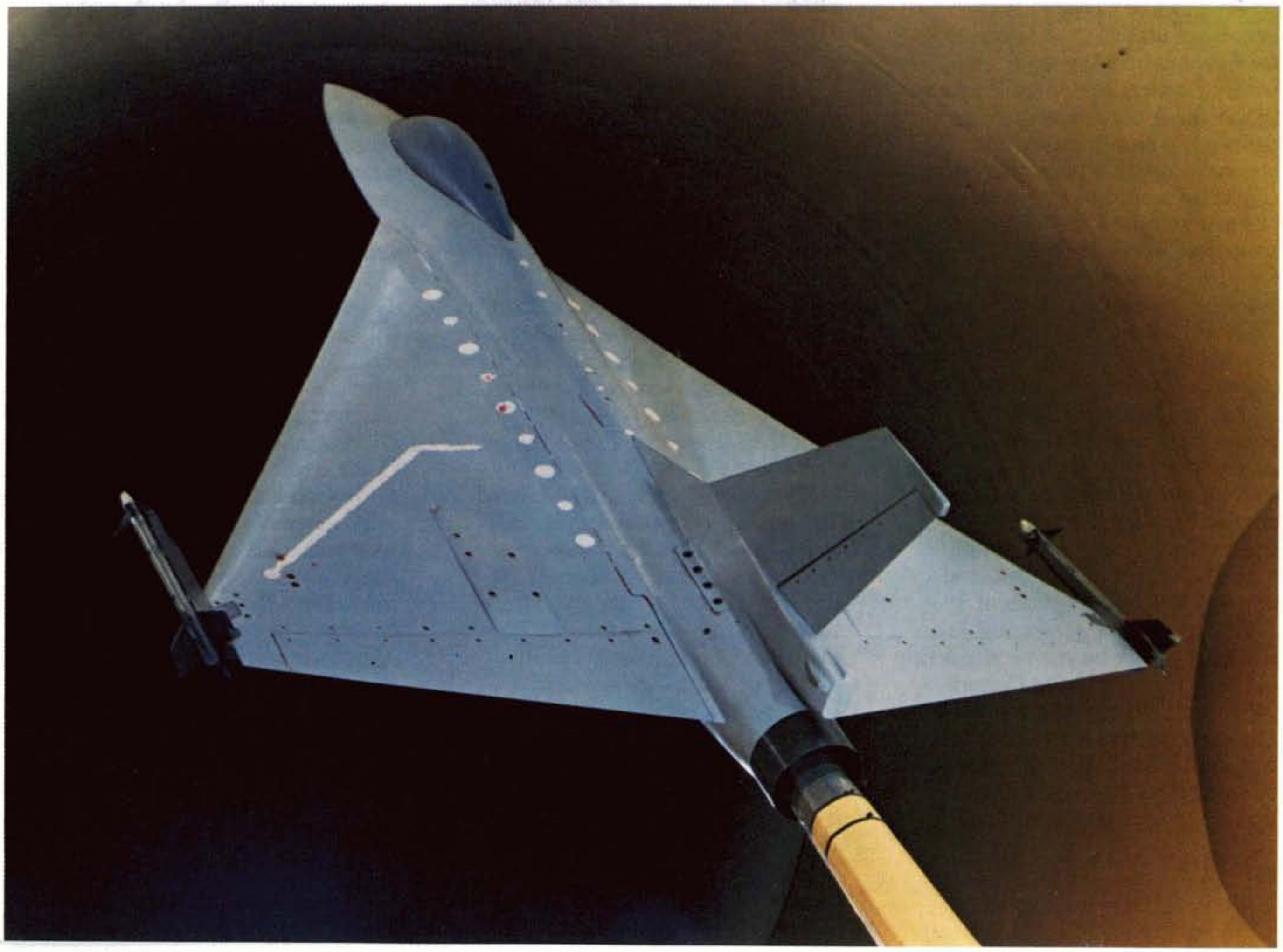
NASA is also conducting, jointly with the Air Force, the Advanced Fighter Technology Integration (AFTI) program. Shown below is the AFTI F-16, the first AFTI project. It is a modification of the General Dynamics F-16 incorporating a number of advancements, principally a system in which electronic signals replace the conventional flight control assembly of rods and linkages. Langley Research Center conducted wind tunnel tests of the AFTI F-16 and Dryden Flight Research Facility is handling the two-year flight test program, which concludes this year.

NASA is a major partner—with DARPA and the Air Force—in a demonstration project on an innovative high-speed aircraft whose wing is swept forward rather than rearward. The airplane is the X-29A (right), built by Grumman Aerospace Corporation. In addition to its novel shape, the X-29A wing is made of composite material. The combination of forward sweep and composites makes it possible to build a low drag, high performance airplane that is considerably lighter than aircraft of equivalent performance with aft-swept metal wings. Wind tunnel tests at Langley and Ames indicate that the X-29A will have longer range, greater maneuverability and better short takeoff and landing characteristics than comparable fighters. Beginning this year, Dryden will conduct the flight test program.

Also due to start flight tests this year at Dryden is

another of the AFTI projects, the AFTI F-111, which features what is known as a "mission adaptive wing" or a "variable camber wing." The terminology means that the airplane has a wing, made of flexible composite material, whose camber—the fore to aft curve of the airfoil—is automatically changed in flight; a computerized system of sensors and controls alters the wing's shape to get the best aerodynamic configuration for a given flight condition—for example, cruise, maneuvering or high speed penetration. Under Air Force contract, Boeing Aerospace Company modified a General Dynamics F-111 fighter to include the variable camber provisions. NASA's role, in addition to Dryden's responsibility for flight testing, included wind tunnel research at Langley.

In addition to these flight programs, NASA is exploring—in wind tunnels, simulators and free flight model tests—new high-speed aircraft concepts involving powered lift technology for V/STOL (Vertical/Short Takeoff and Landing) applications. Powered lift is a NASA-pioneered technique in which the exhaust from aircraft engines is put to work as an additional lifting force. Shown at bottom page is a model of a powered lift V/STOL design ready for test in a wind tunnel at Ames Research Center.



Dividends from Technology Applied

NASA is applying aerospace technology and scientific knowledge in development of systems intended to provide direct public benefit

At left is a view of a 40-kilowatt fuel cell, located at Rawlinson's New System Laundry, Portland, Oregon, which provides electricity and heat for laundry operations (upper right). This was the first installation in a test program evaluating the Earth-use potential of fuel cell power plants, originally developed to supply electricity for manned spacecraft. At lower right, a technician is collecting data on the system's efficiency as reported by a computerized monitor; results indicate that power savings averaging $300 monthly could be realized in similar installations.

With the initial flight of the two-man Gemini in 1965, NASA introduced a new way of generating the electricity needed to power the many systems in a manned spacecraft. In the earlier Mercury capsule, a set of batteries had sufficed, because the longest of six Mercury missions took only a day and a half. But it would have been impossible to provide, within weight and space limitations, enough battery power to serve Gemini's two astronauts and all their equipment for missions ranging up to two weeks. So Gemini's designers elected to use the fuel cell powerplant, a compact, continuously-operating system in which chemical energy is converted directly to electrical energy.

All subsequent U.S. manned spacecraft have employed fuel cells for power generation. There is considerable variance among the types of systems used but all are alike in general principle. A fuel cell is an electrified chamber to which a fuel and an oxidizer—for example, hydrogen fuel and oxygen—are continuously admitted. The resulting electrochemical reaction creates electricity and produces a byproduct—water pure enough to drink, an important bonus in manned spacecraft operation.

The concept of generating electrical power by chemical reaction did not originate in the Gemini program; in fact, it dates back to 1839, but it remained in the idea stage until the U.S. space program brought it to practical reality through extensive research and development and long operating experience. And the success of the fuel cell in space operations inspired efforts to adapt it as an Earth-use power generation system.

In the mid-sixties, the company that was producing fuel cells for NASA's Apollo spacecraft—United Technologies Corporation (UTC)—started research toward terrestrial systems. After the oil crisis of 1973, the Department of Energy (DoE) became interested in fuel cell power plants and subsequently (1976) joined with the Gas Research Institute in a program involving research, development and demonstration of a reliable, cost effective 40-kilowatt onsite fuel cell to provide electricity and usable thermal energy for industrial, commercial and multifamily residential facilities. Lewis Research Center was assigned as program manager and UTC's Power Systems Division, South Windsor, Connecticut was awarded a contract to develop the fuel cell.

The experimental 40-kilowatt system that emerged from this program uses natural gas as a fuel source, but the gas is not burned; hydrogen extracted from the gas is combined with oxygen from the air to produce electricity. The process also generates heat, an extra dividend that can be put to work for space heating, water heating or industrial process applications.

The 40-kilowatt onsite fuel cell

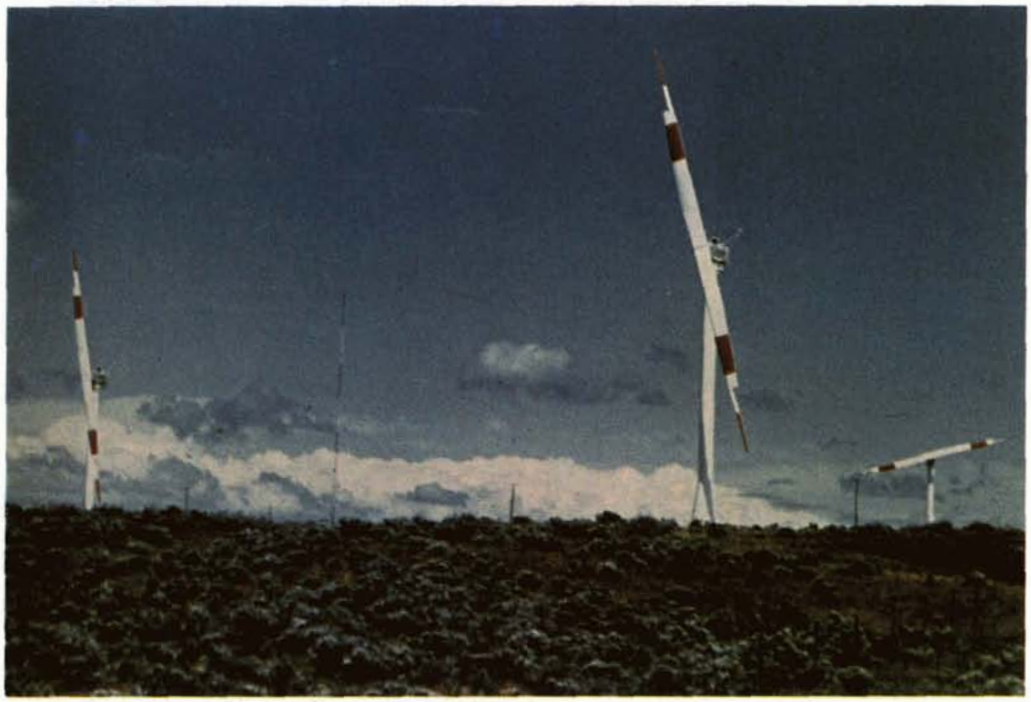
offers a number of other advantages. Its overall fuel use efficiency (including electricity and usable heat) is exceptionally high—about 80 percent when the system operates at full capacity; conventional electric power generation plants deliver only about 35 percent of their fuel's energy. Since there is no combustion, fuel cell systems are clean and quiet "good neighbors," free of the objections that greet proposed siting of combustion power plants. Fuel cell systems can be constructed in modular fashion to provide 40, 80 or more kilowatts, allowing flexibility in tailoring output to a specific requirement. Finally, electricity in excess of the requirement can be sold to the local power utility, reducing the fuel cell user's operating costs.

In the spring of 1982, testing began on the first field-sited 40 kilowatt fuel cell installation, located at Rawlinson's New System Laundry, Portland, Oregon. This test is being directed by Northwest Natural Gas Company, also of Portland; project participants include four other gas utilities serving the Pacific Northwest and Portland General Electric, which buys the surplus power produced by the Rawlinson fuel cell. The system operated for more than 2,000 hours and initial results were pronounced "good"; indications are that savings of about $300 per month can be realized in similar installations.

Meanwhile, NASA, DoE and the Gas Research Institute embarked on the next phase of the effort: an advanced 40-kilowatt On-site Fuel Cell Operational Feasibility Program, in which 30 major utilities, including two in Japan, are participating in a large-scale field test of units produced by UTC. This broad program involves test of 46 fuel cell systems operating in many different types of facilities, such as apartment buildings, nursing homes, banks, stores, restaurants, laundromats and warehouses; three units are to be sited at military installations. The intent is to evaluate existing fuel cell technology under a variety of different operating conditions and to identify problem areas correctible by further technology advancement. The first units in this program went into service late last year; the field test will continue through 1985. The Gas Research Institute, which is funding the major portion of the program, feels that the comprehensive field test will sharpen the focus for advanced technology and it could lead to production of commercially operational units within this decade.

In addition to its work in behalf of the gas utilities, Lewis Research Center is managing development of much larger "megawatt" fuel cell systems for use by electric utilities in the 1990s. This is a cooperative, cost-sharing effort—involving DoE, two contractors, and the Electric Power Research Institute, Palo Alto, California—of great interest to U.S. electric utilities. UTC's Power Systems Division is working toward a system capable of generating 11 megawatts (11,000 kilowatts). Taking a different technological approach, Westinghouse Electric Corporation's Energy Systems Division, Large, Pennsylvania is developing a 7.5 megawatt power plant. Both companies plan to have prototype systems ready for utility testing in the latter 1980s.

Research on fuel cells and other Earth-use energy systems is one example of NASA's effort to generate direct public benefit through application of aerospace technology. Other examples include what NASA calls space applications, orbital systems designed to do Earth jobs better or to do beneficial work that cannot be performed on Earth. Applications projects in being or in development include weather and environment satellites, Earth resources monitoring satellites, a space-based search and rescue system, advanced technology for communication satellites, and systems for processing materials in orbit, a step toward future space manufacture of products not producible on the ground due to the adverse influence of Earth's gravity. These energy projects and space applications have already produced substantial dividends on the national investment in space and they promise to generate benefits of significantly greater order in coming years.

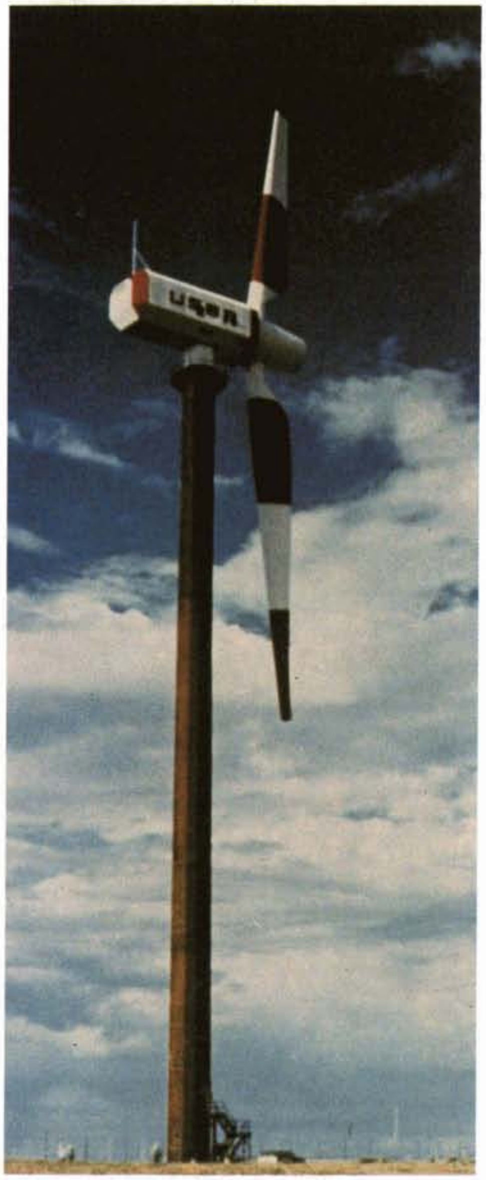


Wind Turbines

At left above is the world's highest capacity wind turbine installation, located at Goodnoe Hills along the Columbia River Gorge in Washington. It consists of three machines, each generating 2.5 megawatts of electrical power for a total of 7.5 megawatts, or 7.5 million watts. Known as MOD-2 systems, each has a 300-foot blade that drives a generator to convert wind energy into electrical energy. The cluster is operated by the Bonneville Power Administration, which feeds the electricity generated—enough to serve 2,000–3,000 average homes—into the northwest power grid for use by regional utilities.

The turbines were built by Boeing Engineering and Construction Company in a Department of Energy (DoE) program—managed by Lewis Research Center—aimed at development of advanced technology wind systems as alternative power sources. Under way for more than a decade, the program involves development and test of a number of differently-sized systems in different geographical locations under a variety of wind conditions.

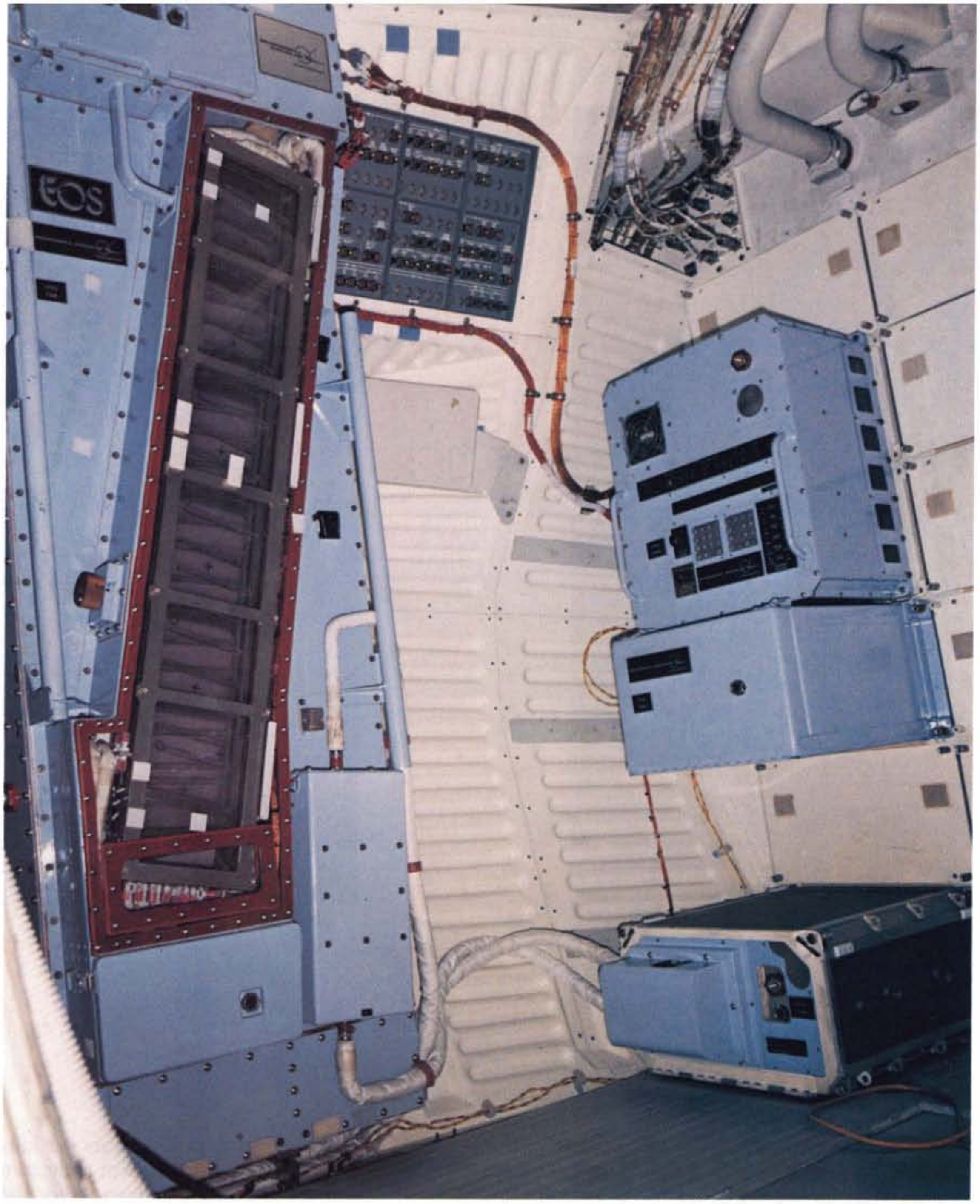
Testing of wind turbines began in 1975 with operation of a research experiment machine known as MOD-0 (left), designed to produce 100 kilowatts. Later, NASA operated four MOD-0A 200-kilowatt turbines, such as the one on Culebra Island, Puerto Rico (above center). Then—in 1979—the first of the megawatt turbines, a MOD-1 machine with a 200-foot diameter blade, was installed at Boone, North Carolina. Built by General Electric Company's Space Systems Division, it generated two megawatts, enough to meet the electrical requirements of several hundred homes. From all these projects, NASA and DoE have acquired more than 40,000 hours of experience in operation of large and intermediate-size wind turbine systems.




In a separate program under Department of the Interior (DoI) sponsorship, Lewis Research Center managed the installation of the WTS-4 system shown above, which employs a 256-foot blade to generate four megawatts. Located near Medicine Bow, Wyoming, it is the most powerful single unit yet operated. WTS-4 is an experiment by DoI's Bureau of Reclamation to determine how effectively wind energy can contribute to conserving water stored behind the agency's hydroelectric dams in the west. The electricity generated by the wind turbine is fed into a Wyoming power grid, reducing the need for hydroelectric generation, thus saving water. The WTS-4 and a Boeing MOD-2 machine sited in the same area are undergoing evaluation by the Bureau of Reclamation; successful test results could lead to construction at Medicine Bow of a multi-machine commercial "wind farm".

NASA and DoE are now working on designs for the next generation wind turbine, the MOD-5, a multi-megawatt machine incorporating advanced technology acquired over a decade of research; one concept is shown at upper right. When in production and used in a cluster at a site, MOD-5 machines should produce electricity at a cost of less than four cents per kilowatt hour. This is a rate that would make them truly competitive with other sources of power. Contractors for the design of the MOD-5 system are Boeing and General Electric, developers respectively of the MOD-2 and MOD-1 systems. Technology advances being considered include variable speed generators, large wood laminate blades and aileron blade control. Output power levels range from 3.3 megawatts to 7.3 megawatts. A decision is expected this year on whether to proceed with hardware fabrication.

Utilities all over the nation have been watching the NASA/DoE research effort. Some utilities are conducting their own experimental programs, some have already put smaller turbines into operational service. Utilization of multi-megawatt machines is expected to grow if large wind turbines achieve the goal of less than four cents a kilowatt hour, which is well below anything yet realized. Wind turbines won't work everywhere, because they need a fairly strong, consistent breeze, but studies show that nearly 40 percent of the United States has average winds strong enough to make electricity generation attractive.



Space Processing

Orbital materials processing technology advanced significantly during the past year with several successful Shuttleborne experiments and a number of new developments. A significant portion of the effort in this area involves experiments in separating biological materials, conducted under a Joint Endeavor Agreement between NASA and McDonnell Douglas Astronautics Company in which NASA provides Shuttle flight time for company developed experiments under a policy designed to encourage private investment in space industrialization.

McDonnell Douglas and its partner—Ortho Pharmaceutical Corporation, a division of Johnson & Johnson—are exploring the commercial feasibility of space-processed pharmaceuticals. Scientists have determined that it may be possible to develop new cures or improved treatments for many diseases by using cells, enzymes, hormones or proteins produced by the body. On Earth, these substances are separated from biological materials by a process called electrophoresis—but because Earth's gravity exerts a negative influence on the separation process, only a tiny amount of sample can be extracted at one time. Processing in gravity-free space offers a means of separating biologicals in the large quantities and high levels of purity needed for pharmaceutical production.

McDonnell Douglas went a long way toward confirming that potential by experiments—in three Shuttle flights last year—with the company developed Continuous Flow Electrophoresis System (CFES) shown above in its Shuttle mid-deck installation. CFES separates materials in solution by subjecting them to electrical stimulation in a computer-controlled process. A continuous stream of material is injected into a solution flowing through a fluid systems chamber, the long rectangular chamber seen at the left of the photo. When the electric field is applied, the materials pull apart into separate streams, flow out of the separation chamber and into a collection tray. The blue box at the right of the photo is the refrigeration module where biological materials are stored before and after processing. Another element of the system is the water cooling module (below the refrigerator) for dissipating heat generated by the process.

McDonnell Douglas reports that materials from a cell culture were successfully separated on Shuttle Flights STS-6 and STS-7 last year. In the photo below, Mission Specialist Dr. Story Musgrave is installing a sample collection tray for this experiment on flight STS-6; the object to his right is a camera placed on the front of the fluid separation chamber to photograph the sample flow. Results from these tests confirmed the ability of the CFES system to separate more than 700 times as much material as could be separated in similar operations on Earth, and to achieve purity levels four times better.

On Shuttle flight STS-8, the CFES was used in a different experiment with another McDonnell Douglas partner, Washington University School of Medicine, St. Louis, Missouri. The company and the university have signed a 15-year joint research agreement to pursue new treatments for diabetes. In tests with laboratory animals, Washington University researchers have successfully controlled diabetes by implanting live, insulin-producing beta cells from pancreatic tissue. They have long sought to improve the isolation and purification of beta cells and space processing may be the answer. The CFES experiment on STS-8 sought to determine the feasibility of producing highly purified beta cells in large quantities.

After two CFES flights in 1984, McDonnell Douglas will introduce a new system to separate material in the greater quantities Ortho will need for the research and clinical testing needed to get Food and Drug Administration approval for a new pharmaceutical. The new system is a fully-automated pre-commercial production plant to be flown in the Shuttle Orbiter's payload bay beginning in 1985; operating continuously throughout a Shuttle flight, it will produce 24 times as much material as CFES.

If continuing research confirms the practicability and profitability of commercial pharmaceutical processing, McDonnell Douglas plans to start production in an unmanned Earth-orbiting facility—perhaps as early as 1987. The space factory would operate continuously for months at a time, serviced by Shuttle crews who would deliver raw materials and collect separated products.

CFES is also used to separate materials for NASA scientists working on independent studies of fluid dynamics in space. NASA is conducting its own series of microgravity processing experiments in such areas as biological material separation, crystal growth and containerless processing.

The capability for Shuttleborne materials processing experiments advanced last year with the debut of Spacelab, developed by the European Space Agency, on Shuttle flight STS-9. Spacelab's pressurized module allows human direction of experiments and it includes special equipment called the Materials Science Double Rack Facility, which has several furnaces and other types of processing chambers. In this facility, the Spacelab 1 science crew performed more than 30 different materials processing experiments for investigators of nine nations.

NASA signed two other Joint Endeavor Agreements for Shuttle-based materials processing experiments, one with 3M Company, St. Paul, Minnesota, the other with Microgravity Research Associates (MRA), Coral Gables, Florida. The 3M Company will initiate Shuttle experiments in the near future, focusing on the growth of organic crystals and development of thin films. The company is targeting this type of research toward potential applications in such fields as memory and imaging media, electronic products, energy conversion and biology. MRA is exploring the potential for producing advanced electronic chips made from gallium-arsenide crystals. This type of crystal is manufactured on Earth, but with a very high rejection rate due to adverse gravitational influences. MRA hopes its research will lead to orbital production of commercially marketable gallium-arsenide crystals for semiconductor chips far superior to the silicon chips now being produced. The company's crystal growing furnace is planned for use on Shuttle flights in the latter 1980s.

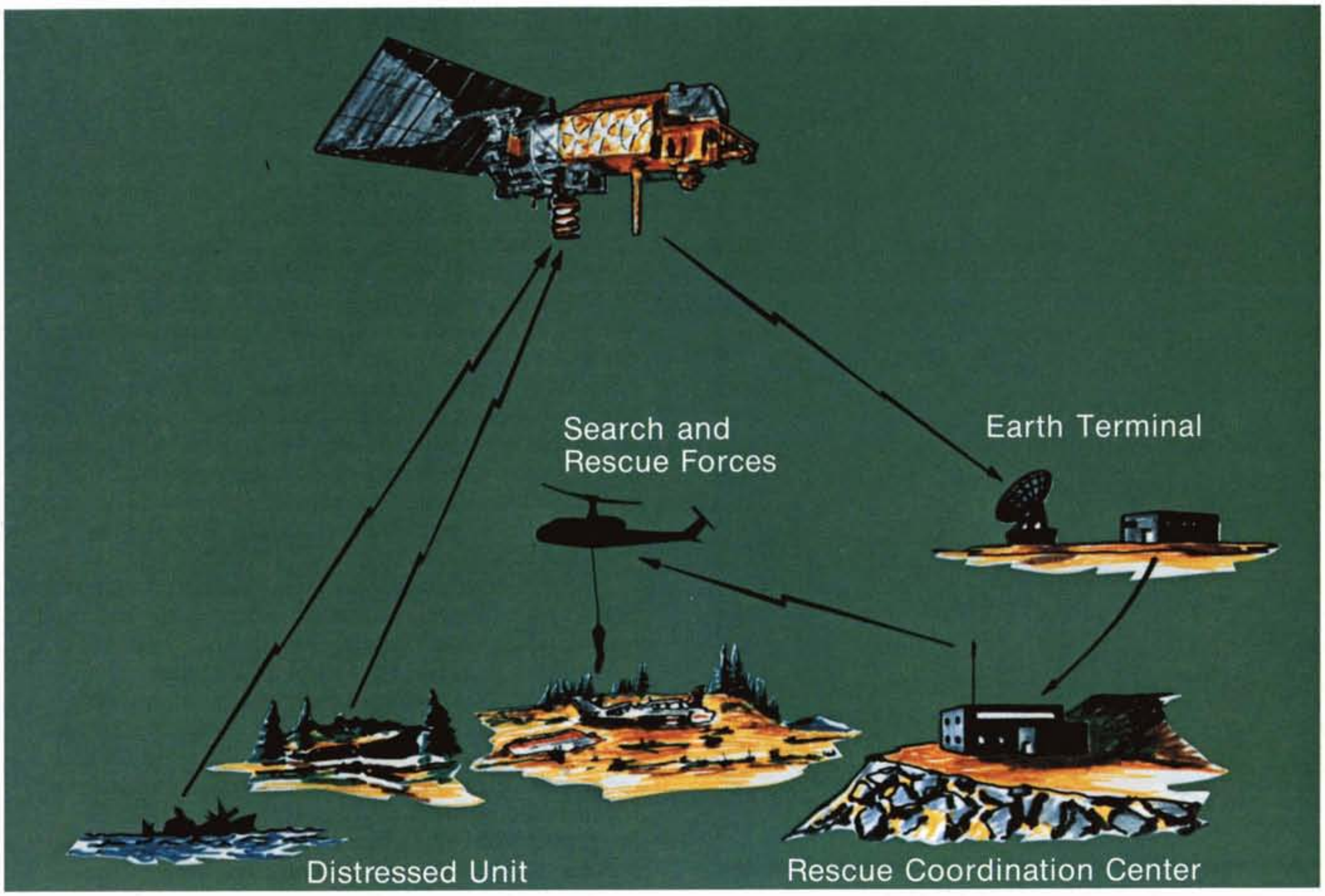
Orbital Factory

The spacecraft pictured is a space platform that could carry a factory module for manufacturing products in the near-zero gravity environment. Called Leasecraft, it is being developed by Fairchild Industries as part of a Joint Endeavor Agreement with NASA. First launch is targeted for 1987; Leasecraft will undergo a six-month orbital testing and demonstration period, after which it will become an operational system available to commercial and government users.

Leasecraft is based on the technology of the Multimission Modular Spacecraft (MMS), developed by NASA with Fairchild assistance; the MMS supplies utility services for such spacecraft as the Landsat earth observation satellite and the Solar Maximum Mission scientific satellite. The Leasecraft platform will measure 15 by 15 by 14.5 feet and it will be equipped with modules supplying power, command, data handling and other utilities required by payload modules, which will be mated to the platform in orbit. The primary use envisioned for Leasecraft is materials processing payloads on either an experimental or an operational basis. Payloads may also be scientific instrument packages or remote sensing systems. Leasecraft is expected to have a service life of more than 10 years.

The platforms will be launched from the Space Shuttle and the Shuttle will rendezvous with them about once every six months to service the platform, to exchange raw materials for finished products in manufacturing operations, or to change scientific or remote sensing equipment packages.

Under the Joint Endeavor Agreement, Fairchild will design and build the Leasecraft platforms and supply ground and flight support equipment and software. NASA is to provide technical assistance, Shuttle flight time and general purpose equipment and facilities needed to support Fairchild's research and development effort. NASA will support Leasecraft flights through Goddard Space Flight Center's mission control facilities.



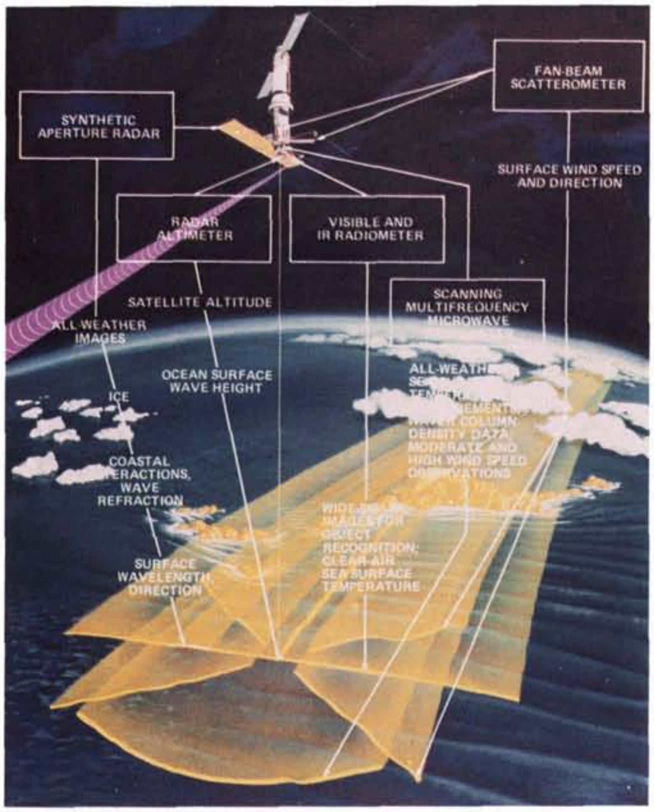
Search and Rescue Aid

Ships and aircraft carry radio beacons to signal emergencies and to provide a homing beam to help rescuers locate the craft in distress. A problem—until recently—was that there was little assurance that anyone would respond to the call for help because there was no method of *continuously* monitoring beacon signals. A solution to that problem, one that greatly increases the probability of saving lives, is an international satellite-aided system for detecting and locating signals from downed aircraft or troubled ships.

The space-based portion of the system is not a satellite but an electronic package carried as a secondary payload aboard an operational satellite; the equipment acquires emergency signals and relays the information to search and rescue stations on Earth. In collaboration with French and Canadian agencies and the U.S. Air Force, Coast Guard and National Oceanic and Atmospheric Administration (NOAA), NASA is operating a system called SARSAT, the monitoring element aboard NOAA weather/environmental satellites. NOAA-8, built by RCA Astro-Electronics and launched last year, houses the initial SARSAT package, which has been operating for more than a year. A second SARSAT system aboard another NOAA satellite will join the network this year, and four additional SARSAT-equipped satellites are being built.

The Soviet Union developed a similar monitoring package compatible with SARSAT and sent two of them into orbit on navigational satellites. The U.S./French/Canadian SARSAT and the Soviet COSPAS have been merged into a joint global search and rescue system, now undergoing evaluation, known as COSPAS/SARSAT. Norway and the United Kingdom are also participating in the program by operating ground listening posts called Local User Terminals (LUTs). There are nine LUTs: three in the Soviet Union, two in the U.S. and one each in France, Canada, Norway and England. The COSPAS/SARSAT system, though technically not yet operational, has already provided life-saving assistance in scores of emergencies.

COSPAS/SARSAT spaceborne monitors "listen" continuously on emergency frequencies used by ships and aircraft. When the monitor picks up an alert, it relays the information to a ground-based LUT as shown in the accompanying illustration. Within minutes, the LUT's computer produces a position fix, locating the distressed craft within 12 miles if it is equipped with existing-type beacons, three miles if it has a new, specially-designed beacon. The LUT notifies search and rescue centers that an emergency has occurred and advises of its whereabouts for guidance of search and rescue craft. COSPAS/SARSAT may lead to establishment of a permanent international operational system that, in addition to its life-saving potential, would allow substantial reduction in the cost of search and rescue work.



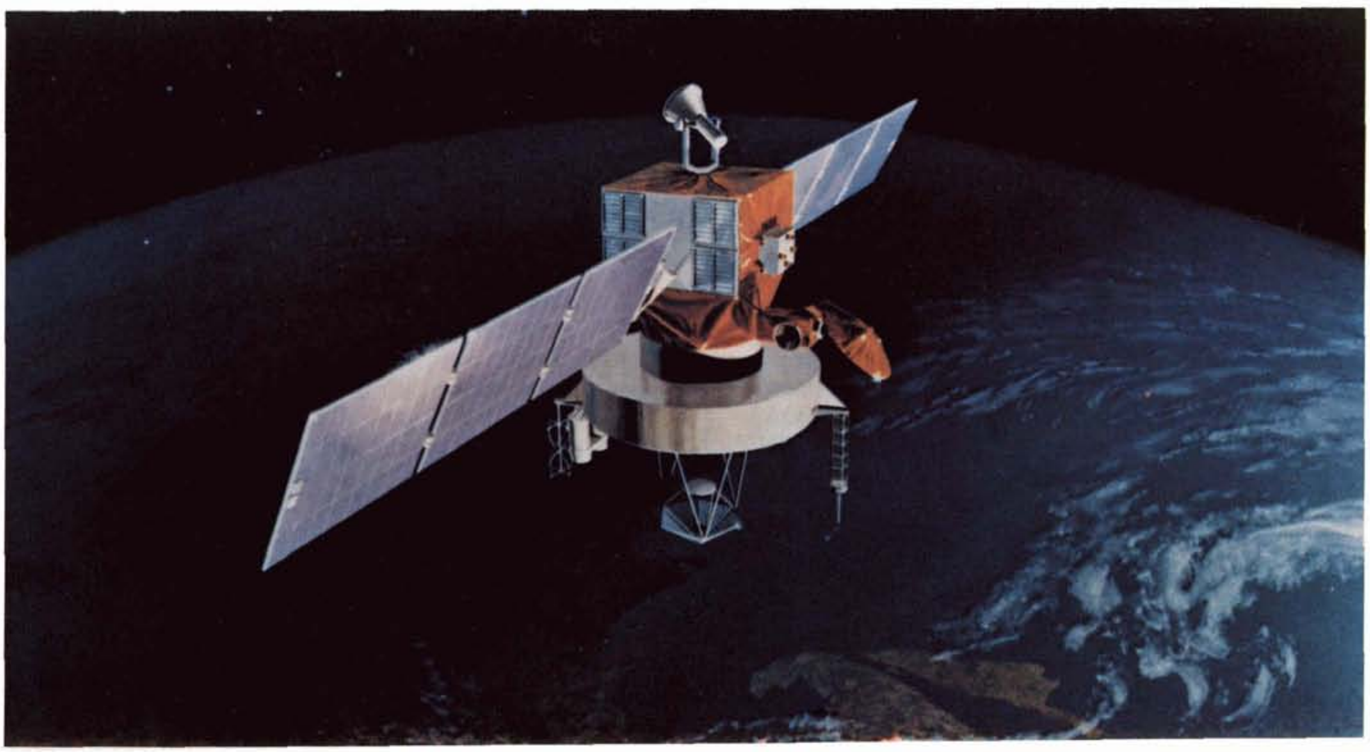
Earth Observation Satellites

Since 1972, NASA has been engaged in developing technology for satellites that continuously monitor changing conditions on Earth's surface, providing voluminous data that offers great potential benefit through more effective management of Earth's resources. The program has been singularly successful. NASA developed and tested a series of Landsat remote sensing satellites, each more advanced than its predecessor. Built by General Electric Space Systems Division, the Landsats have operated for 12 years and thoroughly demonstrated their capabilities for generating information of practical benefit over a broad range of applications—for example, crop forecasting, rangeland and forest management, land use planning, mineral and petroleum exploration, mapmaking, water quality evaluation and disaster assessment. With the most advanced member of the family—Landsat 5—now in operational service with the National Oceanic and Atmospheric Administration, NASA's attention is shifting to a related and equally important technology: observation of Earth's oceans.

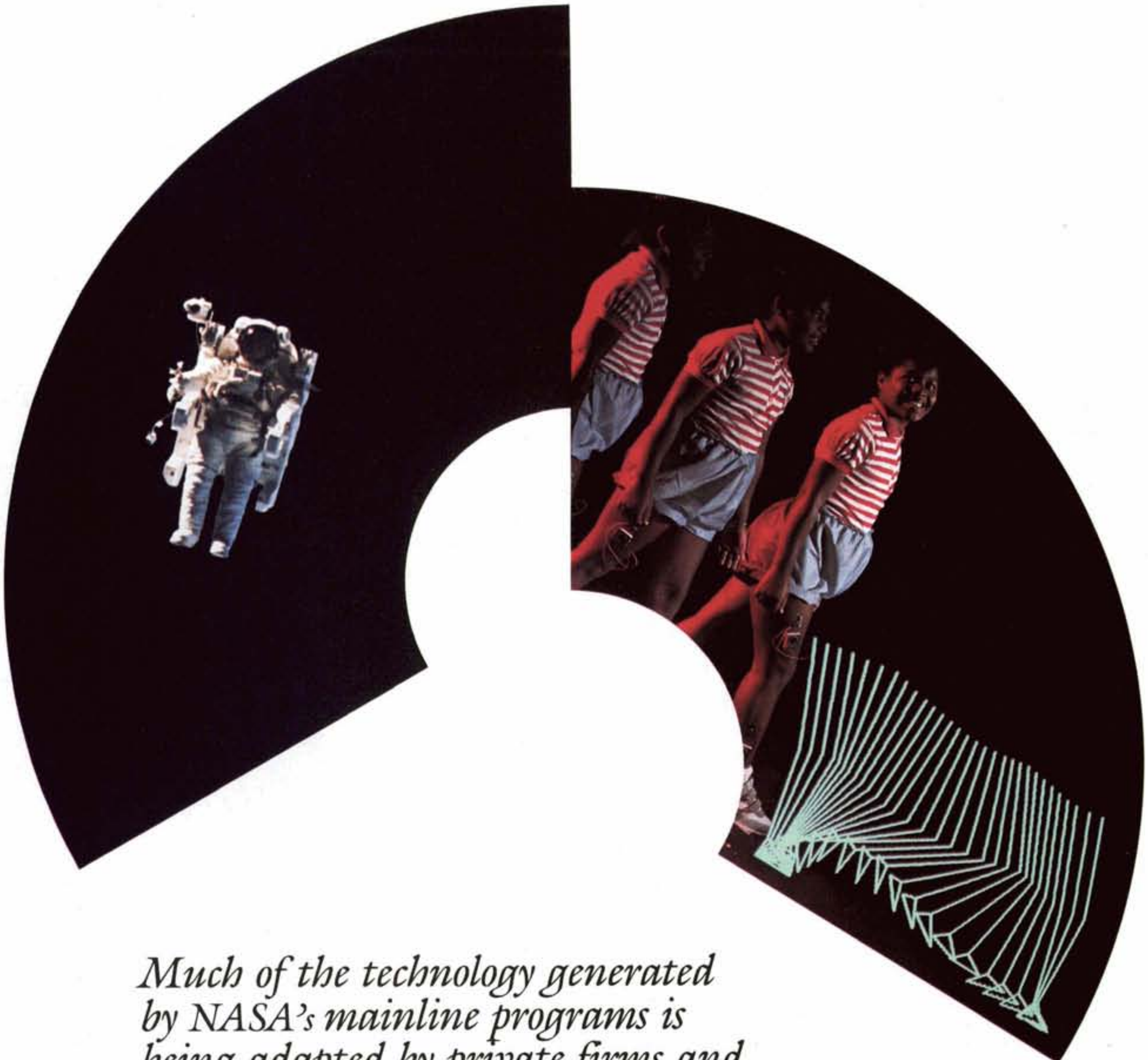
In 1978, NASA launched Seasat (left), an imaging satellite designed to collect data on changing conditions in the world's oceans. Seasat operated only three months, but it produced volumes of data and confirmed that instrumented satellites can provide valuable information that is useful in practical applications as well as in scientific studies.

NASA is now planning a highly advanced successor to Seasat, a satellite that would provide a vastly improved capability for observing the oceans on a global basis. It is known as TOPEX, for Ocean Topography Experiment; one concept of the spacecraft is shown below, but the final design has not been determined. The principal objectives of the TOPEX program are radar measurements of surface topography over entire ocean basins for several years; this input would be integrated with subsurface measurements and used in models to determine the general circulation of the ocean and its variability.

TOPEX would also report continuously on such changing factors as wave heights and directions, surface winds, current and tide patterns and movement of sea ice. The improved knowledge of ocean dynamics that TOPEX would provide suggests many opportunities for practical benefit in such areas as weather and climate prediction, coastal storm warning, maritime safety, waste disposal, ship design, ship routing and food production from ocean sources. TOPEX is planned for launch in the late years of this decade.



Technology Twice Used



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

Partners In Technology

Research collaboration between NASA and a major non-aerospace company exemplifies the benefit potential of aerospace technology transfer

In 1837, a pioneer blacksmith named John Deere perfected the steel plow and founded a company to manufacture farming equipment. Today, Deere & Company is the world's largest producer of farm implements and a leading manufacturer of equipment used in construction, forestry, landscaping, materials handling and other fields. Headquartered in Moline, Illinois, the company employs some 50,000 people, manufactures 600 different products in the U.S. and nine foreign nations, and sells them in more than 100 countries at the rate of about $4 billion annually.

A major reason for Deere & Company's success is its firm commitment to research and development, funded in recent years at an average of better than four cents for each sales dollar—which means an annual investment approaching $200 million. Like the company itself, R&D is highly decentralized; each factory is responsible for developing its own product line. All of the factories are served by the John Deere Technical Center in Moline, which conducts advanced research toward new technology that may eventually be incorporated in the products of the various divisions. Aerospace technology is playing an important part in the company's research effort; Deere's Technical Center is working with NASA in a broad technical interchange program, exploring avenues of aerospace research that promise product improvements.

NASA and the company are cooperating in about a dozen different areas of research. In some instances, cooperation takes the form of Technical Exchange Agreements, wherein NASA and Deere share information, facilities and expertise and jointly conduct research, testing and evaluation. In other cases, NASA and the company are cooperating informally; Technical Center scientists visit NASA field centers, consult with NASA experts in various fields, study reports of aerospace projects and acquire information about new techniques, procedures, materials and other advances originating in aerospace programs. It helps Deere & Company's researchers fill gaps in their knowledge, avoid research "dead-ends," and identify promising new lines of investigation. And it's a two-way street: NASA benefits from interaction with non-aerospace scientists whose objectives are different and from knowledge of the company's own extensive R&D, thus expanding NASA's horizons and suggesting ways by which the agency might broaden and accelerate its transfer of technology to the non-aerospace community.

One example of NASA/Deere collaboration involves experiments in processing materials under near-zero gravity conditions, a burgeoning technology that promises extraordinary benefits in orbital manufacture of products that cannot be made on Earth due to adverse influences of Earth's gravity (see page 00). NASA and several industry firms are performing low-gravity research

Shown above is a four-wheel drive tractor, at upper right a combine harvester and at lower right a grader, equipment representative of the broad product line of Deere & Company. Deere scientists are working with NASA in a multifaceted technical exchange program, investigating areas of aerospace technology that might be applied to the company's products.

aboard the Space Shuttle, in aircraft—where low gravity can be experienced for a few minutes—and in ground-based simulations. Although Deere & Company is not planning to manufacture products in space, it is using the low-gravity environment as a research laboratory, studying what happens to iron as it is melted and solidified in aircraft-borne furnaces.

Cast irons account for about 25 percent of the weight of John Deere products. Therefore, anything Deere & Company can do to improve the strength, quality or producibility of cast irons is very important to Deere and its customers. The strength, castability and machinability of cast irons is highly dependent on the shape of the graphite within the steel matrix. The low-gravity environment provides an opportunity to study the formation of graphite from a new perspective. Deere & Company is currently concentrating on studying the "diffusion phenomenon," where carbon atoms move in the molten iron as it solidifies and form various shapes from spheroids to thin flakes; knowledge of how and why this happens can lead to new Earth processing techniques for producing improved, more economical castings. Deere & Company learned a great deal from experiments in a furnace developed by Marshall Space Flight Center, flown aboard a NASA aircraft that achieves near-zero gravity for very short periods. That research showed promise and the company is now planning long-duration experiments aboard the Space Shuttle with an advanced furnace capable of accommodating larger samples.

Another example of joint effort is the Stirling engine, an external combustion type of engine being investigated by NASA (Lewis Research Center) and the Department of Energy as an alternative propulsion system for road vehicles. The Stirling engine offers a number of advantages, chief among them lower fuel consumption and the ability to use a wide range of fuels. Deere & Company is interested in the Stirling's potential as an alternative to the diesel engines currently manufactured. Under a Technical Exchange Agreement, Deere is conducting controlled laboratory tests of the Stirling, seeking to increase power output and overall efficiency. Under the agreement, NASA furnishes the engine, parts and certain services; Deere conducts testing and analysis and shares the results with NASA. This project is an excellent example of the sharing aspects of NASA/Deere collaboration: Deere & Company is able to explore a technology of interest with a reduced investment and NASA benefits from the results of the company's investigations, which supplement and broaden the data being gathered by Lewis Research Center.

Deere & Company is interested in another area wherein Lewis has extensive expertise: use of ultrasonics to measure the properties of materials for non-destructive testing. Lewis and Deere researchers are working with a committee of the American Foundry Society that is making a detailed study of the mechanical properties of graphite iron; they plan to make a comparison of property measurements acquired by the NASA ultrasonic procedure and by conventional destructive tests. If they find a good correlation, the NASA technique would be highly beneficial—not only to Deere & Company but to the entire foundry industry—as a way of reducing the cost of testing production castings and allowing quality checks of *all* production castings, which obviously cannot be accomplished by destructive tests.

This collaboration between a government aerospace research agency and a major non-aerospace manufacturer exemplifies a different form of the aerospace spinoff process. In the traditional type of spinoff, technology originated to meet aerospace needs is reapplied by industrial firms to create an innovative product or process. Such product spinoff seems likely to result from NASA/Deere cooperation, but in this instance Deere & Company is not simply reapplying technology already available but actively participating in the development of technology, using its own extensive R&D capability to complement NASA's efforts, adapting NASA information to new research paths and providing feedback of importance to NASA's own work.

One of the world's largest manufacturing businesses, Deere & Company produces agricultural tractors, combine harvesters, tillage and planting tools, hay and forage equipment; industrial equipment such as crawler tractors, loaders, motor graders, scrapers, excavators and materials handling tools; and a line of lawn and garden tractors and attachments. A highly integrated firm, Deere & Company also makes most of the components used in assembly of its products—engines, transmissions, castings of all types, hydraulic cylinders, even nuts and bolts.

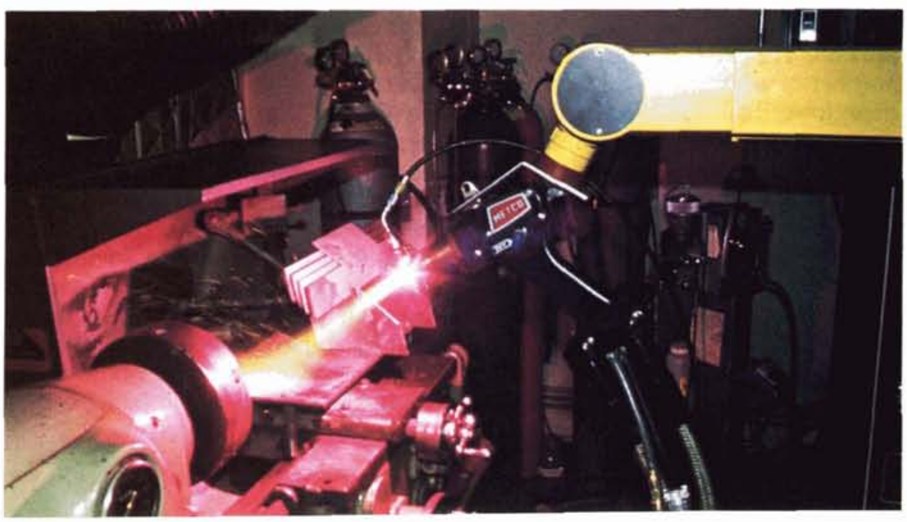
To maintain competitive status over such a broad product line, Deere & Company conducts research and development over a very wide spectrum at its John Deere Technical Center, its Product Engineering Center in Waterloo, Iowa, and each of its many manufacturing plants. Some 3,500 people, backed by an array of sophisticated facilities, are engaged in R&D programs. One phase of the company's R&D involves active collaboration with NASA in a number of research activities, with the goal of adapting aerospace technology to the John Deere product line and to the processes by which these products are manufactured.

In addition to experiments in low-gravity materials processing, advanced propulsion and ultrasonic testing (see page 53), NASA/Deere technical interchange extends to these areas:

Composite Materials. With help from Langley and Lewis Research Centers, Deere & Company is exploring the possibility of substituting fiber reinforced plastic composites or metal composites for certain mechanical components of John Deere equipment. For example, metal composites capable of withstanding very high temperatures are being investigated for applications in diesel engines, where operating temperatures are so high that existing materials are limiting factors on horsepower and fuel efficiency.

Ceramics. Contacts with scientists and engineers at several NASA centers, and with NASA contractors who developed technology for the Space Shuttle's protective ceramic tiles, provided Deere & Company a knowledge base that resulted in a company decision to set up its own ceramic research facility. Deere

Below left, NASA and Deere technicians aboard a KE-135 research transport demonstrate weightlessness as the aircraft flies a parabolic curve to achieve near-zero gravity for brief periods. Deere & Company has conducted metal casting tests under low gravity conditions. In the photo below, technicians are conducting an experimental "pour" of a molten iron sample during a moment of low gravity, their feet strapped to the floor to keep them from floating.



Ceramic research is one area of NASA/Deere cooperation; Deere is testing ceramics to determine their impact on the drag and wear resistance of tillage equipment. Here a robotic arm is spraying hot ceramic onto a tool at the John Deere Technical Center.

scientists are studying ceramics toward their possible use as insulating material for high temperature engine parts or perhaps for making some parts entirely of ceramics.

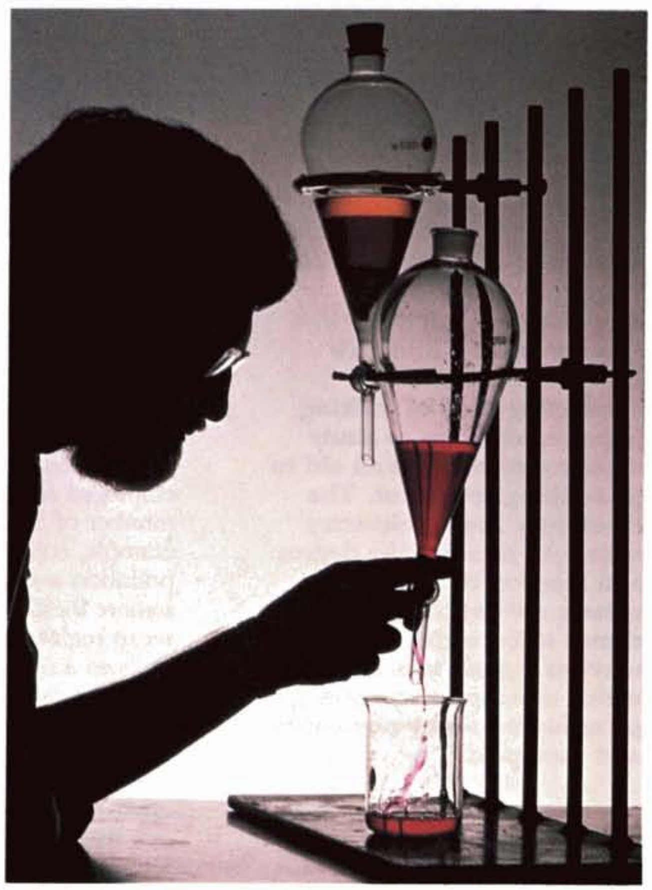
Wear and Lubrication. NASA centers, particularly Lewis Research Center, have provided Deere researchers considerable information on parts wear and advanced lubrication materials and techniques, helpful in company studies of gear wear and protective measures. Although NASA information reflects aerospace interests, it has been found to be readily adaptable to company research on its own problems.

Plasma Coatings. Lewis is conducting extensive research on plasma coatings, used as anti-corrosion protection for aircraft turbine engine parts operating in an extremely hot environment. A visit to Lewis by Deere scientists, and follow-up contacts with NASA personnel, provided the company a wealth of information on techniques for depositing and testing plasma coatings. Lewis' assistance was instrumental in a company decision to create its own laboratory to explore developments in this area. Plasma coatings are being considered as protective shielding for components of farm implements subjected to high-wear environments, such as ground-engaging tools and parts of machines over which hay and grain slide.

Sensors and Electronics. One Deere & Company target is development of simple, inexpensive sensors for determining the depth of an implement in the soil. The company is also interested in sensors and computer programs for robotic welders and manipulators used in the manufacturing process, and in high reliability electronic devices for a variety of applications. Company research in these areas has benefited from information supplied by Marshall Space Flight Center and Jet Propulsion Laboratory.

The NASA/Deere relationship is broader than, but representative of a number of similar arrangements between NASA and industrial firms. Through several different types of cooperation mechanisms (see page 119), NASA seeks to effect broader direct transfer of aerospace technology—as well as indirect secondary applications, or spinoff—in the interest of U.S. productivity.

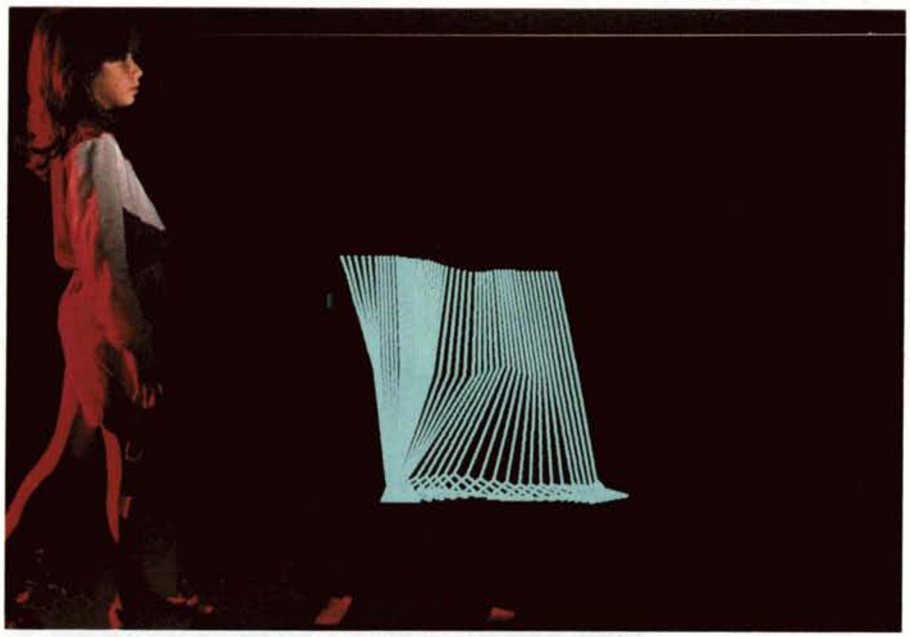
In Deere's new human factors laboratory, engineers study how vibration and noise can affect the performance of a vehicle operator.



The Dyna-Cart (above) was developed by Deere engineers to help them measure the effects of ballasting, tire slippage and other factors on fuel efficiency. Technical Center scientists are also studying the properties of alternative fuels (right) that may power future products.

New Help for the Handicapped

A space-derived biotelemetry system heads a representative group of spinoffs in the field of health and medicine



The motion Analysis Laboratory of Children's Hospital at Stanford is conducting tests of walking impaired children to study muscle movement as an aid to prescribing treatment. The laboratory uses a telemetry system to measure the degree and location of abnormal muscle activity. Leg sensors, shown at far right, send wireless signals to a computer, which develops pictures of gait patterns for use by physicians and therapists.

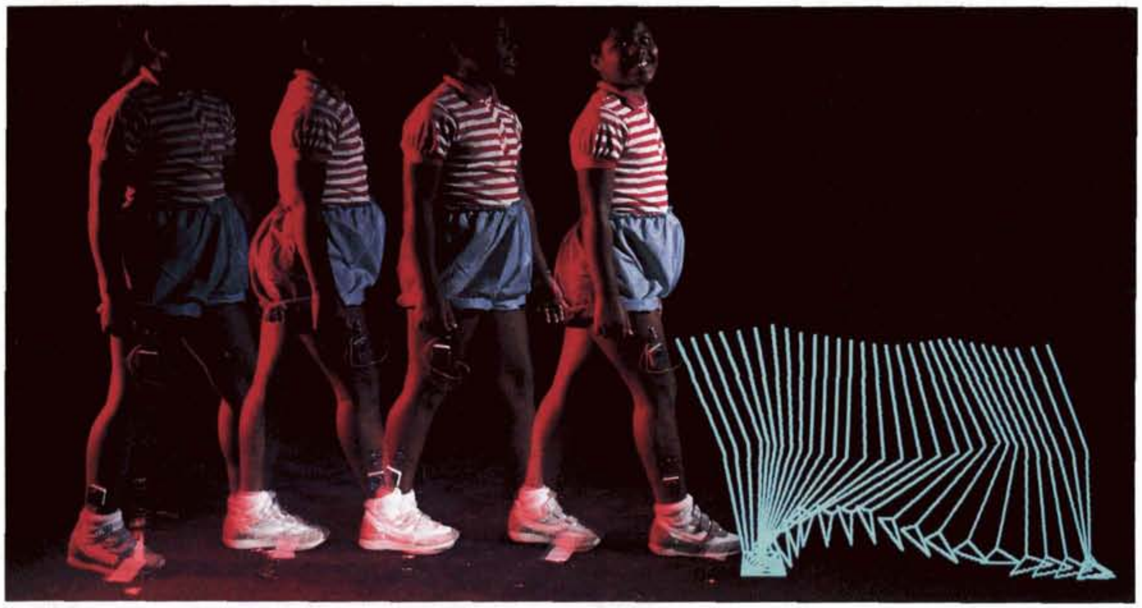
Telemetry is a process whereby data acquired in orbit is sent to Earth by radio in the form of coded signals, which are decoded on the ground to become useful information. The technique has been employed advantageously in a number of Earth applications, for example, collecting weather, air pollution and water quality data from remote locations, or sending flow measurements from unattended oil wells to a central data repository.

Biotelemetry is a specialized form of telemetry in which the coded signals contain physiological information. It has been used extensively in the U.S. space program as a means of monitoring astronaut vital functions from the ground.

Spinoff uses of biotelemetry include its employment by physicians to "interrogate" human-implanted devices and by hospitals to monitor the conditions of a number of patients from a single location. A new and important medical application, in development for more than a decade, is use of biotelemetry as a diagnostic tool in treatment of patients who experience difficulty walking due to birth defects, disease or injury.

Such disorders affect the nervous system, causing muscular spasticity and loss of coordination. The individual muscles affected vary widely, so it is difficult to determine, by physical examination alone, which muscle groups are most involved. But through a process called electromyography—the recording of electrical activity in the muscles—physicians can identify the offending muscles for development of remedial strategy. Sophisticated laboratory equipment can detect the degree and location of abnormal muscle activity, monitor changes and help the physician in prescribing treatment.

At a score of U.S. hospitals, a space-derived biotelemetry system is providing important assistance in electromyographic analyses. The Gait Analysis Telemetry System—a cooperative development of NASA, Children's Hospital at Stanford, Palo Alto, California and L&M Electronics Inc., Daly City, California—enables physicians to obtain detailed information on a patient's leg muscle action during walking tests. Miniature sensor/



transmitters, each about the size of a half dollar, are affixed directly over the muscle group being studied. Each transmitter has its own tiny lithium battery and a pair of sensing electrodes. The muscle activity sensed—called an EMG, for electromyogram—is sent to a computer for analysis and display.

The system's big advantage lies in the fact that telemetry signals are transmitted without wires. Other means of monitoring EMG involve wires connecting leg sensors with a receiver/recorder. But the wires, and an associated battery pack worn on the patient's waist, may hamper the subject's walking pattern and thus reduce the accuracy of the information sought. The spinoff system records the *true* gait pattern, providing an important assist to the physician or therapist.

The basic L&M Electronics receiving unit has four channels, but its informational capacity can be increased by adding additional channels in increments of four. Several hospitals employ eight channel systems to allow simultaneous acquisition of EMG signals from several transmitters; in a typical eight channel test, the patient has three sensor/transmitters on each leg, plus one on each foot to send information on exactly which parts of the foot touch the floor.

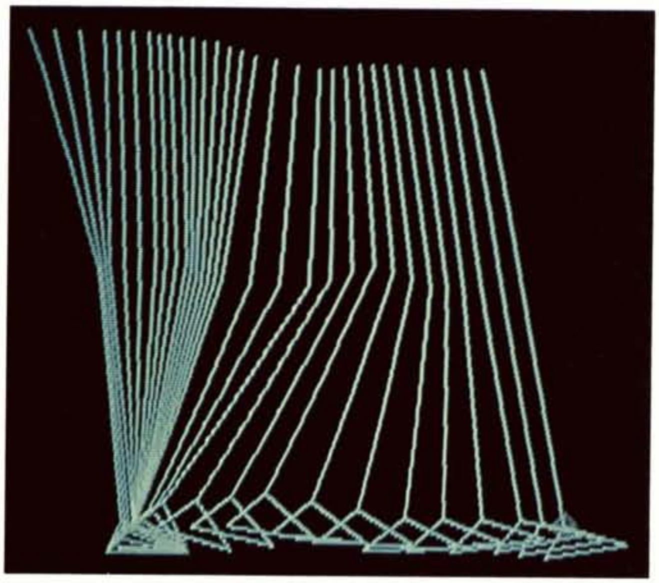
An example of the system's use is the work of the Motion Analysis Laboratory of Children's Hospital at Stanford. The laboratory conducts walking tests of children afflicted with cerebral palsy, muscular dystrophy, congenital disorders or injuries. The telemetry system records, measures and analyzes muscle activity in the limbs and spine; its information is available in printed readout form and in computer-developed pictures of gait patterns. This information helps physicians determine the potential of corrective surgery, evaluate various types of braces, or decide whether physical therapy may improve a child's function. The laboratory's success in this type of service has made Children's Hospital at Stanford a regional center for patients referred from other hospitals in the area.

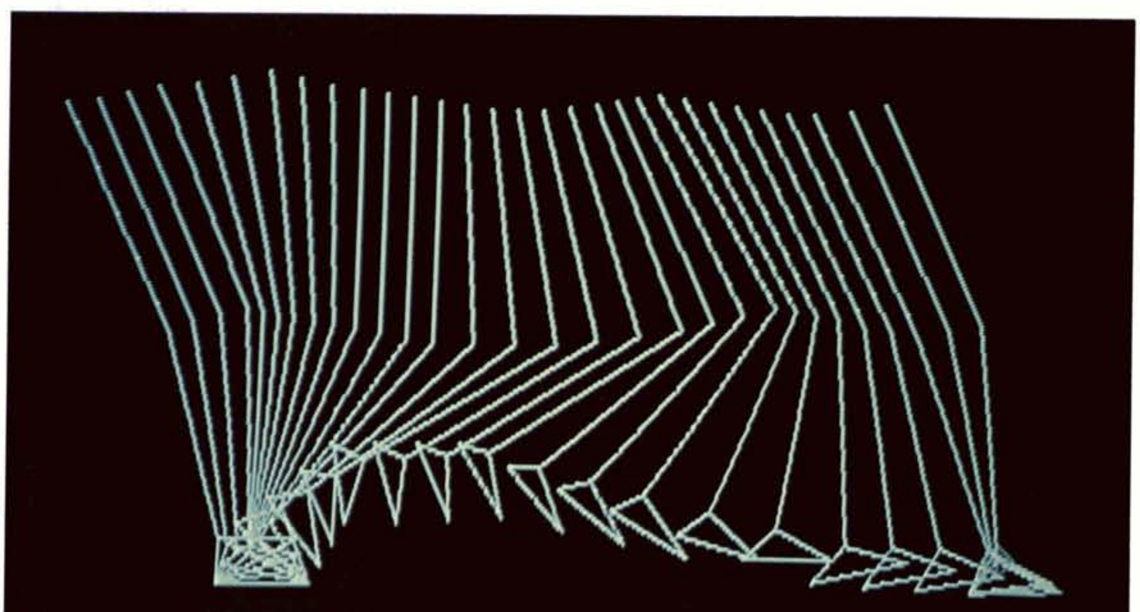
The same biotelemetry system is being used in a research program at the nearby Rehabilitation Research and Development Center (RRanD) of the Veterans Administration Medical Center, Palo Alto, California, where Dr. Michael Zomlefer, in collaboration with Dr. Ronald Gaines of the Spinal Cord Injury Center, are investigating the possibility of restoring locomotor function to patients with spinal cord injuries and others with severe gait disorders.

Experimental work with animals has shown that many mammals can perform stepping locomotor activity even after a complete spinal cord transection. It is not known whether humans with spinal cord transections can perform stepping movements. That is what Drs. Zomlefer and Gaines and their associates at RRanD are investigating. Volunteer patients are suspended in a modified parachute harness over a moving treadmill belt. The only stimulus to the patient is the contact of the foot with the belt. Any movement is recorded by a video system, while the telemetry system measures electromyographic activity in the lower limb muscles.

The thesis of this study is that humans possess some form of spinal "pattern generator" for locomotion. Say Drs. Zomlefer and Gaines: "The presence of spinal stepping in our subjects would strengthen the relevance of existing animal work in the area, and create the groundwork for more quantitative studies with human subjects. Evidence leading to the existence of spinal locomotor pattern generators would be an exciting development, suggesting the possibility of simple controllers for the generation of locomotion in humans with cord injuries."

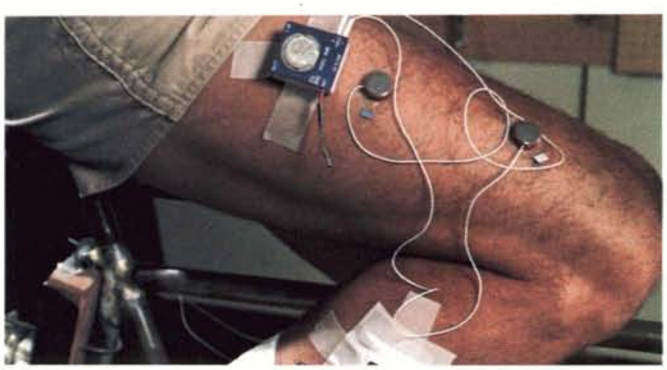
At right, Neil Adler, director of the Motion Analysis Laboratory of Children's Hospital at Stanford, studies a computer printout of a walking test measured by the Gait Analysis Telemetry System. The computer produces video images of walking patterns as an aid to determining remedial measures for children whose mobility is restricted. The photo below shows a normal walking pattern; the bottom photo pictures an abnormal gait.





At the Rehabilitation Research and Development Center of the Veterans Administration Medical Center, volunteer paraplegic Howard Baxter is being readied for a locomotion test (right). At far right, the patient is suspended over a moving treadmill belt, while Dr. Michael Zomlefer (left in photo) and Dr. Ronald Gaines move his legs. The telemetry system records signals received from the muscle sensors and indicates whether there is any vestige of locomotion.

In a related project at the Veterans Administration Rehabilitation Research and Development Center, Drs. Curt Boylls, Felix E. Zajac and Michael R. Zomlefer are developing computerized muscle models and studying the muscle activity involved in various forms of human locomotion. One experiment involves use of a bicycle "ergometer," a stationary pedaling machine in which one leg pedals at a different speed than the other in a study of interlimb coordination. Above, biomedical engineer Douglas Schwandt demonstrates the machine he helped design and construct. The sensors shown in the closeup view below transmit muscle data for computer analysis.



Implantable Heart Aid

The device pictured, a spinoff from miniaturized space circuitry, is a human-implantable heart assist system that could annually prevent thousands of deaths caused by erratic heart actions known to the medical profession as arrhythmias. Called AID®-B and produced by Intec Systems, Pittsburgh, Pennsylvania, it is a second generation version of the AID implantable automatic pulse generator used for several years.

The original AID was designed to correct the heart condition known as ventricular fibrillation (VF), in which the heart loses its ability to pump blood, causing death or brain damage in a matter of minutes. The implanted AID consisted of a microcomputer, a power source and two electrodes for sensing heart activity. Monitoring the heart continuously, the device was capable of recognizing the onset of VF and delivering a corrective electrical countershock to restore rhythmic heartbeat. It was, in effect, a miniaturized version of the defibrillator used by emergency squads and hospitals, with the advantage of being permanently available to patients with high risk of experiencing VF. The AID pulse generator was developed by Intec Systems and Medrad Incorporated, also of Pittsburgh, in conjunction with Drs. Michel Morowski and Morton Mower, both of Sinai Hospital, Baltimore, Maryland. NASA funded an independent design review of the pulse generator, conducted by the Applied Physics Laboratory of The Johns Hopkins University, Howard County, Maryland.

The AID device was highly successful in correcting VF. However, because the sensing circuitry was designed specifically for that purpose, it sometimes failed to detect another form of arrhythmia known as ventricular tachycardia (VT). Therefore, the AID team—Drs. Morowski/Mower and Intec Systems—developed the more advanced AID-B, formally known as the Implantable Automatic Cardioverter-Defibrillator. The second generation device has four sensing electrodes rather than two and it detects and corrects a broader spectrum of arrhythmias, including VT as well as VF. It also has an audio speaker that can be externally activated to determine the status of the device, and it has an internal counter to record the number of countershocks delivered; this information, important to the attending physician, can be telemetered to an external receiver.

The AID-B was introduced to clinical study in the spring of 1982 and by June 1983 there were 231 documented life-saving situations wherein spontaneous arrythmias were detected and automatically converted by the device. By the spring of 1984, some 300 implantations had been effected and the implant rate was about 30 a month. Under a grant from NASA, Intec Systems and the Applied Physics Laboratory of The Johns Hopkins University are developing a still more advanced model.

Heart Rate Monitor

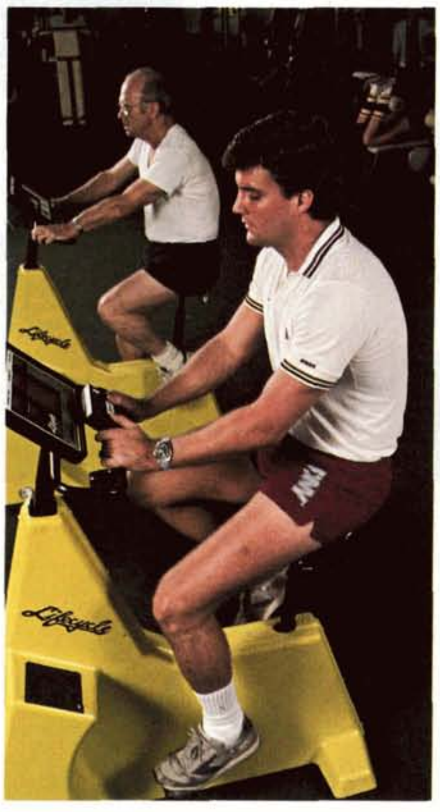
In the mid-1970s, NASA saw a need for a new type of sensing electrode for monitoring the heart action of astronauts over long periods of time. The widely-used conducting electrode, which makes contact with the skin through a paste electrolyte, is generally satisfactory for acquiring electrocardiographic data in normal use by hospitals or physicians, but for long duration use it has disadvantages—for example, the paste may dry, causing unacceptable distortions of the data sensed. Other electrodes make direct contact with the skin without use of a paste electrolyte. They, too, pose problems for long use in space, principally the "motion artifact," wherein movement of the subject causes movement of the electrode's contact and induces signal-distorting noise.

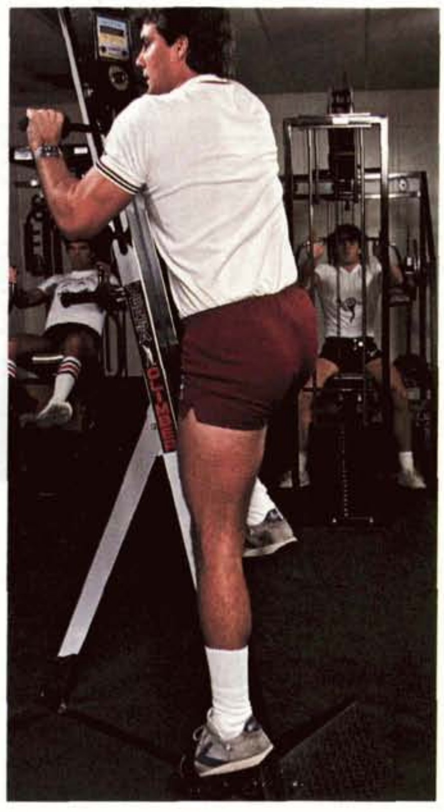
Accordingly, NASA initiated development—through a grant to Drs. Robert M. David and William M. Portnoy of Texas Technical University, Lubbock, Texas—of an advanced electrocardiographic electrode suitable for long term astronaut use. The Texas Tech team responded with an insulated capacitive electrode constructed of a thin dielectric film applied to a stainless steel surface. The electrode functions immediately on contact with the skin and is not affected by ambient conditions of heat, cold, or light, nor by perspiration, dry, rough or oily skin conditions; the insulative film prevents motion artifact. NASA was assigned the patent to the invention and subsequently NASA awarded a license for use of the technology to California entrepreneur Richard D. Charnitski. Charnitski founded Heart Rate Inc. (HRI), Costa Mesa, California to continue development and to produce heart rate monitors and exercise machines for the physical fitness industry and medical markets. At lower left, a heart rate monitor is being assembled by a HRI technician.

HRI has completed prototype demonstrations for three products—a heart rate wrist watch, a chest strap mounted monitor and an aerobic machine controlled with heart rate. The sensors have also been tested and proven to meet the American Heart Association's specifications for electrocardiographic electrodes. HRI is discussing manufacture and marketing of these devices with other companies. One company—Lifecycle, Inc., Irvine, California—is marketing the HRI device as the Lifecycle™ Aerobic Monitor for use by health clubs and sports organizations to assure that a user's heart rate during exercise is within proper limits; the user simply presses his thumbs to two sensors to get an instant digital heart rate reading. The unit can be wall-mounted for use before or after exercise, or it can be affixed to exercise equipment such as the Lifecycle Aerobic Trainer (below center), a programmable hill pedaling device with an electronic display that shows such factors as pedaling speed, calorie expenditure rate and exercise time. In such an installation, the HRI heart monitor can be a separate unit or the circuitry can be added to the existing electronic system, with the heart sensors activated by hand contact with the handlebar grips.

HRI is also marketing a monitor called 1.2.3, Heart Rate™ with a product of its own manufacture, the Versa-Climber™ (below right), a vertical stepping exerciser designed to use all the major skeletal muscle groups for aerobic conditioning and strength training. The Versa-Climber has a microcomputer and a digital display showing exercise time, climbing rate and step rate.

™Lifecycle and Lifecycle Aerobic Monitor are trademarks of Lifecycle, Inc.
™1.2.3 Heart Rate and Versa-Climber are trademarks of Heart Rate Inc.



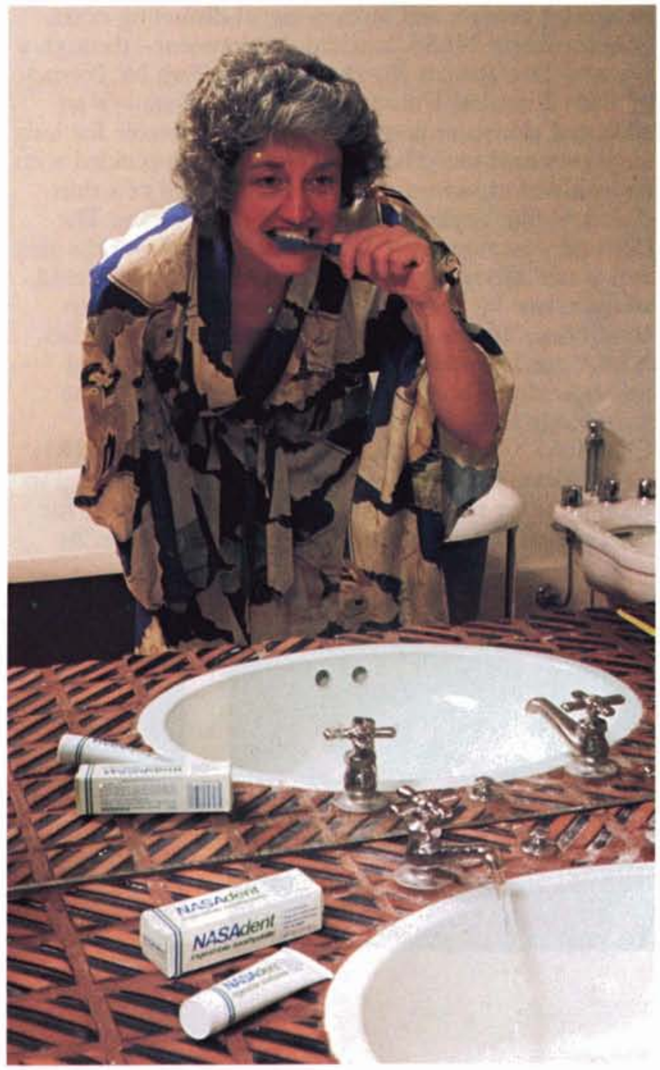


Ingestible Toothpaste

Toothpaste is not something one readily associates with the space program but it was one of the myriad considerations of putting man into space. Back in the 1960s, manned spacecraft were small and cramped, every available inch packed with mission-related equipment. It was impractical to include facilities for brushing teeth in the normal fashion, for example, a lavatory basin for expectorating and a system for handling the expectorated waste in a zero-gravity environment. Planning for long duration flights, NASA became concerned about astronauts' oral hygiene and sought an answer.

It was supplied by Dr. Ira L. Shannon, a dental consultant to Johnson Space Center associated with the Oral Disease Research Laboratory of the Veterans Administration Hospital in Houston, Texas. Under NASA contract, Dr. Shannon developed a new type of toothpaste that is foamless and can be swallowed after use. Comparison tests with a commercially available dentifrice showed that there was no significant difference in the cleaning ability and user acceptance of the two types of toothpaste. Applied without water, the pleasantly-flavored ingestible toothpaste has been used for years by astronauts in space and on Earth, in some instances even by their families. Last year it was introduced to the commercial market by Scherer Laboratories, Inc., Dallas, Texas as NASAdent.

The dentrifice is by no means a fad product; it is an important aid to maintaining oral hygiene among patients in hospitals, nursing homes and other special care facilities. A prime advantage is the fact that NASAdent's formulation eliminates the possibility of choking on air bubbles, a problem among total nursing care patients. It also offers major benefit to certain categories of patients, such as those bed-confined in hospital wards who might not have facilities for expectoration; paraplegics confined to wheelchairs; patients with oral-facial paralysis whose ability to expectorate is limited; the mentally handicapped; and others whose illness require that attendants carry out the teethbrushing for them. Scherer Laboratories suggests that NASAdent is also useful as a first toothpaste for children because of its ingestibility and lack of foam.



Slow Scan Telemedicine

In the upper photo, CT (computer tomography) technician Glenn Gray of Washington Adventist Hospital, Takoma Park, Maryland is transmitting a CT scan of a patient over a standard telephone line. The lower photo shows radiologist Dr. James Nelson viewing the image on a TV monitor in his home at Burtonsville, Maryland. The rapid transmission of medical information allows Dr. Nelson to make an immediate preliminary diagnosis, for use by the attending physician at the hospital, without making the half-hour trip to the hospital—a time saving that could be vitally important to an emergency patient and one that is also important to the productivity of hospital staff and consulting physicians.

Washington Adventist Hospital and Dr. Nelson use equipment manufactured by Colorado Video Inc., Boulder, Colorado, a pioneer in Slow Scan TV. This technology, which originated in the U.S. space program, permits transmission of still video images inexpensively and conveniently over telephone lines, or over radio, microwave and satellite channels. In commercial television, a viewer sees 30 pictures per second. Slow Scan TV—also called narrowband video and "freeze frame"—takes 30 seconds to a minute to transmit a single still frame, but the motion factor is not a requirement in most medical applications. Slow Scan employs a standard closed circuit camera connected to a device called a scan converter, which slows the stream of images to match an audio circuit, such as a telephone line. Transmitted to its destination, the image is reconverted by another scan converter and displayed on a monitor; Dr. Nelson's brief case unit shown in lower photo is a portable converter, usable wherever there is a telephone and a power source.

Because 30 redundant pictures per second are not transmitted, narrowband transmission costs represent only a fraction of wideband, full-motion transmission costs; Slow Scan operating costs are little more than the expense of a phone call. The cost factor, together with the availability and convenience of telephone networks, has inspired wide acceptance of Slow Scan among the medical community. In addition to CT scans, the technique allows transmission of x-rays, nuclear scans, ultrasonic imagery, thermograms, electrocardiograms or live views of a patient. Such transmissions enable extension of physicians' and specialists' services to remote communities, through paramedics or nurse practitioners at Slow Scan-equipped clinics. Slow Scan also allows consultation and conferencing among medical centers, general practitioners, specialists and disease control centers. Colorado Video's equipment is easily installed and easily operated with minimal training. One phone circuit serves both conversation and picture transmission, and the receiving unit may be connected to a hard copy machine for a permanent record of the images transmitted.

Medical facilities in more than 20 states and some foreign countries are using Colorado Video Slow Scan equipment. But use of the technology goes far beyond telemedicine. Its major employment is in the business/industrial community for a wide range of applications, among them teleconferencing, cable TV news, transmission of scientific/engineering data, security, information retrieval, insurance claim adjustment, instructional programs, and remote viewing of advertising layouts, real estate, construction sites or products. Slow Scan also has utility in such remote sensing activities as weather observation, ship movements and highway traffic monitoring.

Colorado Video's Slow Scan equipment traces its origin to the early days of the U.S. space program, when NASA sought a means of acquiring visual information from lunar and planetary spacecraft. Existing TV systems were considered prohibitive in terms of size, weight and power requirements. Therefore, Jet Propulsion Laboratory initiated a program aimed at use of narrowband transmission from deep space missions; one contractor was Ball Brothers Research Corporation, Boulder, Colorado. An early highlight result was Mariner 4's 1965 transmission of pictures from Mars, the first closeup views of another planet; since then, narrowband video has been used extensively on NASA planetary missions. Ball Brothers continued development of narrowband video technology under a series of NASA contracts and under company-funded programs. In 1965, Colorado Video was formed as a Ball Brothers spinoff company to pursue development of Slow Scan TV for both government and commercial markets. Today, the company lists scores of major users of its equipment including—in addition to medical institutions—government agencies in the U.S. and abroad, universities and some of the largest corporations in the U.S.

Safer Passage in the Flying Canoes

A privately sponsored aircraft crashworthiness program leads a sampling of spinoffs in the field of public safety

Noba, a teenager of eastern Peru's Culina tribe, was critically wounded by gunshot on a wild pig hunt deep in the jungle. Prompt action by Jungle Aviation and Radio Service (JAARS) saved his life; the boy was airlifted to a medical outpost for emergency treatment, thence over the Cordillera Andes to Lima for surgery.

Half a world away in the rugged mountains of the northern Philippines, Jojo Soberano fell into a deep ravine, injured her back and lay helpless for five days. An extensive search by a JAARS helicopter located her; Jojo was taken by the helicopter to a nearby village, then by another JAARS plane to a hospital in Manila.

These are examples of the type of work JAARS pilots do in their "flying canoes." That's what one Colombian tribe calls the JAARS aircraft, because they reach places in the roadless jungle otherwise accessible only by boat. JAARS pilots are frequently called upon for rescue jobs because often their planes are the only transportation in the area. But JAARS' regular work is transporting missionaries to remote corners of the world. Headquartered in Waxhaw, North Carolina, JAARS is a department of Wycliffe Bible Translators, a private missionary organization whose members live with the peoples of Third World lands, learn their languages and translate the Bible into those languages. The Service operates a fleet of assorted aircraft ranging from single-engine lightplanes to a DC-3 transport. It is part bush airline

Jungle Aviation and Radio Service (JAARS) delivers missionaries to remote outposts under sometimes hazardous flying conditions, exemplified by these photos; above, a landing at a tiny airstrip hacked out of the Philippine jungle, at left, a helicopter touchdown on a promontory, typical of operations in New Guinea and Indonesia. A serious accident led to JAARS' initiation of a crash survivability research program that is based on NASA technology.

and part communications link, maintaining daily contact with the missionaries living in remote tribal villages and otherwise cut off from the outside world.

Remote is the key word. Most of the places where Bible translations do not yet exist are really remote, some of them all but inaccessible. Getting to them means flying over jungle and mountain areas that offer few emergency landing sites, or operating into airstrips not much longer than driveways, or slithering to a landing in slippery muck after a rain forest deluge, or setting a floatplane down on uncleared waterways where a submerged log may rip it apart. It is definitely not routine flying and there is the ever present chance of accident. That's why JAARS is engaged in its own technology development program designed to increase plane occupants' chances of survival in the event of a crash.

JAARS' safety record is surprisingly good: only one fatal accident in its 35-year history. There have, however, been a number of accidents, some of them causing serious injury. JAARS' goal, like that of all flying organizations, is zero accidents, but the Service is realistically preparing for future crashes. With NASA assistance, JAARS and another missionary group—Mission Aviation Fellowship—are conducting a privately-funded Joint Mission Aviation Crashworthiness Committee Crash Protection Program. The program focuses on survivability on the types of aircraft used in missionary activities; about 30 missionary organizations operate some 500 aircraft of the general aviation variety—lightplanes, light transports and helicopters—in virtually every Third World country.

The NASA connection dates to 1978, when JAARS sought help from Langley Research Center and was invited to participate in Langley's crashworthiness research, a comprehensive program that includes deliberate crashing of surplus aircraft, study of the forces involved, and development of technology to increase passenger survivability by minimizing the effect of crash forces. JAARS people visited Langley on a number of occasions, witnessed crashworthiness tests, attended flight safety conferences, studied NASA reports on crash dynamics, and filled in their knowledge gaps through frequent interviews with their Langley mentor, research operations supervisor Dwight McSmith, who has since retired.

By 1981, JAARS had acquired sufficient crash dynamics expertise to embark on its own technology development program. For its initial project, JAARS decided to develop a seat for general aviation aircraft that absorbs much of the energy of a crash impact so that the forces acting upon the seat's occupant are substantially reduced. The Service came up with an innovative design—based on NASA technology—that was twice tested at Langley in controlled crashes with an instrumented dummy strapped in the seat. These tests dictated certain modifications, which JAARS made.

Last year the seat passed its final hurdle with successful tests at the Federal Aviation Administration's Civil Aeromedical Institute, Oklahoma City, Oklahoma. Now JAARS is installing the safety seats in all its aircraft at its Waxhaw maintenance facility. The seat design is available to all missionary aircraft and JAARS is offering it for commercial manufacture. The next step contemplated is design of a new missionary aircraft incorporating not only the seats but a number of other advanced safety technologies.

With technical assistance from Langley Research Center, JAARS developed an impact-absorbing aircraft seat designed to minimize crash injury. Occupied by an instrumented dummy, the seat was tested in a controlled crash of a full-size aircraft dropped from this structure at Langley (above).

With mechanic Terry Heffield (standing), Paul Duffey looks over a blueprint for modification of the airplane in the background. Duffey is director of aviation for Jungle Aviation and Radio Service (JAARS), which is conducting a program to increase occupant survivability by modifying its aircraft. The program grew out of Duffey's crash landing in the jungle of Ecuador, which left him confined to a wheelchair.

At its Waxhaw, North Carolina maintenance facility, JAARS is modifying each of the aircraft in its fleet to incorporate an innovative safety seat, designed by the Service with NASA research and testing help. In the above photo, a technician is working on a key feature of the JAARS seat: the "S-frame," in which S-shaped front legs absorb much of a crash impact so that substantially less force is transmitted to the occupant.

Additional crash protection is provided by installing a special type of impact absorbing foam block over a solid metal seat pan. The holes drilled in the foam block are another way of reducing crash impact.

Shown above are JAARS safety seats with and without the foam pad and fabric covering.

Next to last step in the modification process is installation of a seat track in such a manner that the track becomes an integral part of the airplane, further improving passenger protection. In the photo below, mechanic Terry Heffield models the completed seat installation.

Firefighting Module

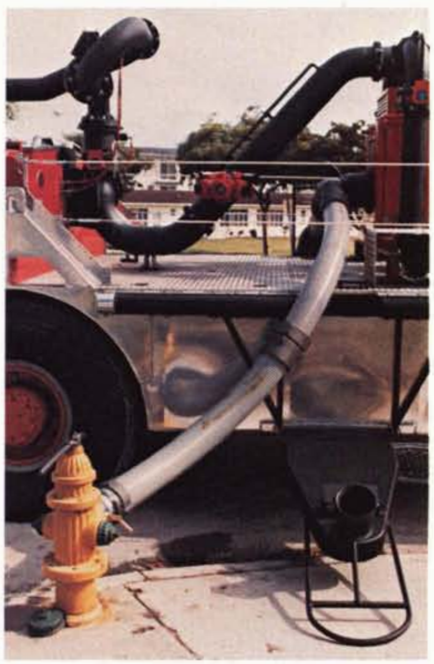
Shown below is *Amphib One,* a versatile firefighting vehicle that can operate effectively on either land or water. First developed by the City of Miami (Florida) Department of Fire, Rescue and Inspection Services, the amphibian was introduced last year by LTI Marine, an element of Ladder Towers Incorporated, Ephrata,

Pennsylvania, a leading producer of aerial ladders and towers for firefighting services.

Located just aft of *Amphib One's* soundproofed and air-conditioned cabin is the vehicle's key component: the Firefly II pump module, a commercial offshoot of a NASA/U.S. Coast Guard program involving development of a lightweight, helicopter-transportable firefighting module for quick response in combating shipboard or harbor fires. In directing the development, Marshall Space Flight Center (MSFC) drew upon its aerospace experience in high-capacity rocket engine pumps, lightweight materials and compact packaging. MSFC built and initially tested the module; manufacturing and sales rights were subsequently acquired by Kinetic Technology International (KTI), Santa Ana, California, whose president R. L. Chaney had worked with MSFC in the development phase and designed the commercial Firefly modules. KTI is now developing higher pressure and higher flow models of the Firefly.

Amphib One stemmed from the work of Louis D. Dechime—then chief of support services for Miami's Department of Fire, Rescue and Inspection Services and now associated with LTI Marine—in developing a fireboat for Miami's rather unusual requirements. Miami has 21 miles of shoreline, dozens of marinas, yacht clubs and boatyards, and a large number of uninhabited offshore islands where brush fires occur frequently. Dechime witnessed a NASA demonstration of the Firefly and, with assistance from MSFC, developed the idea of combining the Firefly II module with an amphibian vehicle to allow more rapid response to a shoreline fire incident than a fireboat could provide. The basic vehicle selected was a surplus LARC (Lighter, Amphibious Resupply Cargo) originally built for Army use in Vietnam.

The resulting craft is remarkably versatile. Its Firefly II pump module incorporates advanced technology in its engine, pump and electronic controls; power is supplied



by a gas turbine engine—a derivative of a helicopter engine—built by Detroit Diesel Allison Division of General Motors. Firefly's simplified design requires only minimal operator training; thus, *Amphib One* can be based at land fire stations and manned by existing fire apparatus crews. For overland travel, its compact size and tight turning radius enable it to maneuver through city streets en route to a marine incident. For entering the water, ramps are usually not necessary because *Amphib One* can negotiate steep grades on sand, coral beaches or rough terrain.

The craft is equipped with three monitors, or water cannons, two on the bow and one stern-mounted; when all three are operating (far left), Firefly II pumps more than 3,000 gallons a minute through the guns. The upper left photo shows a demonstration of *Amphib One's* ability to douse island brush fires; the bow guns can swivel through an arc of 90 degrees and they have an effective reach of well over 200 feet. At upper right is a simulation of another of the unit's multiple talents; it is feeding water to conventional land-based fire trucks at a location where there are no hydrants. The photo at left illustrates how *Amphib One* can operate on land by bypassing the unit's water intake plumbing and hooking up to a hydrant.

NASA-Marshall has been engaged in development of the module for nearly a decade. The center has conducted a number of demonstrations in cooperation with the Coast Guard and the Maritime Administration. The program moved into a new phase last year when MSFC initiated development of an improved, higher capacity module for the U.S. Navy. Capable of pumping 5,000 gallons a minute, it is designed for such applications as fighting onboard ship fires; emergency dockside water pumping; "dewatering" ships in danger of sinking; flood control; and emergency water supply at remote locations.

Protective Coating

Because of exposure to salt spray and fog, coastal or ocean structures—such as bridges, pipelines, ships and oil rigs—require more corrosion protection than is needed inland. One study found that anti-corrosion coatings with a 25-year lifetime inland were good for only a few years in coastal areas.

Seeking to reduce maintenance costs for gantries and other structures at Kennedy Space Center—which is located on Florida's Atlantic Coast—Goddard Space Flight Center conducted a research program aimed at development of a superior coating that would not only resist salt corrosion but would also protect Kennedy launch structures from the very hot rocket exhaust and the thermal shock created by rapid temperature changes during a space launch. The successful research effort resulted in a new type of inorganic coating that is being marketed commercially.

Anti-corrosion coatings formulated of zinc dust have been available for years in both organic and inorganic forms. They provide protection, but they require two or three coats and a relatively long curing period. Looking for maximum maintenance cost-effectiveness, Goddard

sought to improve upon the inorganic chemistry by boosting the ratio of potassium silicate. The result was an easy-to-apply coating that would provide long term protection with a single application, a zinc-rich coating with a water-based potassium silicate binder. It offers cost advantages in materials, labor hours per application and fewer applications over a given time span.

In 1981, NASA granted a license for the coating technology to Shane Associates, Inc., Wynnewood, Pennsylvania. In 1982, Inorganic Coatings, Inc., West Chester, Pennsylvania signed an agreement to become sole manufacturer and sales agent under the Shane license. Inorganic Coatings is now marketing the product under the trade name K-ZINC 531.

Because K-ZINC 531 is water-based, it is non-toxic, non-flammable and has no organic emissions. The high ratio silicate formulation bonds to steel and in just 30 minutes creates a very hard ceramic finish with superior adhesion and abrasion resistance. The improved technology allows application over a minimal commercial sandblast, fast drying in high humidity conditions, and compatibility with both solvent and water-based topcoats.

The formula has been tested in severe environments around the world and over long periods of time; in every case, the coating has displayed outstanding corrosion resistance. In June 1976, six test panels were sprayed just 100 feet from the high tide line at Kennedy Space Center. Seven years later, an inspection of the panels showed them completely free of corrosion, and thickness measurements disclosed essentially no film loss despite constant sun, moisture and salt attack.

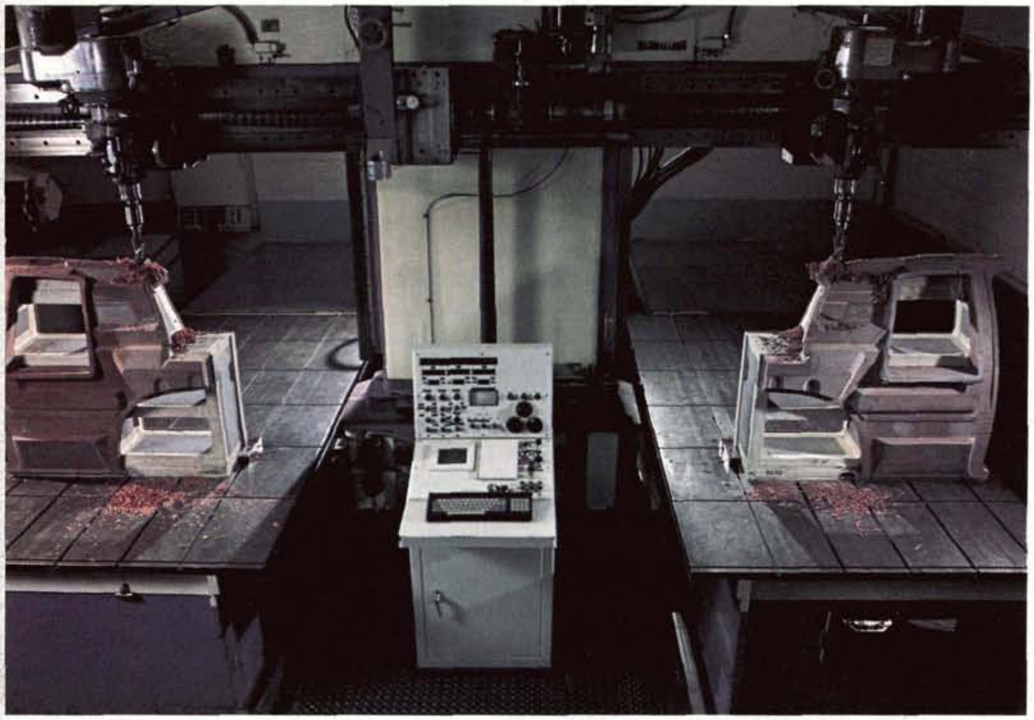
Similarly, the California Department of Transportation tested a coated panel in a salt spray chamber; after 7,000 hours of exposure, the coating showed no sign of breakdown. Federal Electric Corporation applied coatings to antennas in Hawaii and on Canton Island in the South Pacific; both were in excellent condition after two years of exposure to salt air.

The formula was applied to a girder panel on the Columbia River Bridge (far left) at Astoria, Oregon in July 1977. Five years later, inspection uncovered some slight deterioration at one point on the panel but otherwise there was no failure or loss of film due to weathering. The photo at top center shows William Bangert, a bridge maintenance specialist with the Oregon State Highway Division, inspecting the test girder; at bottom left, Bangert is using a 30-power magnifier for a closeup examination.

An example of a commercial application is one made last year at a warehouse of Birdsboro Company, Birdsboro, Pennsylvania. In the photo above, a worker is applying the coating to a surface that was first sandblasted. The photo below is a comparison view showing areas of the building before sandblasting and after application of K-ZINC 531.

The Space Block

Among a sampling of spinoffs that contribute to industrial productivity is a new line of materials offering cost and efficiency advantages in master modeling



At left is a numerically controlled Duplex Milling Machine invented by Visioneering, a Fraser, Michigan modeling firm. Computer-guided by taped instructions, it cuts die models from boards made of a plastic material derived from a substance originally developed for modeling Space Shuttle protective tiles. At right, a Visioneering engineer is using a coordinate measuring machine to check tolerances of the auto hood model pictured, which was made from the spinoff material. Developed by Ren Plastics, East Lansing, Michigan, the new epoxy resins are attracting broad interest as a replacement for traditional materials used in modeling auto, aerospace or other parts.

To protect it from the searing heat of atmospheric re-entry, the Space Shuttle Orbiter is covered by more than 30,000 thermal tiles that can withstand extreme temperatures. To do this important job, the tiles must fit perfectly, thus the Shuttle prime contractor—Rockwell International—is allowed virtually no deviation from design specifications. The tiles are cut precisely to the design shape by numerically-controlled (NC) machines guided by instructions digitally recorded on tape. Since no two tiles are exactly alike, that means a separate computer program for cutting each tile, and every program must be tested for accuracy, because even a tiny error by the programmer would result in an unacceptable finished tile.

To test the machines' accuracy, Rockwell makes master models of the tiles and compares the model dimensions with specifications. Since it would have been prohibitively expensive to make models of the actual material—a special form of silica—Rockwell originally selected polyurethane foam. But NASA, the Air Force and the Occupational Safety and Health Administration ruled out that material; when machined, the urethane emitted hazardous fumes and dust that could cause an explosion in the presence of an electrical spark. So Rockwell began an extensive search for a machinable, stable, fireproof material free of dust hazards. Twenty-seven companies contacted were unable to meet specifications with existing materials or were unwilling to attempt to formulate an acceptable material. One company—Ren Plastics, CIBA-GEIGY Corporation, East Lansing, Michigan—agreed to make the research and development investment needed to create a new material for the master models.

The result was the "Space Block," technically known as the TDT-177-51 Ren Shape™ epoxy model block, a two-foot by two-foot by five-inch plastic block from which master models of the Shuttle tiles are cut by NC machines. The Space Block is made of epoxy resin with low viscosity and slow curing time, enabling the large block to cure uniformly without cracking. The block is filled with very small, lightweight glass globules, or "microspheres," that reduce its density to the required level. It is less porous than polyurethane, thus has a better surface for machining, and it is less prone to swelling or shrinkage due to fluctuations of temperature and humidity.

The Space Block proved to be the answer to Rockwell's needs. It has allowed Rockwell to machine tiles to very close tolerances and reduce the time needed to make an average tile. Where initially the company was able to make only a small percentage of the tiles by NC machining—the rest being made manually—it was able to use NC cutting for more than two thirds of the tiles for the newest orbiter, *Discovery*.

Ren Plastics' willingness to undertake the complicated task of developing the Space Block is paying off in a new line of Ren Shape epoxy blocks and boards designed to replace wood, urethane and other traditional materials in commercial master modeling applications. NC programs can be checked easily and at low cost with these materials, and since they can be shaped by sawing, sanding and carving as well as machining, their use is not confined to NC operations. Companies in a number of industries are looking at the Ren Shape line and Ren Plastics expects wide acceptance of its space derived materials.

An example of a Ren Shape materials user enthusiastic about them is Visioneering, Fraser, Michigan, an established company that has produced models for all U.S. auto makers, most European car makers and a number of U.S. aerospace companies. Visioneering now makes extensive use of NC machining, where formerly all of its models were hand-made of laminated Cativo wood and checked from drawings. Because inspections were time-consuming, they were done infrequently, giving rise to the possibility of human error. With NC machining and Ren Shape materials, tolerance requirements can be more carefully observed.

But, in the view of Visioneering's vice president Tom Vertin Jr., the big attraction of the Ren Shape material is its dimensional stability. Any type of wood continues to "grow," or change in heat, cold or humidity; once it changes shape, it stays that way. Ren Shape modeling material is not affected by humidity and it will snap back to tolerance even after exposure to extreme temperatures. This is an important advantage in modeling auto parts.

Vertin met with a European auto manufacturer to discuss models for a small car to be imported into the U.S. by 1986. Visioneering had planned to use Cativo wood for the 150 parts models needed, but the client would accept only epoxy board. The reason is that European auto makers rely on their models far longer than do their American counterparts, because new designs are introduced less frequently. Typically, a European model is used three to five years, then modified and used another three years; sometimes model lifetimes exceed 10 years. Only epoxy models retain their dimensional stability without rework over such long periods.

American auto models, not needed as long, are still made mainly of wood. But that is changing. Models are shipped around the country and often exposed to weather conditions that cause them to swell and warp; eventually all tools and checking fixtures made from wood models may be out of tolerance, resulting in poorly-fitting production parts. Because American car builders are now demanding tighter tolerances to reduce gaps between parts, they are exploring the use of epoxy materials.

The Ren Shape material Visioneering uses is TDT-178-27, a variant of the Space Block Ren Plastics developed for the Space Shuttle. It comes in boards, like lumber, and the boards are epoxy bonded to form large blocks. Visioneering's Tom Vertin Jr. has found that the Ren Shape board takes 10 percent less time to machine and finish than does wood, and that adds up to significant labor savings. "This material is best for our industry," Vertin says. "It's a quality product."

™Ren Shape is a trademark of Ren Plastics, CIBA-GEIGY Corporation.

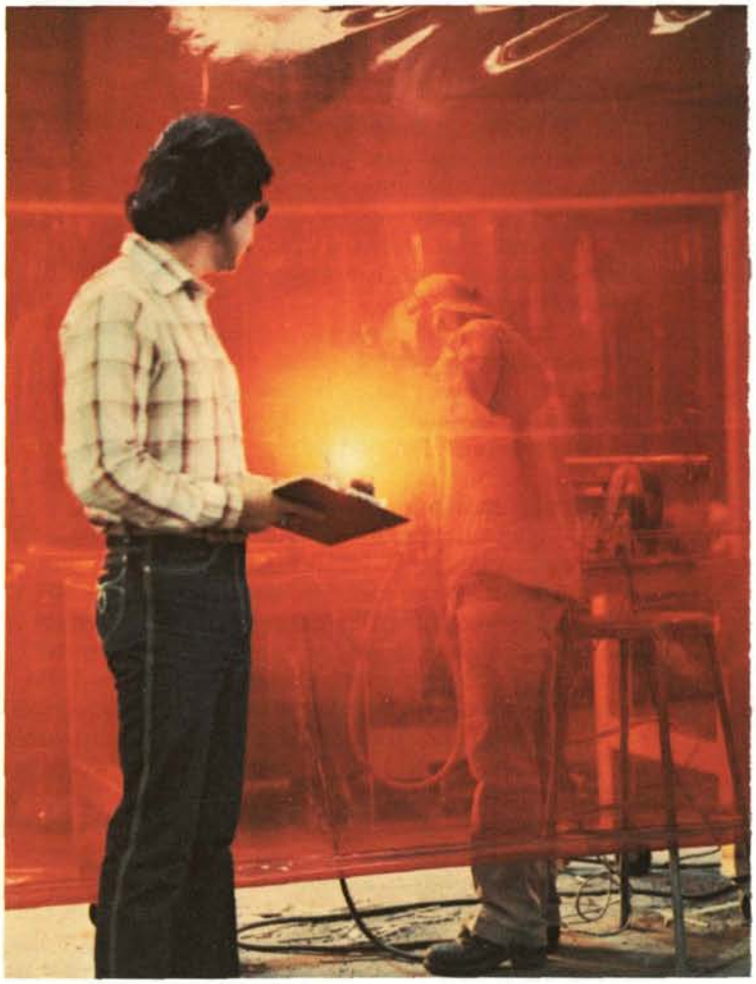
Welding Curtains

Electric arc welding emits brilliant light that can cause eye irritation or retinal damage if the observer stares at the light for an extended period. The potential for eye damage varies with the type of welding process employed, the strength of the electric current and other factors. There is greater danger from light emitted in certain wavelengths, in particular invisible ultraviolet radiation and a hazardous "blue light" that occurs at certain wavelengths in the visible portion of the light spectrum.

The welder is protected by a helmet with dark glass filter plates that enable continuous viewing of the welding arc without harm. But there was a need in industrial operations for a means of protecting bystanders, supervisors who observe progress of a welding job or safety inspectors who check for accident causing procedures. In 1968, David F. Wilson, president of Wilson Sales Company, Rosemead, California, originated the concept of the transparent welding curtain made of heavy duty vinyl. Marketed in several versions, Wilson curtains reduced the glare of the welding arc and blocked the far ultraviolet radiation. When later research uncovered the blue light hazard, Wilson sought to improve his product line.

He contacted the late Dr. Charles G. Miller and James B. Stephens, both of Jet Propulsion Laboratory, and they agreed to undertake development of a curtain capable of filtering out harmful irradiance—including both ultraviolet and blue light—and providing protection over a broad range of welding operations. Miller, a nuclear physicist specializing in the interaction of photons with materials, brought to the undertaking his considerable knowledge of hazardous radiations and ways of reducing the hazard. Stephens, a systems engineer, applied problem-solving methodology based on his JPL experience.

Working on their own time, the JPL pair spent three years developing a patented formula that includes light filtering dyes and small particles of zinc oxide. The result was the Wilson Spectra™ Curtain pictured, now being marketed commercially. The curtain absorbs, filters and scatters light to provide a better working environment for welders, their co-workers and supervisors. It meets the design goal of filtering out ultraviolet and blue light, has good visibility, reduces arc glare better than any of Wilson's other transparent curtains, and, in addition, a fluorescent characteristic of the dye formula puts light back into the welding booth, a boon to the welder. Spectra Curtain transmits less than seven-thousandths of the glare-producing effects that the company's conventional yellow curtain transmits and returns four times as much useful light to the welding booth. The work of Miller and Stephens on this project led to another light-filtering development, sunglasses that protect against ultraviolet, blue and other radiations.



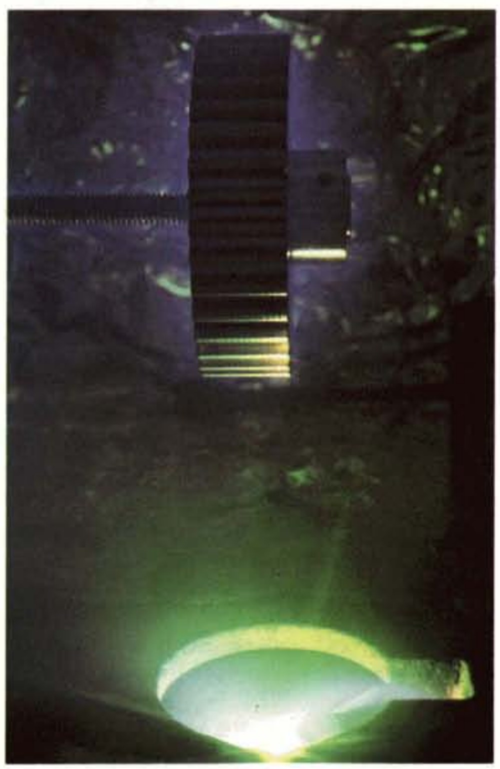
™Spectra Curtain is a trademark of Wilson Sales Company.

High-temperature Lubricants

In future aircraft flying at three or more times the speed of sound, aerodynamic heating can result in vehicle skin temperatures as high as 1600 degrees Fahrenheit, well above the temperature limitations of airframe bearings. Solid lubricants oxidize or dissociate at temperatures below 900 degrees; other lubricants could meet the temperature requirement, but only after complex and time consuming secondary treatment. Therefore, Lewis Research Center started a program several years ago to develop improved high-temperature lubricants.

A material that emerged from Lewis' research is a plasma-sprayed, self-lubricating metal-glass-fluoride coating able to resist oxidation at very high temperatures. That technology is now in commercial use under the trade name Surf-Kote C-800, marketed by Hohman Plating and Manufacturing, Inc., Dayton, Ohio under a patent license from NASA. Surf-Kote C-800 contains a special sodium-free glass for oxidation protection, silver for protection in the low temperature range and calcium fluoride for high-temperature protection. The coating is intended for service from minus 200 degrees to 1600 degrees Fahrenheit to reduce wear and prevent galling and seizure of metals. Among its uses are lubrication for sliding contact bearings, shaft seals for turbopumps, piston rings for high performance compressors, and hot glass processing machinery; it is also widely used in missile and space applications. At upper left, a Hohman worker is coating a shaft with plasma spray.

Company president Bernard Stupp has consulted with Lewis Research Center on vacuum deposited coatings and has adapted NASA technology in several coating areas, such as sputter deposition and ion plating. Sputtering involves bombarding a surface with high energy particles to deposit an extremely thin dry film lubricant; at lower left, Stupp is observing a sputtering device he invented as it deposits a coating on a bearing race. Ion plating is a coating process whereby a metal is vaporized, ionized and attracted to the surface to be coated by the influence of electrical fields. Ion plating allows use of almost any metal that can be melted to coat surfaces with uniform thickness and excellent adhesion; below, a gear is being ion plated with a soft metal that will act as a dry lubricant. About half of Hohman's ion plating work is for lubrication; other coatings are for corrosion resistance, electrical conductivity or insulation.



Ceramic Powders

Advanced Refractory Technologies, Inc. (ART), Buffalo, New York is a new company, founded in 1981, that produces specialty ceramic powders and related products for government and industrial customers, including companies in the oil, automotive, electronics and nuclear industries. Fine ceramic powders are ingredients in a new generation of materials that help improve industrial production efficiency, lower energy usage and reduce demand for scarce raw materials. Their properties are particularly applicable to materials that will be exposed to extreme heat, materials that must be corrosion or wear resistant, and materials used as electricity insulators.

In developing its product line, ART sought technical assistance from the New England Research Application Center (NERAC); located at the University of Connecticut, Storrs, NERAC is one of 10 NASA

sponsored dissemination centers that provide information and technical help to industrial and government clients. ART requested information in specific areas of ceramic materials and silicon technology and also asked for assistance in identifying possible applications of these materials in government programs and in the automotive and electronics industries.

NERAC conducted a computerized search of several data bases and provided extensive information in the subject areas requested. ART vice president Dr. Peter T. B. Shaffer followed up the NERAC search by contacting officials of NASA and other organizations to get more detailed information on NERAC-provided reports of special interest to the company. NERAC's assistance resulted in transfer of technologies that helped the ART staff develop a unique method for manufacture of ceramic materials to precise customer specifications.

ART now produces all grades of material and specializes in high purity, extremely fine powders. The left photo shows a sampling of particle sizes, ranging from three-quarter-inch chunks to submicron powders.

The firm has filled a void in the marketplace for ultrafine boron carbide, used as an abrasive in lapping, grinding and ultrasonic machinery; as a neutron absorber for shielding applications in the nuclear industry; and for application on ceramics and other hard materials for surface finishing and polishing. ART either sells boron carbide in powder form or uses it internally to make parts for the nuclear industry. The photo above shows a variety of parts fabricated by ART for use in demanding nuclear reactor core applications.

Among other company products are silicon carbide, an excellent abrasive on most hard materials that need finishing and a candidate for many structural applications; chrome oxide, a coating for guard against wear; zirconium oxide for protection against heat; and titanium diboride, used in electrodes in production of primary aluminum. This latter material was until recently considered too costly for the aluminum application, but ART developed a titanium diboride powder which, fabricated into solid components, may extend the useful life of electrodes from three to 300 days, offering increased production and decreased energy consumption at lower cost.

Robotic System

A complicated design project, successfully carried out by a New York manufacturing consultant with help from the NASA-sponsored New England Research Application Center (NERAC), has resulted in a new type of robotic system being marketed for industrial use.

Consultant Robert Price, operating as E.S.-I (Enlightened Self-Interest), Albany, New York, was awarded a contract by Watervliet Arsenal, Watervliet, New York to develop an automated tool and the necessary software for deburring the inside of eight-inch breech ring assemblies for howitzers produced by the arsenal. The assembly is a 450-pound unit with complex, stepped internal threads needed to hold the breech block in place when the howitzer is fired. Deburring involves smoothing, or finishing, hundreds of small steel burrs in edges of the teeth of the breech ring. Formerly the burrs were removed by hand grinding, with some hazard to workers from noise, metal fragments and dust. The arsenal wanted a more efficient, hazard-free way of doing the job. This required design of a special tool called an end effector to go inside the breech ring bushing. Additionally, Price's contract called for development of a computer program that would enable an operator to direct the cutting tool over the very complex contours of the breech ring.

Price sought help from NERAC, which conducted a computerized search of the NASA data base and six others; this work was co-sponsored by the Small Business Administration Technology Assistance Program. The NASA data base yielded basic information on robot off-line programming methodology. NERAC's research also identified university and industry sources that provided additional information on which Price could base his work.

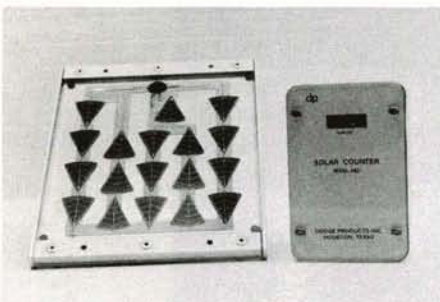
Price designed a system consisting of a standard industrial robot arm (top)—manufactured by ASEA, Milwaukee, Wisconsin—with a specially engineered six axis deburring tool fitted to it, a microcomputer and a computer program to direct the tool on its path through the breech ring. To assemble the hardware and provide software assistance, Price enlisted the help of a subcontractor—Henderson Industries, West Caldwell, New Jersey. The resulting robotic deburring tool, or end effector, is shown in the center photo; a graphic display unit, such as the one shown at right, allows Watervliet Arsenal personnel to monitor the deburring operation. E.S.-I. is now marketing the system to aerospace and metal cutting industries for deburring, drilling, routing and refining machined parts.

Solar Energy Systems

At left below is a new device known as the Solar Counter. Calibrated in kilowatt hours per square meter, it provides a numerical count of the solar energy that has accumulated on a surface; power and sensing for the device are provided by the remotely-located small solar panel shown at the left of the counter. The sensor is weatherproof and may be permanently located out of doors; counting will continue even on cloudy days to provide an accurate value of the total accumulated solar radiation.

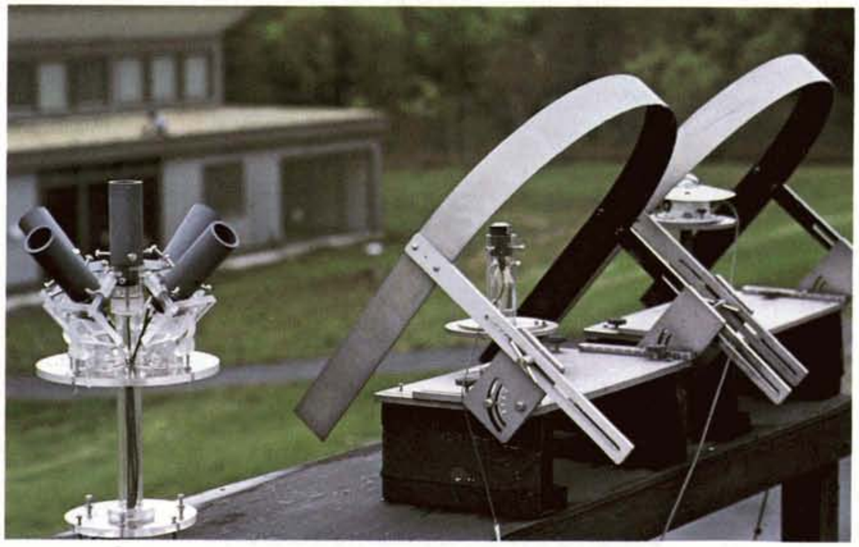
The Solar Counter Model 482 is the latest in a line of solar energy sensing, measuring and recording devices produced by Dodge Products, Inc., Houston, Texas. They incorporate solar cell technology developed by Lewis Research Center, which has conducted extensive research on solar cells for space applications and which also manages—for the Department of Energy—a project intended to build a market for solar cells by demonstrating their advantages in practical Earth-use applications. Dodge Products was formed to bring this photovoltaic technology to the commercial marketplace. Its customers for the various devices include architects, engineers and others engaged in construction and operation of solar energy facilities; manufacturers of solar systems or solar-related products, such as glare reducing windows; and solar energy planners in federal and state government agencies.

Among other products in the Dodge line are the Portable Solar Meter Model 776 shown below, used to estimate the performance of solar arrays, lenses and mirrors; the Solar Integrator Model SI-377, an instrument for automatic measuring, computing and recording the amount of solar energy that has fallen on a surface for periods up to nine months; and the Solar Sensor SS-100, an outdoors weatherproof system that senses solar radiation and sends input signals to the Solar Integrator. The latter two devices are used, for example, to check the efficiency of solar arrays, such as the one pictured at bottom, an installation that provides cathodic protection for the 12″ Four Corners Pipe Line Company, a subsidiary of ARCO Transportation Company, Independence, Kansas. Cathodic protection involves impressing a DC current, generated by the solar array, on the pipe line to protect the pipes against corrosion. The solar array is one of four installed by ARCO to replace diesel-powered electricity generating units, which required considerable maintenance and constant care. Located near Farmington, New Mexico, ARCO's initial solar array has operated successfully without interruption for more than four years.



Measurement Instruments

At right, National Bureau of Standards (NBS) engineer Steve Treado is using an instrument called the Willey Alpha Meter to measure the reflectivity of a mirrored substance commonly used in manufacture of windows. Below left, Treado is using the meter with a projector attachment to check the reflectivity of a wall in a test unit at the NBS Center for Building Technology. Treado's work involves research toward optimizing window energy performance and design of window controls and lighting controls. He develops a model to measure interior daylight, then tests to see how it



compares with actual daylight. He employs several types of instruments to measure daylight (above right) and instruments like the Alpha Meter to measure the optical properties of various window and interior materials.

The Willey Alpha Meter is one of a line of instruments—manufactured by International Technology Corporation (INTEC), Satellite Beach, Florida—for determining the optical properties of materials used in solar energy applications. Some of the INTEC instruments are based on NASA technology, including the Willey Alpha Meter and the McDonald Emissometer. The latter instrument was the first of the INTEC line, introduced in 1976; it is a commercial version of a system developed by Lewis Research Center to test efficiency-increasing coatings on solar panels. The emissometer tests a coating sample to determine its emissivity, the degree to which it emits radiant energy. Such measurements are important because the best coatings are those that absorb maximum solar heat with minimal emittance of infrared radiation, which occurs when the solar collector plate gets hot. Too much coating causes energy loss by emittance, too little reduces the collector's ability to absorb heat.

There was equipment available for testing emittance, but it was complex and expensive. To provide manufacturers of solar equipment an accurate but lower cost means of testing coatings, Lewis Research Center developed the McDonald Emissometer in conjunction with Willey Corporation, Melbourne, Florida and the University of Rochester. The instrument is placed above a pre-heated sample and a heat sensor determines the degree of emittance, which is displayed on the meter.

In 1979, INTEC expanded its line of commercial instruments with the Willey Alpha Meter to include measurements of reflectance—the amount of energy reflected by a surface—as well as emittance. The following year INTEC introduced the Ambient Emissometer, which directly heats the coating sample and produces emittance measurements similar to those of the McDonald Emissometer. INTEC's emissometers and reflectometers can be combined with a digital display unit also produced by the company. The company's instruments are in service in more than 40 countries; customers, in addition to manufacturers of solar equipment, include government, university and private research laboratories.

Heat Recovery System

The equipment pictured at left is a series of rooftop heat exchangers at Ball Metal Decorating & Service Division of Ball Corporation, Chicago, Illinois; the ducting and controls for the heat exchangers are shown at lower left. Their design was inspired by *Tech Briefs,* a NASA publication intended to let potential users know what NASA technology is available for transfer (see page 118). Dwight Raddatz, Ball Metal's director of engineering, used NASA heat transfer information contained in *Tech Briefs* as a departure point for his design of the energy-saving heat recovery system.

Ball Metal's heat exchangers are 12 feet long and composed of 64 three-inch diameter tubes with spiral heat "slingers" to improve heat transfer efficiency. Along with the heat exchangers, the company uses an economical, highly-efficient catalyst to decompose hydrocarbons in the exhaust flowing out of ovens used in the metal decorating process. The heat exchangers are installed on eight press and coating lines used to decorate metal sheets. Below, printed metal sheets are coming out of the drying ovens. Raddatz estimates that the heat recovery system is providing energy savings of more than $250,000 a year.

Thermal Insulation

For a number of years prior to the introduction of the Space Shuttle, Johnson Space Center conducted research on advanced flame-resistant materials toward minimizing fire hazard in the Shuttle and other flight vehicles. From that research emerged a polyimide foam material that resists ignition better than any material used earlier. It is applicable not only to aircraft and spacecraft, but also to surface transportation systems such as rapid transit cars, trains, buses and ships. Known commercially as Solimide®, it has application in such vehicles for acoustical treatment and for door, wall and ceiling panels; as a means of reducing vibrations (see page 96); and as thermal insulation. In the latter application, it is also useful in industrial equipment.

An example is the use of Solimide in the ThermoStream® System shown, one of several systems manufactured by Temptronic Corporation, Newton, Massachusetts for testing such electronic devices as semiconductor wafers, chips, components, modules and circuit boards over a wide range of temperatures. Temptronic's equipment offers a different approach to electronic thermal testing, involving the use of localized temperature-inducing systems rather than conventional temperature chambers. Chamber testing poses difficulties in employing many types of automatic test equipment, because the item in the chamber is physically separated from the test socket; the conventional solution has been to run wires from the device being tested in the chamber to the test socket outside. Temptronic systems make this cumbersome procedure unnecessary by applying temperature directly to the object undergoing test. In the ThermoStream System, Solimide is used as thermal insulation to prevent the outlet air/gas from affecting the temperature of the tester circuitry.

Solimide was originally developed under contract from Johnson Space Center by Solar Turbines International, San Diego, California, a division of International Harvester. The assets and business of International Harvester's Solimide operations were subsequently acquired by Imi-Tech Corporation, Elk Grove Village, Illinois, which is producing the material for a variety of defense, industrial and transportation vehicle applications.

®Solimide is a registered trademark of Imi-Tech Corporation.

®ThermoStream is a registered trademark of Temptronic Corporation.

Insulation Material

Manufactured by Hitco Materials Division of Armco, Inc., Gardena, California, a ceramic fiber insulation material known as Refrasil™ has been used extensively as a heat-absorbing ablative reinforcement for such space systems as rocket motor nozzles, combustion chambers and re-entry shields. In the Space Shuttle, for example, it is used to cover rocket nozzles and it lines the walls of the main fuel tank to keep temperatures within proper limits. Refrasil fibers are highly porous and do not melt or vaporize until temperatures exceed 3100 degrees Fahrenheit. Due to these and other properties, Refrasil has found utility in a number of industrial high temperature applications where glass, asbestos and other materials fail.

An example is a problem-solving project wherein NASA's Aerospace Research Application Center (ARAC), a component of the Indianapolis (Indiana) Center for Advanced Research, provided assistance to a manufacturer of hard rubber and plastic molded battery cases. Richardson Battery Parts Division of Witco Chemical Corporation, located in Indianapolis, asked ARAC's help on a problem related to heavy steam-heated molds employed in the manufacture of battery cases. Richardson wanted to reduce the heat loss from the sides of the molds to curb the high energy costs of generating steam and to increase worker safety in handling the molds. A Richardson engineer calculated that up to 95 percent of the input heat into the molds was being wasted in radiation to the outside of the molds. Due to clearance restrictions, Richardson needed an insulating material less than one-quarter inch thick to fit around the outside of the molds. The material had to withstand rough treatment during mold block changes and resist exposure to hot water, steam, hydraulic fluids and mold temperatures that average 390 degrees Fahrenheit. Richardson tried applying conventional materials but found none suitable.

ARAC conducted a search of 11 data bases, identified more than 100 pertinent reports and followed up by discussing the problem with officials at three NASA centers. ARAC's analysis report to Richardson Division listed several materials that seemed to meet company requirements. Richardson studied the options and selected one-eighth thick Refrasil ceramic fiber cloth as best suited.

Some 500—about 80 percent—of the company's molds are now fitted with Refrasil insulation, which is wrapped around the mold and tightened by easily installed and readily removable steel bands. In the upper photo, Robert K. Beacham, Richardson's manager of manufacturing engineering, is examining a Refrasil mold installation with an ARAC engineer; the material is shown in closeup below. Steam usage for molding at Richardson Division has been reduced by 20 percent due to Refrasil application, and the initial cost of installation was paid back in only 35 days. The company now plans to insulate the steam lines leading to the molds with Refrasil cloth.

™Refrasil is a trademark of Armco Corporation.

Workplace Design

In designing the interior of the Space Shuttle Orbiter, NASA encountered a number of considerations that demanded a different approach from earlier spacecraft design: the Orbiter would be the largest spacecraft ever built and would carry more people than prior spacecraft, missions would involve more motion within and outside the spacecraft, the type of work would differ from earlier

experience and crews would include persons of both sexes, many of them non-pilots and most of a different age bracket than earlier astronauts. These and other factors affected design criteria for crew clothing, equipment, workplaces and living quarters. Johnson Space Center (JSC) felt that the many new design considerations demanded a broader data base on anthropometry, the study of the size, shape and motion characteristics of the human body.

JSC therefore initiated a project to assemble the information available worldwide and produce a centralized collection of anthropometric knowledge. The result was the three-volume *Anthropometric Source Book,* compiled and edited under JSC contract by Webb Associates, Yellow Springs, Ohio. Designed primarily for use by NASA, the military services and aerospace contractors, the book was also intended to help non-aerospace engineers, architects and others engaged in design of clothing, equipment and workplaces. The work has won considerable acclaim as an important addition to Human Factors Engineering and it has spawned a number of non-aerospace spinoff applications.

An example is its use by Eastman Kodak Company, Rochester, New York, whose Human Factors Section of the Health Environment Laboratory has several sets of the *Anthropometric Source Book.* They use the data frequently for such purposes as designing protective clothing, studying placement of controls on Kodak EKTRAPRINT copiers/duplicators, or designing workplaces. The latter use is exemplified by the company's application of the NASA data to design of efficient, productive and comfortable workplaces for employees in the Rochester (New York) processing laboratories. In designing these workplaces, where employees process disc film negatives before sending them to the printing area, Kodak's Human Factors Section used the source book to determine such dimensions as leg space, work surface height and thickness, employee reach distances, proper height for the computer terminal screen, seat height and knee space. The type of workplace that emerged from the design effort is shown in the accompanying photo.

Big Savings from Smart Motors

A motor controller that cuts energy consumption highlights a selection of spinoffs for consumer, home and agricultural use

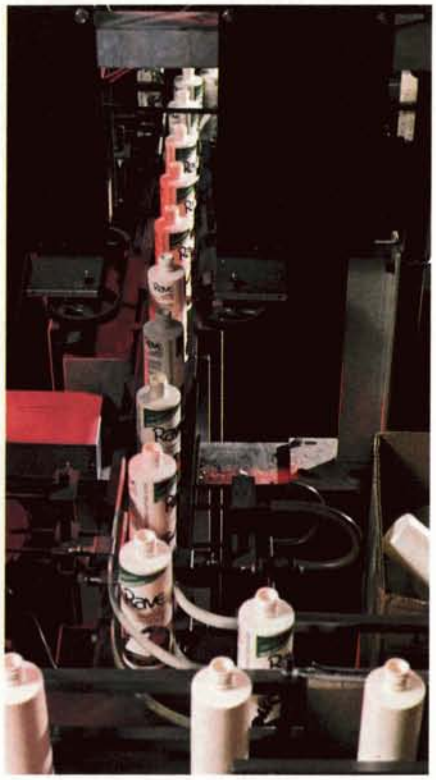
Chesebrough-Pond's Inc. is a consumer-oriented company whose annual sales volume approaches two billion dollars. Headquartered in Greenwich, Connecticut, it operates 32 plants across the nation and in those plants are more than 10,000 electric motors. That's why Chesebrough's electric bill used to run as high as $8 million a year. It will be a great deal lower this year, thanks to a company developed device that makes electric motors "smart" enough to regulate their own output and dramatically reduce the energy they use.

The device is an inexpensive, computerized motor controller that cuts power wastage by sensing a motor's load and feeding the motor only the minimum voltage it needs to do its job. Chesebrough has developed one version for retrofitting existing motors, another for new single-phase small general purpose industrial motors, and a third for controlling large three-phase motors in industrial use.

In laboratory tests, single-phase motors equipped with the controller have demonstrated energy savings as high as 90 percent. Realistically, Chesebrough expects savings in an actual plant environment to range from 10 to 50 percent, depending on the type of motor and how it is used. Even the lower figure represents a tremendous saving for industrial firms that operate as many or more motors than does Chesebrough. The company estimates that reduced electric bills will pay back the cost of retrofitting the motors in Chesebrough plants in only two years.

What makes the Chesebrough controller development particularly interesting is the fact that the company is not an electric-motor manufacturer nor a high technology enterprise. Chesebrough-Pond's manufactures and markets consumer products; perhaps best known for Pond's skin cream, the company produces a widely diversified line ranging from Q-tips to Cutex, children's clothing to home permanents, perfume to spaghetti sauce. Chesebrough never intended to get into the controller business; it was simply looking for a way to trim its substantial electric bill and, unable to find a commercially-available

At left is a conveyor line at the Clinton, Connecticut plant of Chesebrough-Pond's Inc., where the widely diversified company manufactures such products as vaseline, hair spray and permanent lotions. The red box in the center photo is a computerized single-phase motor controller, based on NASA technology, that dramatically reduces the amount of energy required to run the conveyor line. At right is a three-phase unit, used to control larger industrial motors, in the boiler room of the Clinton plant.



controller suited to its special needs, it proceeded to invent one.

The controller traces its origin to work in the mid-seventies at Marshall Space Flight Center (MSFC) which—as part of its energy conservation research in support of the Department of Energy—was seeking a means of curbing power wastage caused by the fact that alternating current motors operate at a fixed voltage. The fixed voltage is what motors need to handle the heaviest loads they are designed to carry, but a motor usually does not operate at full load conditions; even when it is idling, it is still getting full-load voltage and, with multimillions of electric motors in the U.S., the cumulative wastage is of enormous order.

MSFC engineer Frank Nola developed a device—called the Power Factor Controller (PFC)—that matches voltage with the motor's need. Plugged into a motor, it continuously determines load by sensing shifts in the relationship between voltage and current flow. When the controller senses a light load, it cuts the voltage to the minimum needed, thus effecting large-scale savings.

In 1977, Chesebrough organized a Corporate Advanced Technology Group at Clinton, Connecticut to devise ways of improving productivity and cutting manufacturing costs. As its major project, the group tackled energy reduction and evaluated a number of energy control devices, none of which met company requirements. In 1979, Chesebrough acquired a license for the NASA Power Factor Controller technology. The PFC, while effective in many applications, was not the answer to Chesebrough's particular needs, principally because it required many user adjustments to meet the many variable factors associated with operating electric motors in a manufacturing plant.

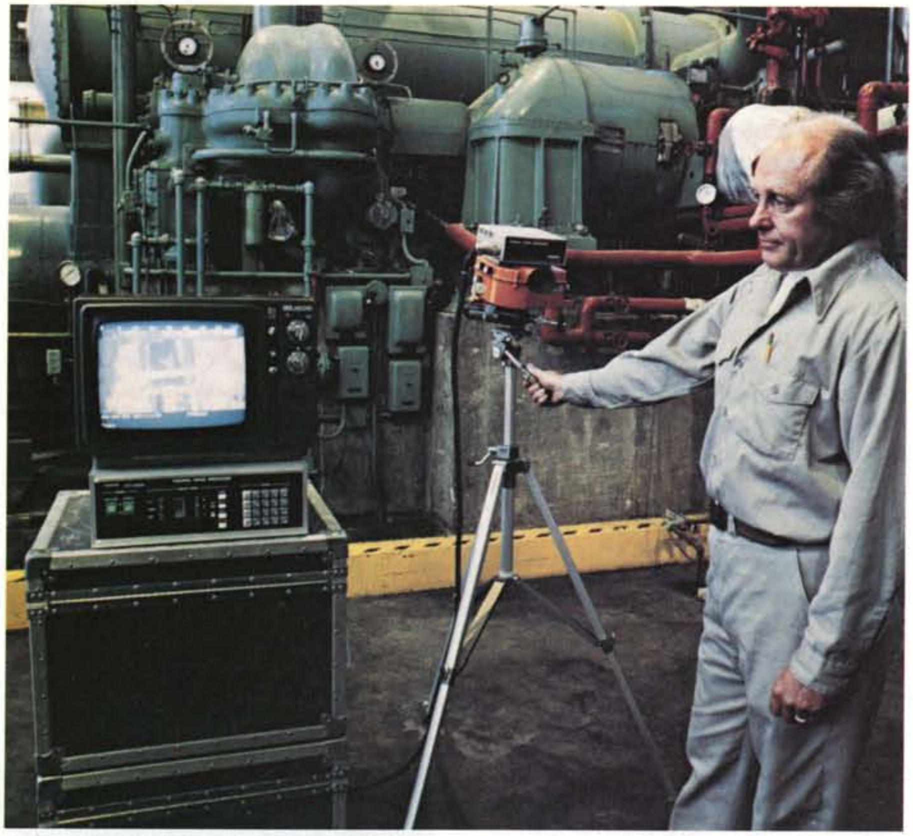
Chesebrough, therefore, used the NASA technology as a departure point for development of a "user friendly" smart system—a computerized motor controller that would monitor the variables, evaluate their impacts, and calculate the appropriate commands that would enable the motor to operate at maximum efficiency regardless of the motor's application or operating conditions. The key element of the controller that emerged from the Chesebrough development program is a microprocessor that does the calculations and sends the command signals. The system also employs solid state components to perform motor functions traditionally handled by mechanical parts.

Ray Davis, director of the company's Corporate Advanced Technology Group, sums up the development this way:

"The Chesebrough controller makes it possible for motors to have their own built-in control intelligence. Instead of being dumb machines, they can now be smart. Smart motors will maximize their efficiency and automatically protect themselves from environmental or user abuse. Smart motors can take data and send commands to solid state sensors and controls at speeds, and with a degree of reliability and accuracy, not possible with mechanical devices. And smart motors can monitor their own performance and warn of impending failure before it becomes a cause of critical system shutdown."

In 1980, Chesebrough completed the design of its single-phase controller and built 50 units for field trials. Twenty-five of them were installed at the company's Hospital Products Division, Watertown, New York; they have operated continuously and successfully ever since, providing annual energy savings of 20–30 percent. The company also built and similarly field tested several models of the three-phase controller. In 1982, Chesebrough was granted a patent for the invention.

The company decided to license the technology, something it rarely does, so that American home and industrial users could benefit from a development that Chesebrough chairman Ralph E. Ward says is "too good and too important to keep to ourselves." The company has signed an agreement with National Semiconductor Corporation for manufacture and marketing of the single-phase controller; Chesebrough will similarly license production of the three-phase unit. The market potential for the single-phase system alone is estimated at $100 million a year by the late 1980s.



Hair Styling Appliances

In hair styling, heat is applied to soften the protein structure of the hair and make the hair receptive to new curl formation. Correctly applied, heat is safe, fast, efficient and it creates long-lasting curls. But heat styling equipment that is defective or improperly used can cause cracks, blisters or pinching of hair fiber.

Redken Laboratories, Canoga Park, California has been conducting hair care research for more than 20 years. Seeking answers to the specific problems of heat styling, Redken made a comprehensive investigation of hair's reaction to heat and how heat damage might be eliminated by development of advanced styling equipment. This effort led to formation of a new Redken division—Styling Research Company, also of Canoga Park—and a new line of styling appliances.

A key tool of Redken's research program was an instrument called a thermograph, a heat-sensing device originally developed by Hughes Aircraft Company under U.S. Army and NASA funding. The Army sponsored the work as part of its missile guidance research; NASA sponsored a demonstration project designed to explore civil applications of the system under the NASA Technology Utilization Program.

Called the Probeye® Thermal Video System, or TVS, the Hughes system consists of a portable, tripod mounted infrared scanner that detects the various degrees of heat emitted by an object, and a TV monitor on which the results are displayed in colors representing the different temperatures detected. At upper left is the original version of the Probeye, shown examining the heat levels in an industrial boiler complex. The center photo shows the current Probeye Thermal Video System, produced for a number of industrial heat sensing applications by Hughes Industrial Products Division, Carlsbad, California; it is built in three models, each of which combines the image processor and the display equipment in one compact unit.

Redken Laboratories bought one of the early models from Hughes and used it in development of its hair styling equipment. In the upper right photo, the Probeye system is being used to test one of Styling Research Company's hair dryers; the monitor shows the heat being applied evenly and efficiently. At right center is a

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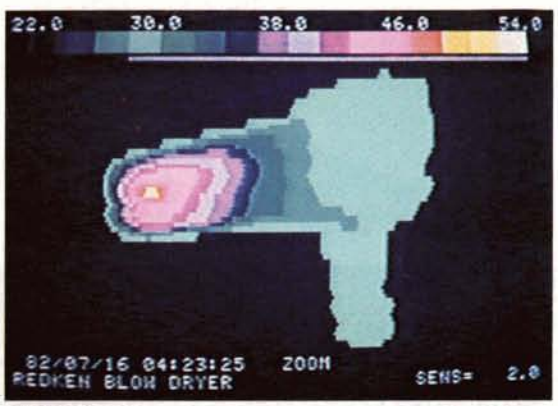


thermographic view of the dryer itself, with temperatures at various parts of the appliance indicated by the coded colors; the thermograph shows a proper heating pattern in the barrel and also indicates—by the low temperature readings for handle and housing—that the appliance is properly insulated. Although the TVS is used primarily for testing new appliances, Redken has employed it in other research, for example, to differentiate facial surface temperatures (bottom); such research is aimed at detecting how moisturizers hold heat in the skin and how astringents cool off the skin.

The Styling Research Company line that emerged from Redken's research includes the blow dryer, two types of curling irons and a curling brush, all designed for professional use. The irons and the brush do not employ the conventional coil heating element; instead they have a unique ceramic heating bar—derived from space and medical technology—that eliminates troublesome hot spots because heat is dispersed evenly along the barrel. The curling brush has plastic teeth designed to glide through hair with minimal friction to prevent mechanical damage to hair fibers. The band heater in the blow dryer is positioned at the front of the barrel to bring the source of heat as close as possible to the hair for more efficient delivery and greater control.

Sunglass Lens

For many years, glass was the most commonly used material in eyeglass lenses. Its principal advantage is that it resists scratching; its main disadvantage is that it is brittle and breakable.

Since 1972, when the Food and Drug Administration issued a regulation that all sunglass and prescription lenses must be shatter-resistant, use of plastic lenses has increased dramatically; today the majority of sunglass, corrective and safety lenses sold in the U.S. are made of plastic. Plastic lenses typically weigh only half as much as glass, they can be readily shaped to conform to facial contours, and they offer far better absorption of ultraviolet rays. But even with delicate handling, many types of plastic lenses develop visibility-reducing scratches. Until recently, the best plastic available fell far short of glass in scratch resistance.

Foster Grant Corporation, Leominster, Massachusetts, a major producer of sunglasses, spent more than a decade of research effort looking for a coating that would provide plastic lenses with glass-like scratch resistance while maintaining the advantageous properties of plastics. The answer eventually found combined NASA technology with Foster Grant's own technology. The NASA contribution was a highly abrasion-resistant coating developed by Ames Research Center as a means of protecting plastic surfaces of aerospace equipment from the sometimes harsh environments to which they are subjected. The result is the Foster Grant SPACE TECH Lens, manufactured under license from NASA. Illustrated in the accompanying photos, the SPACE TECH Lens surpasses glass in scratch resistant properties and has five times better scratch resistance than the most popular corrective lenses. The new lens is available in the 1984 Foster Grant line.

Irrigation System

Shown above is a Zimmatic center pivot agricultural irrigation system built by Lindsay Manufacturing Company, Lindsay, Nebraska. Systems like this one are composed of multiple lengths of water pipe and spray nozzles supported by wheeled towers such as the one at right. The whole system rotates around a center pivot, watering hundreds of acres—depending on the number of tower units—in a single revolution. Each three-ton tower has its own electric motor; power is transmitted to the wheels by individual gear boxes (bottom photo) that incorporate NASA lubrication technology to protect them from wear and heat stress.

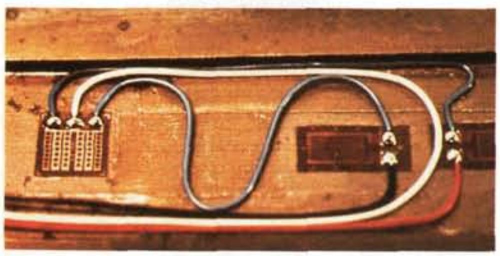
Under contract with Marshall Space Flight Center, Midwest Research Institute compiled a Lubrication Handbook intended as a reference source for designers and manufacturers of aerospace hardware and crews responsible for maintenance of such equipment. The handbook details the chemical and physical properties, applications, specifications and test procedures for some 500 liquid and solid lubricants used by companies in the aerospace industry.

Engineers of Lindsay Manufacturing Company learned of the handbook through the NASA publication *Tech Briefs* (see page 118) and used it for supplemental information in redesigning gear boxes for their center pivot systems. In the new design, gears are immersed in NASA-developed lubricants that provide wearing surfaces and bearings with low-friction protective coatings. The NASA information helped reduce the amount of lubricant required and allowed selection of comparable but less expensive lubricants. The Lubrication Handbook has become a permanent part of the company's technical library, used frequently for decisions on lubrication problems, for information on specific greases, temperatures and compatibilities, and for recommending oil brands to dealers.

Weight Control for Highway Trucking

Electronic scales for vehicle payload management highlight a representative group of technology transfers in the field of transportation

Shown above is a LODEC load cell (bar with connector attached) that supports the bridgebeam on a logging trailer. Within the load cell, tiny strain gages (at right below) sense and measure the increased weight as logs are added to the trailer. An indicator in the cab of the truck (center photo) converts signals from the load cell into weight information and displays it to the driver.



In the trucking industry, continuing high operating costs and stepped-up enforcement of vehicle weight laws are generating broad interest in electronic payload management systems that originated in aerospace technology. Produced by LODEC, Inc., Lynnwood, Washington, these systems are scales that tell truck drivers or fleet operators the exact weight a vehicle is carrying at all times.

That's important to trucking productivity. An overloaded truck can damage highways and bring a costly fine, but an underloaded vehicle means reduced revenue and profit. With a highly accurate weighing device such as the electronic scale, a vehicle can be loaded to the legal limit on every trip, maximizing payload without risking an overweight ticket. Payloads can also be optimized for best fuel efficiency. Keeping truck loads within design limits offers bonuses in reduced breakage, vehicle downtime and maintenance costs.

The most widely used LODEC product is an on-board electronic scale, mounted on the truck frame, that reports total truck weight to an indicator in the cab. The heart of the system is the load cell, machined from a solid bar of alloy steel and welded to the truck's supporting structure. Within the load cell are four strain gages. The load cell bends slightly—a few thousandths of an inch—under the applied load. As it does, the strain gages change their electrical resistance in proportion to the bending, which in turn is proportional to the weight added to the truck. Electronic components in the load cell report the changes in resistance—through a connecting cable—to an indicator in the truck's cab, which converts the information to a digital display of truck weight. Some types of indicators signal an alarm automatically when a preset limit has been reached, or switch a pump on or off when a given amount of weight has been loaded or offloaded. LODEC guarantees the system's accuracy within one percent, but frequently gets much better accuracy; when properly installed and maintained, the company says, its on-board electronic scale can weigh an 80,000-pound vehicle with an accuracy within 300 pounds.

LODEC scales trace their origin to the space program of the 1960s, when ELDEC Corporation—then LODEC's parent company—acquired advanced electronic technology as a subcontractor on such projects as Apollo and the Saturn launch vehicle. From this experience evolved an electronic weight and balance system for the Lockheed C-5A military transport; it was used to calculate the gross weight and center of gravity of the giant airlifter prior to takeoff. During the aerospace recession of the 1970s, ELDEC began looking for alternative markets. LODEC, at that time the Industrial Division of ELDEC Corporation, initiated a program to adapt the weight and balance technology to commercial applications.

The first product was an on-board scale for logging trucks in the Pacific Northwest. Although there were

LODEC uses the same load cell technology, a spinoff from aerospace technology, in manufacturing electronic axle scales for weighing trucks and trailers to insure that they are within legal highway limits. At right is a portable version for use by truckers in remote locations or by weight enforcement officers on the highway.

systems for weighing trucks at terminals, there was no accurate method of weighing a vehicle in the remote mountain areas where logs were loaded; loggers had to rely on the "eyeballing" technique of visually estimating truck weight, which often resulted in overloading or underloading. The built-in electronic scale was a natural for loggers, enabling them to load to the maximum legal limit for highway travel without incurring fines. The Industrial Division's system consisted of four load cells, two on the truck

frame and two on the trailer frame supporting the truck and trailer bridgebeams, which in turn support the weight of the logs. The on-board scale proved highly accurate and it brought productivity increases of as much as 25 percent; demand for the system grew rapidly until today about 90 percent of all the log trucks operating from northern California through British Columbia have electronic scale systems. And since the technology is applicable to nearly all types of trucks, the success of the scale in the forest products industry quickly attracted the attention of other truckers. LODEC estimates that there are now more than 10,000 vehicles using electronic on-board scales in the U.S., Canada, Europe and Australia.

In the mid-1970s, the Industrial Division adapted the technology to a related type of product, the axle scale system, used to insure that vehicle loads are correct before a truck leaves a loading area. Built in both permanent and portable versions, the system consists of two platforms, each of which contains two load cells; when trucks are driven over the platforms, data from the load cells is translated into the weight on each axle and total truck weight. The permanent version is used at truck terminals. Portable systems are used in trucking operations at remote sites and by highway weight enforcement authorities. In the latter application, weighing platforms are towed on a trailer behind a standard sedan and set up in less than 10 minutes at any selected site where there is reasonably level ground. A single enforcement officer can weigh trucks at the rate of one a minute from his patrol car.

In March 1981, the ELDEC Industrial Division became LODEC, Inc. when general manager Douglas G. Brooks—now president of LODEC—and his management team purchased the division. In addition to on-board and ground scales, their load cells and accessories, the company produces a number of types of indicators and automatic calculating printers of various degrees of sophistication. Some of the more advanced indicators have capabilities that add a new dimension to electronic weight management: they measure incremental changes where a truck takes on weight or offloads weight at different stops. The systems have found wide application in trucking operations where incremental weight-change information is important for record keeping or billing purposes, for example, in liquid cryogenic carriers and vehicles used for agriculture, mining, asphalt spreading, batch mixing and feed delivery.

LODEC has become an international company with about one-third of its sales outside the U.S. The customer base includes more than a dozen foreign countries, more than 40 U.S. state and local government agencies, hundreds of major truck and trailer manufacturers, and numerous small truck and scale service facilities.

Motor Controllers

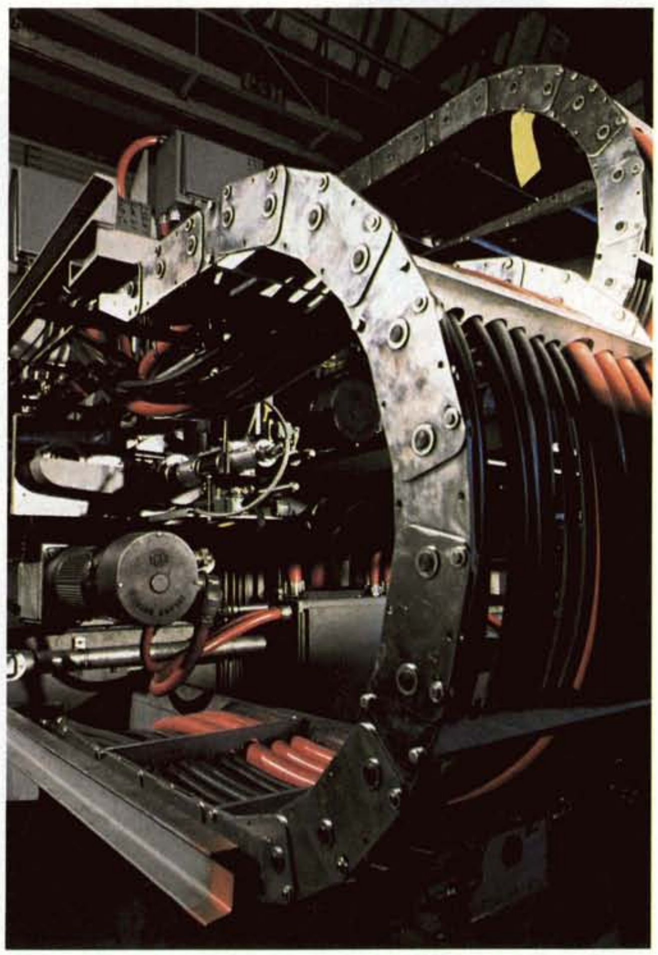
At right, the Mermaid II two-person submersible is being lowered into the Pacific Ocean from a ship off Santa Barbara, California. Below, the underwater vehicle is ready to submerge; the craft's interior is pictured on the opposite page. Operated by International Underwater Contractors, Inc. (IUC), City Island, New York, Mermaid II can reach depths of 1,000 feet to perform a variety of underwater assignments, such as checking pipelines for oil companies, studying fish feeding habits for the National Oceanic and Atmospheric Administration, and charting the continental shelf for the U.S. Geological Survey. The submersible is propeller-driven by a system of five DC brushless motors (one shown at far right) with new electronic controllers that originated in work performed in a NASA/Department of Energy (DoE) project managed by Lewis Research Center.

In cooperation with Virginia Polytechnic Institute and State University, the Industrial Drives Division (IDD) of Kollmorgen Corporation, Radford, Virginia developed an electric vehicle traction motor system as part of a NASA/DoE program aimed at advancing propulsion technology for electric and hybrid vehicles in the interest of national energy conservation. The IDD system was based on a permanent magnet DC motor to take advantage of the high efficiency it offered. A key feature of the system was electric commutation rather than mechanical commutation for converting AC current to DC. Electric commutation enabled elimination of the brushes and commutator conventionally used in DC

motors, resulting in a motor system of high performance in relation to size and weight, high reliability and—because there are no brushes to replace—minimal maintenance requirements.

From this project evolved an IDD family of DC brushless motor controllers known as the ECC (Electronic Commutation Controller) series. The ECC employs a six-transistor bridge to supply electric current to the motor in a sensor-regulated sequence, providing smooth torque delivery over a wide operating range. It found its principal application in the propulsion systems of underwater vehicles, including Mermaid II, several other IUC submersibles, and submarine craft of other companies that use IDD brushless motors.

More recently, IDD introduced the brushless motor/ECC to industrial use as a drive system for large machines. Customers include a General Electric Company plant in Fort Wayne, Indiana and Ingersoll Milling Machine Company, Rockford, Illinois. The photo at right shows an IDD motor installed on a large machine tool built by Ingersoll.



Control Systems

Boeing Commercial Airplane Company, Seattle, Washington is the world's largest producer of airline transport aircraft, such as the new standard body 757 (flight deck pictured) and wide body 767 jetliners. For advancement of the technology incorporated in Boeing airplanes, the company conducts a broad and continuing program of research and development. One facet of this effort involves research on control systems, devices whose electronic signals guide or control specific aircraft functions, for example, flight management computers that provide accurate engine thrust settings and flight path guidance throughout a flight, or electronic engine controls for precise engine operation.

Boeing's Flight Control Department has developed an advanced control synthesis package for both continuous and discrete (discontinuous) control systems. As a starting point for development of discrete control systems, department engineers relied on a software package known as ORACLS; developed by Langley Research Center, it was used by Boeing for computerized analysis of new system designs. Resulting applications include a multiple input/output control system for the terrain-following navigation equipment of the Air Force's B-1 bomber, and another for controlling in-flight changes in wing camber—the fore-aft curve of the airfoil—on an experimental airplane.

The Flight Control Department reported that use of ORACLS saved at least two years of programming time in development of the advanced control synthesis package. ORACLS is one of 1,300 computer programs developed by NASA and other agencies that are available for use by industrial and other organizations. The programs are supplied by NASA's Computer Software Management and Information Center (COSMIC)®, located at the University of Georgia.

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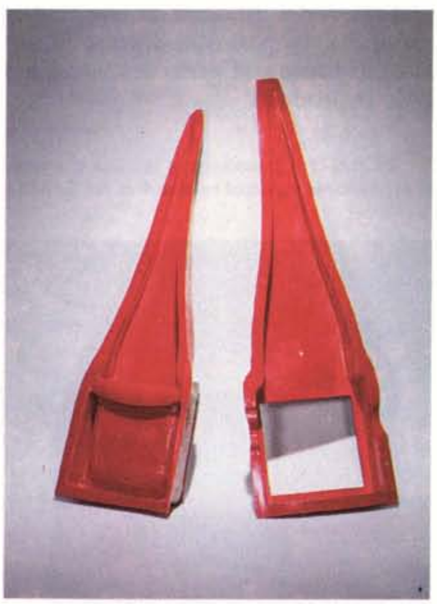


Aircraft Inlet Ducts

The above photo shows the nose section of a Mooney 231 turbocharged lightplane that has been modified to incorporate air inlet ducts (one shown in top photo) and an intercooler (heat exchanger) to increase engine efficiency. The modification, intended to improve the performance of turbocharged lightplanes over that of standard production models, was designed by Wilhelm Cashen of Roseburg, Oregon and based on NASA technology. Modification kits, including the ducts (left) and the intercooler system are marketed and installed by Turboplus Inc., Auburn, Washington.

In this and similar lightplane installations, the two submerged ducts introduce cool "ram" air to the propulsion system for greater operating efficiency. One duct feeds ram induction air to the turbocharger compressor, the other provides cooling air to the intercooler assembly. The compressor-heated induction air is then routed to the intercooler, where heat is extracted by the cooling air. This air cooling technique results in increased air density, requiring less manifold pressure for a given horsepower and elevating critical altitude by several thousand feet. Lower manifold pressure and lower temperature allow the engine to operate with a leaner fuel mixture for substantially improved fuel efficiency. Additionally, lower cylinder, oil and exhaust gas temperatures promote longer engine life and reduced maintenance costs.

Wilhelm Cashen had designed a heat exchanger for light turbocharged aircraft but he faced a problem in designing a method for drawing in cool ram air. He needed an inlet with very low drag to cool the engine without adversely influencing the aerodynamic characteristics of the airplane. Cashen found the information he needed in the NASA publication *Tech Briefs* (see page 118). After studying three *Tech Briefs* reports on NASA submerged duct technology developed for high performance aircraft, he was able to adapt the technology to the induction/intercooler system.

Flame Resistant Foam

Below, a technician is installing—on the interior skin of a business jet—a new vibration damping product incorporating fire-resistant, lightweight polyimide foam. Introduced last year under the trade name SOLDAMP™, the material has gained rapid acceptance among operators of business jets because of its superior damping characteristics, lighter weight, and fire barrier properties. The airplane shown is the French-designed Dassault/Breguet Falcon Jet, outfitted in the United States by the Little Rock Division of Falcon Jet Corporation, Little Rock, Arkansas.

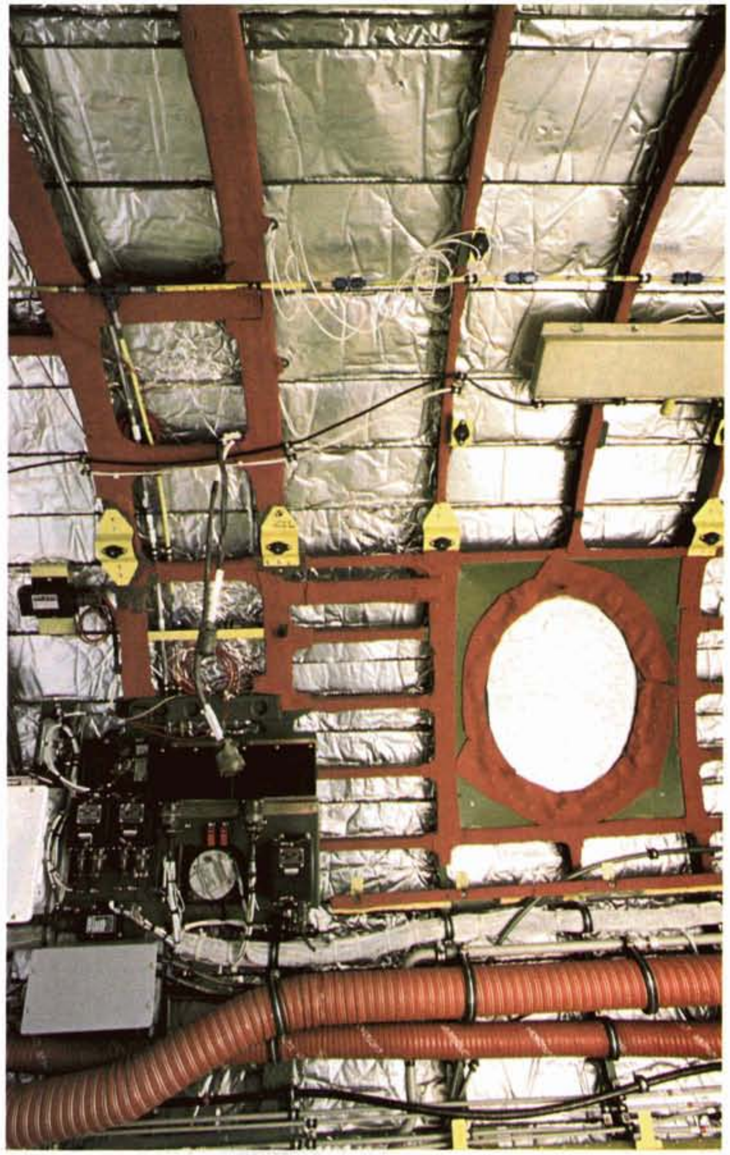
The photos illustrate the Falcon Jet installation sequence. Below, a company employee is cutting sheets of the material into various shapes and sizes to fit between structural parts of the airplane. For easy installation, SOLDAMP has an adhesive backing, exposed by peeling off the outer skin (right). The far right photo shows a completed area of the Falcon Jet interior.

Some business aircraft—notably those outfitted by Georgetown Aircraft Services, Georgetown, Delaware—are now available with a complete thermal/acoustical blanket incorporating both SOLDAMP and a thicker layer of the same polyimide foam. This treatment provides superior acoustical results, lighter weight, and fire-resistant encapsulation for the passengers and crew.

SOLDAMP is a member of the family of polyimide foam materials known as Solimide®, and manufactured by Imi-Tech Corporation, Elk Grove Village, Illinois. Solimide was originally developed by Solar Turbines International, San Diego, California, a division of International Harvester Company, under contracts with Johnson Space Center in a program aimed at minimizing fire hazard in the Space Shuttle and other flight vehicles. The assets and business of International Harvester's Solimide operations were subsequently acquired by Imi-Tech, which has expanded production and developed a number of new products based on the original technology. The technology is covered by several patents, some of them owned by Imi-Tech and others waived by NASA for Imi-Tech use.

Solimide is a lightweight fire-resistant material produced under a manufacturing process that allows it to be uniformly foamed. It can be produced in a variety of densities and structural configurations, and it remains resilient under exposure to temperatures ranging from minus 300 to plus 500 degrees Fahrenheit. It is resistant to open flame and generates virtually no smoke or toxic byproducts.

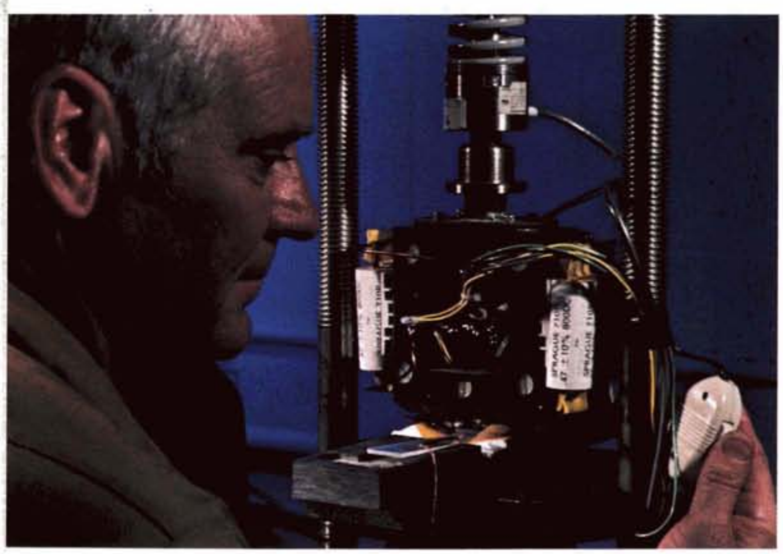
™ SOLDAMP is a trademark of Imi-Tech Corporation.
® Solimide is a registered trademark of Imi-Tech Corporation.



In addition to their use in aircraft for vibration damping, insulation and noise reduction, materials of the Solimide family have applicability to aircraft interior panels and potentially for seat cushions after further development, because they resist ignition better than any materials in use; Imi-Tech is developing a special, more durable formulation for the latter application. Solimide is used aboard the Space Shuttle for packaging and insulation of equipment.

Another application in air transportation is in refrigeration equipment produced by Acurex Aerotherm, a division of Acurex Corporation, Anaheim, California. Acurex Aerotherm supplies about 40 percent of the refrigeration equipment used in galleys of the free world's commercial airliners. The company uses a form of the material, known as Solimide TA-30, as a thermal barrier in the walls of the air chilling system, located separately from the airliner's galley, and in the refrigeration units in the galley (right). The material allows Aerotherm to meet and surpass the strict flame resistance, smoke and toxicity specifications demanded by commercial airframe manufacturers. Other aerospace applications include thermal/acoustical blankets on helicopters, cryogenic insulation of rocket fuel tanks and cabin insulation of several other executive jets.

In non-aerospace applications, Imi-Tech offers a broad family of Solimide-based products for marine use. The U.S. Navy is using Solimide for cushioning of critical parts aboard ship, and approval has been received for several other Solimide-based insulating products on Navy ships. In addition, Imi-Tech has a new acoustical blanket under test for use in submarines and is conducting research and development for use of the material as submarine hull insulation. Solimide is also used in industrial applications, as thermal insulation for sensitive electronic equipment (see page 00) and as acoustical insulation in manufacturing environments where extreme conditions and a risk of fire or explosion exist. As a material for thermal and acoustical insulation, vibration damping, paneling and—in the longer term—seat cushions, it is applicable not only to aircraft and ships but to such surface transportation systems as rapid transit cars, trains, buses, and automobiles.



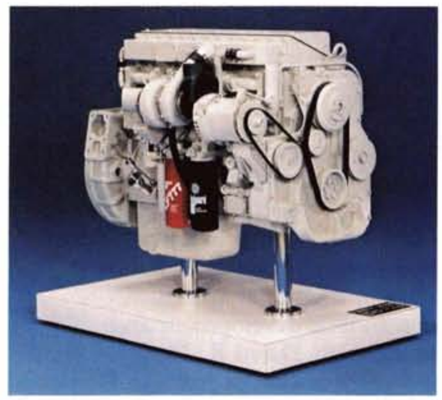
Portable Welder

At left, and in closeup at left center, an engineer is repairing a damaged helicopter windshield, using an Inductron Toroid Welder produced by Inductron Corporation, Grafton, Virginia. The device is a commercial version of a unit developed by Langley Research Center. A low cost, low power, self-contained portable welding gun, it was designed for joining thermoplastic materials, which become soft when heated and harden when cooled. The welder has a broad range of applications for joining both thermoplastic and, using adhesives, non-thermoplastic materials in the aerospace, automotive, appliance and construction industries.

Langley developed the device to meet a need for a better way of repairing helicopter windshields. Conventionally, windshields are repaired either by using mechanical fasteners to clamp a patch, by fusing the patch with the windshield, or by adhesive bonding of the patch. Each method has drawbacks; mechanical fasteners require hole preparation and special hardware, fusing often deforms the acrylic or polycarbonate windshield material, and adhesive bonding requires fixturing and time for curing.

The simply-operated induction welding gun employs a wire-wound toroidal (ring-shaped) core to transmit magnetic flux to a screen, generating heat to the parts to be joined. In the helicopter application, the only preparation required to repair a windshield hole is cutting a metal screen, or "susceptor"—a circular strip one quarter inch wide—slightly larger than the hole. The metal screen is placed between the thermoplastic windshield and a thermoplastic patch somewhat larger than the screen, then the welding gun is positioned directly above the screen. When the toroid is energized, the alternating current produces inductive heating in the screen; the screen transmits the heat to the patch material, causing it to melt and flow into the screen, forming a bond.

Langley conducted extensive tests of the welder before making it available for commercial use. Laboratory tests (bottom left) of acrylic specimens fabricated by the toroid heating technique demonstrated high shear strength values. The welder's portability and low power requirement allow its use on-site in any type of climate with power supplied by a variety of portable sources.



Turbocharged Diesels

The truck shown above is powered by a turbocharged L10 engine (right), one model of a diversified line of diesels and components manufactured by Cummins Engine Company, Columbus, Indiana. The company's principal market is the heavy duty truck industry; every major U.S. truck manufacturer offers Cummins engines as standard or optional equipment.

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

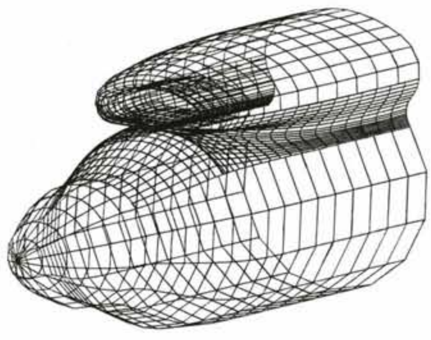
Solving the 'Hidden Line' Problem

Highlighting spinoff examples in the field of computer processing is an important software advance in computer-aided design

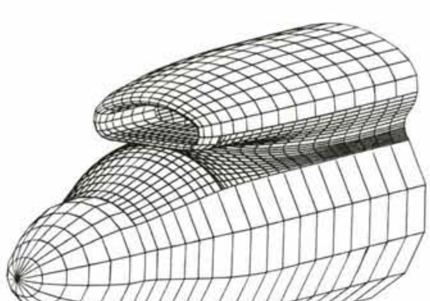
Aerospace engineers have been using computer-generated graphics as a design tool for years and the technique has spread to many other fields of industrial design, such as architecture, automobile development and metallurgy. David R. Hedgley, Jr., a mathematician at NASA's Dryden Flight Research Center has made an important contribution to further advancement of this art by solving a problem that has confounded graphics experts since computer-aided design began.

The problem was that a computer does not "see" a solid object as the human eye sees it; the computer defines the *whole* object without regard to perspective. For example, imagine looking at an office desk; you see the top surface and one or two sides, depending on your viewing angle. But—prior to Hedgley's solution—if a computer was asked to produce a picture of a desk it would show all the desk's surfaces, angles and curves, regardless of whether they were on the side facing the viewer or on the back and under surfaces hidden from the viewer. This resulted in a cluttered, confusing picture that slowed and complicated the design process.

Mathematicians around the world worked for years on this "hidden line" problem, considered to be one of the most difficult in the field. Some achieved partial solutions, but they were incomplete or insufficiently accurate. Working at Dryden on aircraft wing flutter analysis, David Hedgley saw a need for a more accurate method of simulating wing aerodynamics by computer. In 1981, after two years of effort, he came up with a computer program that considers whether a line in a graphic model of a three-dimensional object should or should not be visible. Known as the Hidden Line Computer Code, the program automatically removes superfluous lines and permits the computer to display an object from a specific viewpoint, just as the human eye would see it.



The above illustration is a computer-generated drawing of an engine nacelle for an advanced turboprop aircraft design investigated by Lockheed-Georgia Company. The initial drawing has hundreds of extra lines, because the computer shows all the lines resulting from its stored input without regard for perspective. A new NASA-developed computer program automatically removes the hidden lines to produce clean, unambiguous drawings like the one below.



In April 1982, the Hidden Line Computer Code was made available to public users through NASA's Computer Software Management and Information Center (COSMIC®). It was an immediate best seller. In its first year, the hidden line software package set a record for sales of an individual COSMIC supplied program. Hidden Line Computer Code users now number in the hundreds; they range from small companies to Fortune 500 corporations and they embrace a wide variety of industries.

An example of a user is Rowland Institute for Science, a new non-profit center for basic research located in Cambridge, Massachusetts. Rowland chemists have used the Hidden Line Computer Code to model molecule shapes visually; removal of hidden or overlapping lines provides an accurate image of molecular structure, free of ambiguities of perspective that could be misinterpreted.

Among the many applications of the Hidden Line Computer Code are drawings of planned construction site locations. The computer presents graphics of many different viewpoints, so that engineers can determine the most effective design of earthwork and structure to assure that the facility will blend with the environment. Such techniques were used by the Nebraska Public Power District in construction of the Gerald Gentleman Station pictured, a power generating plant near Sutherland, Nebraska.

Several departments of Lockheed-Georgia Company, Marietta, Georgia use the program in generating computer drawings of aircraft models. These models are combinations of individual panels representing a particular airplane component—a wing, tail or nacelle, for example. A model may have as many as 2,500 panels, resulting in hundreds of excess lines; removing the hidden lines presents a clear, unambiguous drawing, which is used to verify that the aircraft design has been properly modeled. After verification, aerodynamicists use the drawings to determine airflow around the component; airflow analyses help refine the aircraft design. The speed and accuracy of the Hidden Line Computer Code reduce computer time and improve productivity at Lockheed-Georgia; at current levels of usage, the company recovers the purchase cost of the program every two days.

The Nebraska Public Power District (NPPD), Columbus, Nebraska uses the program in several different ways, for example, in producing drawings of substation site locations or of transmission towers. NPPD also operates a nuclear power station, and engineers use the program to depict a three dimensional simulation of the power distribution in the nuclear reactor; displaying power levels graphically helps determine whether power generation in any one segment should be suppressed or increased for greater efficiency. Another application of the code is generation of 3-D bar charts showing power usage in individual towns served by NPPD.

The hidden line program is an example of how NASA is helping American businesses reduce automation costs by making available already-developed computer programs that have secondary utility. Development of an entirely new program may entail costs equivalent to 30–40 percent of the total cost of computerizing a business or a process. Frequently, however, a program developed for one purpose can readily be adapted to a totally different application. Thus, business and industrial users can save time and money by taking advantage of the service COSMIC provides in the interest of national productivity.

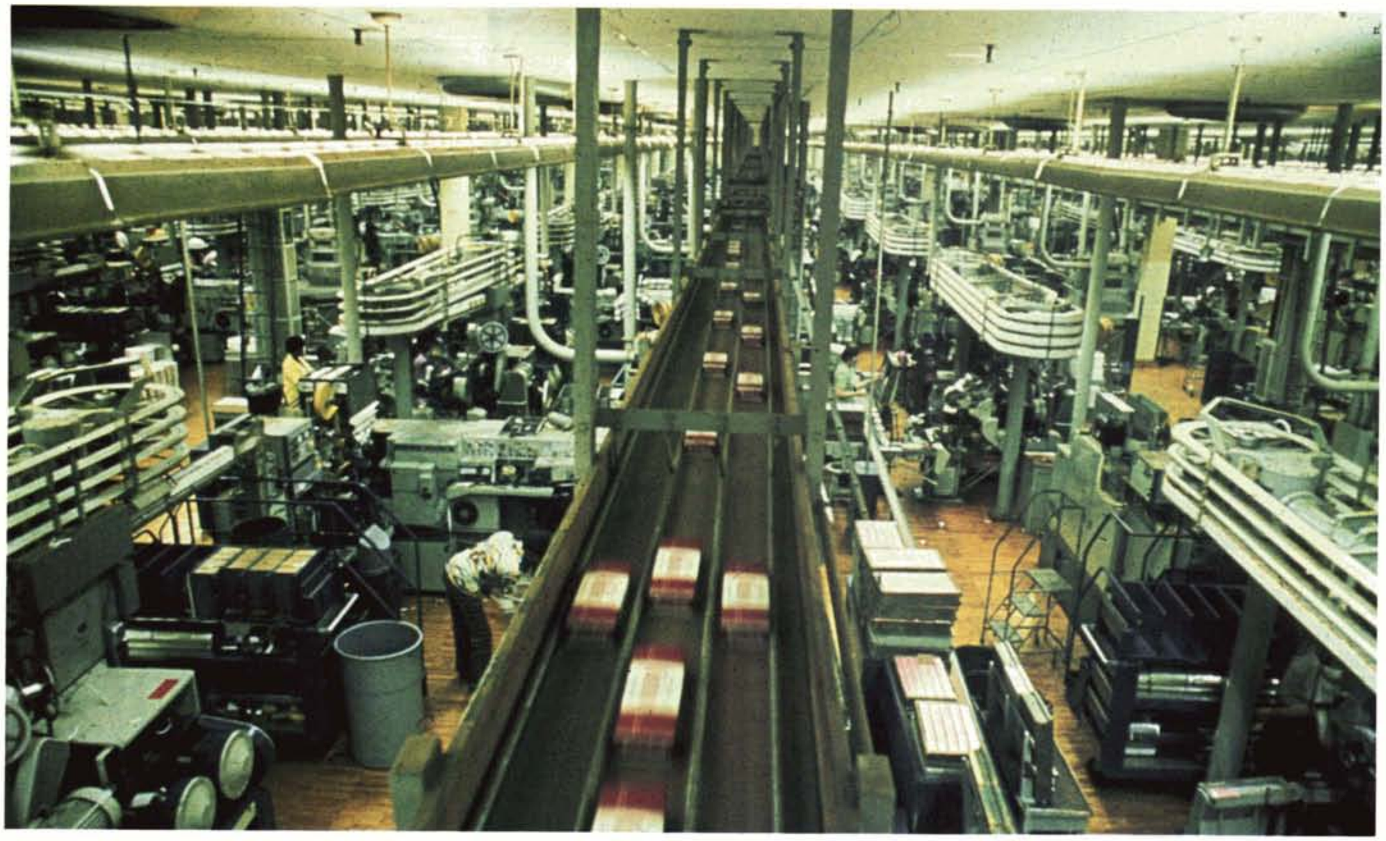
Located at the University of Georgia, COSMIC gets a continuous flow of software developed by NASA, the Department of Defense and other technology-generating agencies of the government. COSMIC identifies those that can be adapted to secondary usage, stores them and notifies potential customers of their availability through a catalog and through the NASA publication *Tech Briefs*.

COSMIC's library numbers some 1,300 programs applicable to a broad spectrum of business and industrial applications. Customers can purchase a program for a fraction of its original cost—the Hidden Line Computer Code, for example, costs less than $400—and in most instances they get a return many times their investment, even when the adaptation cost is included.

Acceptance by business and industry has been extraordinary; the Center has distributed thousands of programs, some of which have allowed savings amounting to millions of dollars. Thus, COSMIC's service represents one of the broadest areas of economic benefit resulting from secondary use of technology developed by the government.

Noise Prediction

United Information Services (UIS), Charlotte, North Carolina, provides computing services to business and industry, combining advanced hardware and software facilities with skilled programming assistance to meet clients' special needs. Through COSMIC, NASA's software dissemination center, the UIS office in Raleigh,



North Carolina purchased a software package—Computer-aided Noise Prediction Model—consisting of NOIZ and RAYTR, two computer programs developed by Virginia Polytechnic Institute and State University under a National Science Foundation grant. These programs, enhanced by UIS for its particular applications, are used to provide computer analyses of noise level predictions for clients.

An example of UIS service to clients is a computer analysis performed for R. J. Reynolds Tobacco Company, Winston-Salem, North Carolina, which seeks to reduce plant noise levels so its employees will not have to wear ear protection devices. Reynolds' facilities used in cigarette manufacture and packaging are shown in the accompanying photos. The NOIZ and RAYTR programs calculate predictions of the noise levels caused by the equipment pictured. The predictions are then used in design of new buildings or in remodeling existing plants; they enable engineers to determine accurately the amount of sound absorption required to effect an improved working environment for employees. Reynolds—and other clients—can avoid installation of excess absorption, which increases cost but does not improve the working environment.

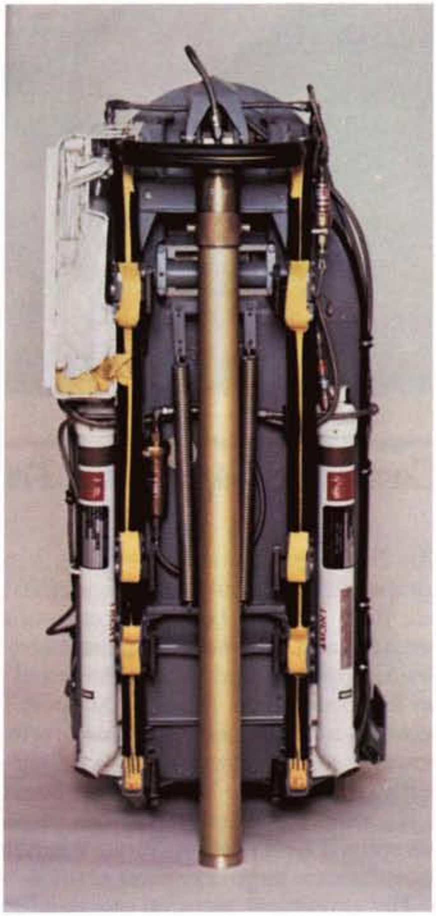
Crew Escape System

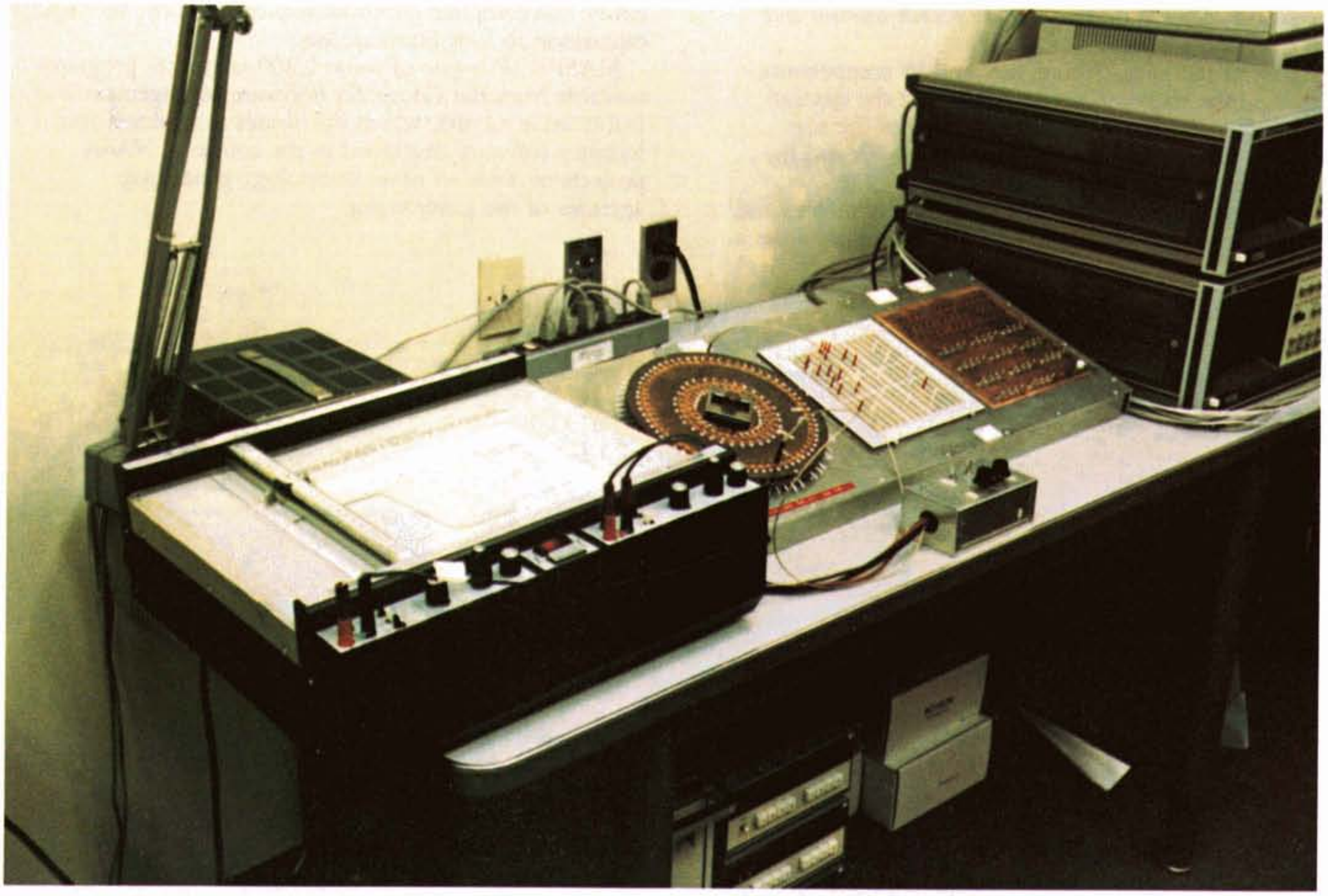
Talley Industries of Arizona, Mesa, Arizona is a recognized leader in rocket propellant research, noted particularly for a number of advances in the application of propellants to aircrew escape systems. Among the company's major product lines are rocket motors and gas generators.

At lower left is an ejection seat and its components, including the rocket motors that provide the ejection thrust. The photo at right is a rear view of the seat showing the installation of the rocket motors and the parachute canopy.

To calculate the mass properties of rocket motors and gas generators for escape systems, Talley engineers use a computer program developed by Langley Research Center. Called MASPROP (Determining Mass Properties of a Rigid Structure), the program performs calculations needed to determine the center of gravity for a particular thruster, a determination essential to accurate positioning of the motor or generator in the aircrew escape system. Talley's use of MASPROP replaced hand calculations that sometimes involved several weeks of effort; the computer program reduces the time for each calculation to four hours or less.

MASPROP is one of some 1,300 computer programs available from the Computer Software Management and Information Center, which distributes to business and industry software developed in the course of NASA projects or those of other technology-generating agencies of the government.





Computer Component Tester

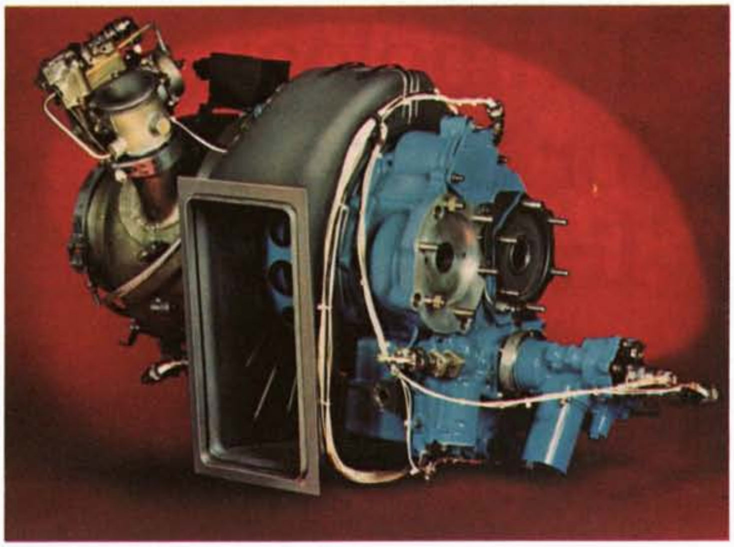
The NASA publication *Tech Briefs,* a quarterly compendium of new technology available for transfer (see page 118) has been the source of many spinoff products and processes. In most cases, an item in *Tech Briefs* supplies a lead, which interested firms can follow up by requesting a Technical Support Package that provides more detailed information. In some cases, however, the information in *Tech Briefs* is by itself sufficient to inspire a new development. An example is the work of Carlos F. Horvath, senior engineer of Burroughs Corporation, Paoli, Pennsylvania, which manufactures large computer systems.

The equipment pictured was developed by Horvath as a better way of testing ECL (Emitter Coupled Logic) chips, integrated circuits used in Burroughs' computer systems. The equipment shown is an AC/DC tester with an associated ramp voltage generator. The latter, a separate development that is an accessory to the basic tester, is the rectangular box at the front edge of the table. The AC/DC tester includes the circular bank of switches and the pin board in the elevated panel adjacent to the ramp voltage generator. The instrument at left is a plotter that records test results.

The AC/DC tester checks out ECL logic devices and their functionality within the computer. Each ECL device has a specific task in the computer's operation and the tester determines whether the device is performing that function properly. Horvath's invention allows rapid manual checking without extensive programming, as is required by other test methods; thus the ECL tester makes it easier to find out what is malfunctioning, and it also does the job faster. With minimal training, anyone can use the equipment, where prior test systems required highly skilled technicians.

Carlos Horvath reports that a single article in *Tech Briefs* provided the information that led to his development of the ramp voltage generator. The AC/DC tester did not evolve from any specific article but from an accumulation of information on new electronic circuit and component technology published in a number of issues of *Tech Briefs*.

Auxiliary Power Units



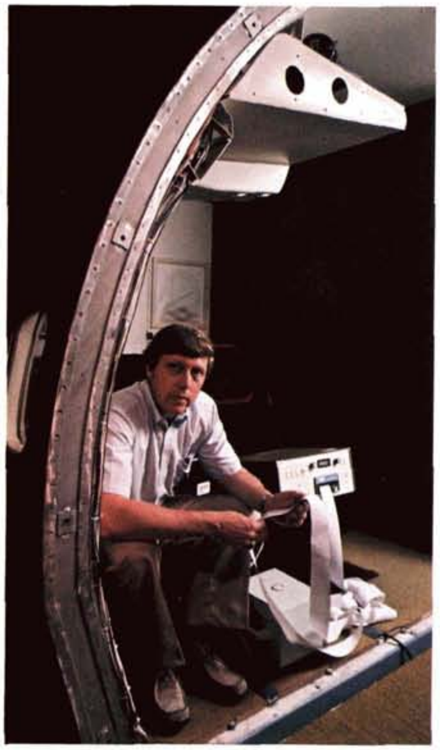
AiResearch Manufacturing Company, Los Angeles and Torrance, California, is a division of The Garrett Corporation engaged in manufacturing a broad variety of products for the aerospace, energy, metals, transit and marine industries. Among many activities at its Torrance facility, AiResearch provides design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

An example of the Garrett gas turbine line is the GTCP36-100 auxiliary power unit (APU) shown at right. These APUs provide pneumatic power for starting airplane engines, for cabin air conditioning and for electric power supply to other aircraft systems while the plane is on the ground. The GTCP36-100 is installed in such business jets as the French-built Dassault-Breguet Falcon 50 (below), the Canadair Challenger and the Grumman Gulfstream; it is also used on the new British Aerospace Model 146 short-haul airline transport. More than 20 other types of Garrett APUs are in service aboard commercial jetliners and military aircraft; they log more than one million operating hours each month.

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

Technology for Smoother Transit

A system for assessing passenger ride comfort exemplifies NASA demonstrations of technology for better ways to meet public needs



At left, project engineer Jack Leatherwood is conducting a test in a Langley Research Center facility that simulates vehicular motion; sensors report information on noise and vibration levels. Test results are computed and printed by the central processor shown in closeup at far right. The sensors and the processor comprise the Langley-developed ride quality meter, an aid to designers of transportation systems for improving passenger comfort in air, sea, road and track vehicles.

In designing transportation systems, one of the toughest jobs is that of the ride development engineer, who must insure that passengers get a smooth, comfortable ride. His problem—until recently—was lack of a completely reliable method for assessing the ride quality of the vehicle being developed. As a result, he was often faced with the necessity of making costly and time-consuming design changes to get an acceptable level of ride comfort.

Langley Research Center has come up with an answer to the problem: a generalized model—applicable to air, sea, road or track vehicles—for estimating passenger ride comfort in the presence of complex vibrations and interior noise. As part of this research, Langley developed a portable, self-contained ride quality meter for assessing ride quality during actual vehicle operations.

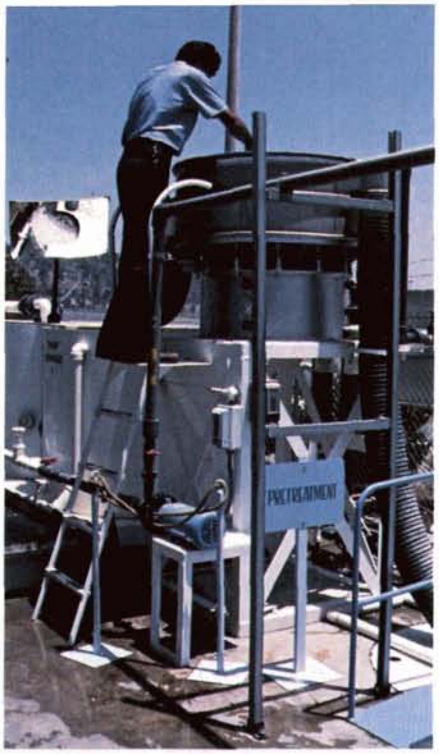
More than 3,000 people participated in the model development project. The subjects took turns in Langley's ride quality simulator, where they were exposed to controlled combinations of vehicle vibration and noise. Each then completed a questionnaire detailing the level of discomfort experienced. This input provided the basis for development of the computer model, which transforms individual vibration/noise elements into subjective units, then translates the subjective units into a single discomfort index that typifies passenger sensation of the total vibration/noise environment.

The ride quality meter has three components: a package of vibration sensors, a microphone and a computer. Installed on the floor of the vehicle being tested, the sensors measure vibration in five different axes: vertical, longitudinal, lateral, roll and pitch. The microphone measures noise levels.

The computer processes the input from microphone and sensors, according to the Langley-developed model, to give the user a printed readout including a number of options for assessing ride quality. Among the options are the total discomfort index; the vibration component of the total; the noise component; discomfort due to individual axes of vibration; discomfort due to individual noise bands; and discomfort corrected for trip duration.

The meter, in essence, serves as a reliable and accurate passenger "jury." It provides the first known capability for summing the effects of noise and vibration into a single ride quality index and, therefore, has attracted a lot of attention. Several automobile and truck companies are interested. Ford Motor Company and Langley teamed to test the meter's ability to assess ride quality in an automobile environment and Ford was sufficiently impressed to initiate purchase of meters. Amtrak has tested the system on its trains. Budd Company and the Department of Transportation have participated in simulator tests and representatives of the helicopter industry, the U.S. Coast Guard, Consumers Union and the Federal Railroad Administration have also expressed interest in the meter's capabilities. NASA has been granted a patent for the invention and Wylie Laboratories, Hampton, Virginia has applied for a license to produce the meter for the commercial market.

The ride quality model and meter exemplify a special area of NASA effort: demonstrations to show how application of advanced technology may help solve major problems or create better ways of meeting public needs. As seems likely in this instance, spinoff products sometimes emerge from such projects. Commercialization, however, is not the primary aim; NASA's intent is to expand public awareness of advantageous technology and inspire its broader application by government agencies, communities, medical institutions and other organizations. The following pages contain additional examples of NASA technology demonstrations.

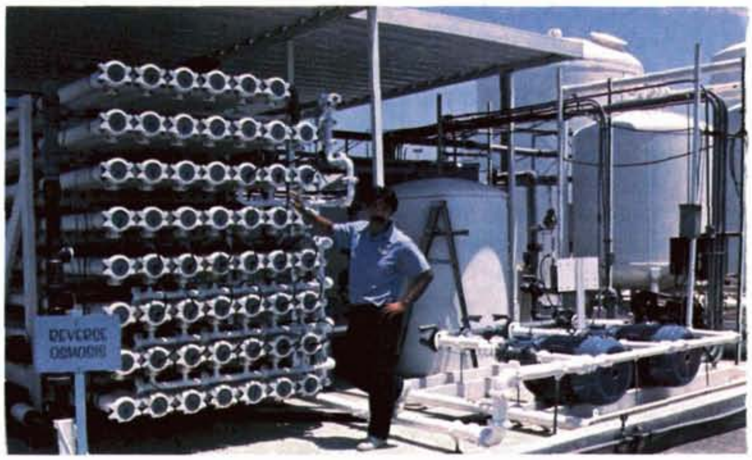


Sewage Treatment

For more than a decade, NASA's National Space Technology Laboratories (NSTL), Bay St. Louis, Mississippi, has been conducting research on the use of aquatic plants—principally water hyacinths—for treatment and recycling of wastewater. Already serving a number of small towns, the "aquaculture" technique has advanced significantly with its adoption by a major U.S. city. The Water Utilities Department (WUD) of San Diego, California is using water hyacinth filtration as part of a multi-step reclamation process designed to recover potable water from sewage.

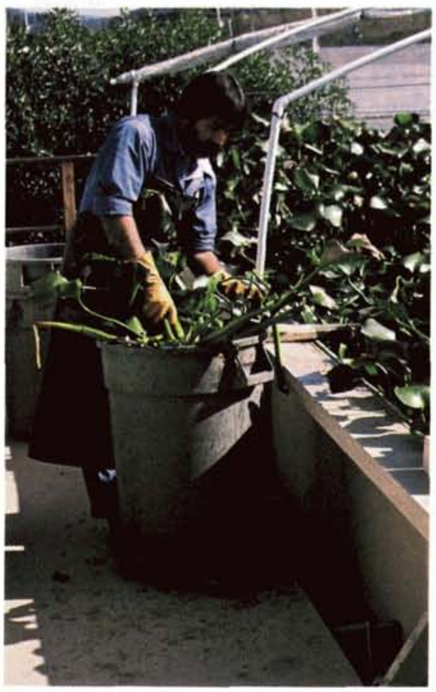
In the early 1970s, NSTL discovered that the glossy green water hyacinths literally thrive on sewage; they absorb and digest nutrients and minerals from wastewater, converting sewage effluents to clean water. Thus, they offer a means of purifying water at a fraction of the cost of a conventional sewage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

NSTL first tested the practical application of aquaculture in 1975, when hyacinths were planted in a 40-acre sewage lagoon at Bay St. Louis; the once-noxious lagoon soon became a clean water garden.



NSTL published a study report that attracted considerable attention and followed up by providing technical guidance to communities interested in applying the technology. Several southern towns, with populations ranging from 2,000 to 15,000, use water hyacinths as their year-round primary method of treating wastewater. Other towns employ aquaculture as a part-time or supplementary process in sewage treatment operations. In its Experimental Prototype Community of Tomorrow, Walt Disney World, Buena Vista, Florida operates a water hyacinth facility to explore advanced applications. Wastewater treatment capacity of these installations ranges from 50,000 to 350,000 gallons a day.

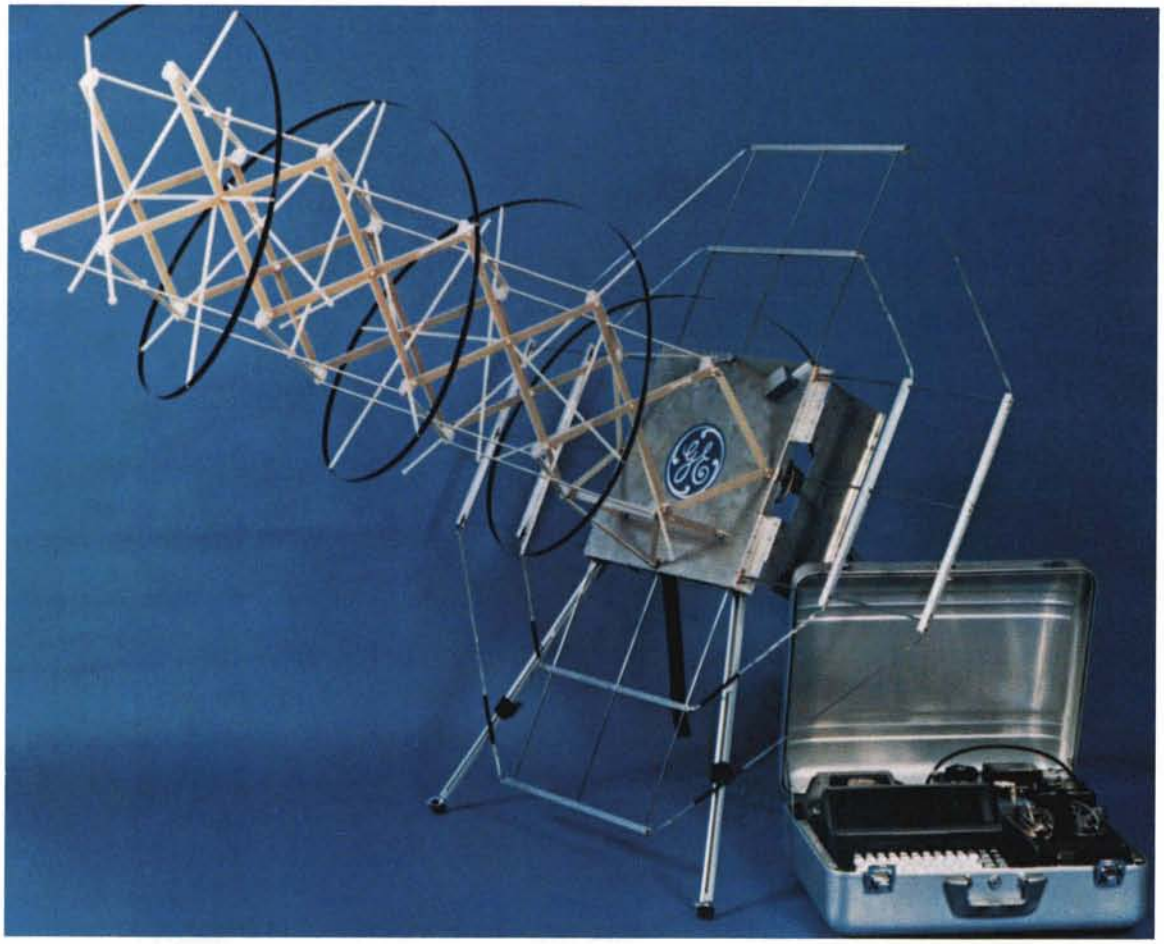
San Diego has been involved in experimental water reclamation projects since the 1950s because the city does not have enough potable water to meet the needs of its population; it must import water from the Colorado River and from northern California.



In the late 1970s, WUD developed a two-phase reclamation system involving a process called "reverse osmosis," which removes most of the salt and viruses from the sewage, and a carbon absorption technique that further purifies the wastewater. Early tests found the system efficient and cost-effective, but there was need for a means of removing other pollutants, such as metals and suspended solids. After consultation with NSTL, the city added a water hyacinth treatment facility and the combined processes began operation as an experimental system in 1981, treating 25,000 gallons of sewage daily. Additional testing demonstrated the system's capability for producing reclaimed water of extremely high quality; the tests also showed that toxic waste buildup, a normal result of other methods of treatment, does not occur in the aquaculture facility because the hyacinths reproduce rapidly and must be harvested frequently, thus toxin accumulation is limited. The prototype facility operated so successfully over a two-year span that San Diego built a one million gallon per day plant for service in 1984. The new facility has an aquaculture component that employs—in addition to water hyacinths—a reed-rock filter unit, the latest wastewater treatment developed at NSTL. The hybrid aquatic plant/microbial filter combination, unlike the water hyacinth system, will operate in cold as well as warm climates.

The accompanying photos illustrate the sewage treatment process in the initial San Diego facility. At upper left on the opposite page is the first step, in which the sewage passes through a screening device for removal of large solids. The raw sewage is pumped into greenhouse-like aquaculture tanks, such as the one shown below the screening device. After aquaculture cleansing, the water is further treated by an "ultrafilter," then it passes into the reverse osmosis facility (left center) where it is demineralized. A final cleanup is provided in a carbon absorption tank. San Diego's WUD projects that, within the next decade, the system will be able to treat 40 percent of the city's sewage, substantially reducing water and sewage bills and providing drinking water of much better quality than could be obtained by other reclamation methods.

WUD is also investigating the byproduct bonus potential of harvested water hyacinths. The photo at lower left shows hyacinths being harvested. The left-hand photo above pictures an experimental garden in which hyacinths are used as compost. Animals are fed chopped harvested hyacinths (top right) and they also drink the processed water. Other harvested plants are ground up and pumped into a bacterial digester (right center) that produces methane gas (right) for use in generating electricity.



Suitcase Communicator

The equipment pictured is a portable communications system designed to relay messages over long distances by satellite. A joint development of Ames Research Center and General Electric Company, Schenectady, New York, it consists of a collapsible antenna and a computerized transceiver, a terminal for sending and receiving messages. The whole system fits into two Pullman-size suitcases and can be powered from a conventional outlet or a vehicle's battery.

Use of satellite relay permits transmissions in almost any terrain, even in areas where mountains block normal line-of-sight transmission. In initial tests, the relay spacecraft was NASA's ATS-3 direct broadcast satellite; with ATS-3, an operator anywhere in North or South America and most of the Atlantic and Pacific Oceans can communicate with fixed Earth stations in those areas. If a network of compatible satellites were available, the system could be used globally.

The principal use envisioned is communications in disasters and other emergencies where it is necessary to get short but vital messages out of the emergency area. The 1980 eruption of Mount St. Helen's illustrated the need for rapidly deployable long distance communications not dependent on wirelines, because such lines are often destroyed in disasters. Another application is long range communications between transportation vehicles and their dispatch offices. In a seven-month test concluded last year, drivers of Smith Transfer Corporation cross country trucks exchanged information via satellite with their dispatchers in Staunton, Virginia. The drivers reported excellent communications except on brief occasions where trees or overpasses blocked line-of-sight transmissions. Such a communications system offers advantages to the trucking industry in keeping track of equipment, improving maintenance schedules, avoiding improper routing and reducing theft losses.

The system is alphanumeric, meaning that messages are sent and received in letters and numbers. The operator types a message on a keyboard, then transmits it to the Earth station by punching a single key. Another keystroke enables him to receive messages stored at the Earth station. The terminal can be set up in two minutes. The antenna is unfolded and pointed toward the satellite; the proper direction and elevation are available from a simple chart.

ATS-3 is 17 years old and nearing the end of its useful life, but if enough public service and commercial applications are found, the system could be redesigned to work with other satellites. Mobile Satellite Corporation, King of Prussia, Pennsylvania plans to build and operate such a satellite; the company has filed an application with the Federal Communications Commission for a frequency allocation.

Firefighting Trainer

In the photo, a firefighting trainee is conducting a fire control exercise using a prototype simulator known as the Emergency Management Computer Aided Training System (EMCAT). Developed by Marshall Space Flight Center (MSFC) in response to a request from the Huntsville (Alabama) Fire Department, EMCAT enables a trainee to assume the role of fireground commander and make quick decisions on best use of his firefighting personnel and equipment.

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

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

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

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

Essex Corporation is now in the design phase of the advanced EMCAT program and the company is working on an initial set of six scenarios simulating a railroad accident and residential, garden apartment, hotel, shopping mall and chemical plant fires. The first simulator and at least one new scenario will be ready for test next year.

Methane-powered Airplane

The airplane pictured above is a Beechcraft Sundowner, a four-place lightplane produced by Beech Aircraft Corporation, Wichita, Kansas. This Sundowner, however, differs from production line models; it is powered by liquid methane (LM), which is stored in two 18-gallon tanks installed in place of the Sundowner's rear seat (left).

Beech Aircraft conducted extensive tests of the experimental Sundowner to determine the feasibility of using LM instead of gasoline in future piston-driven aircraft. Methane, the principal component of natural gas, is in abundant supply and is 40–60 percent cheaper than conventional fuel; it also offers bonuses in safety and reduced pollution from exhaust emissions. The company had earlier developed a system, now in production, for converting cars and trucks to LM use.

Use of methane in liquid state was necessary to reduce the space needed for fuel storage to practicable dimensions; as a gas, it would have required a volume 630 times greater. But liquid methane is a "cryogenic" fuel that must be stored at a temperature of 260 degrees below zero Fahrenheit to keep it liquefied. Thus, the key technology in both the aviation and automotive applications is the cryogenic storage tank, developed by Beech Aircraft's Boulder (Colorado) Division; company engineers say the tank is so efficient it would keep a cup of coffee hot for 10 years. In designing the tank, Boulder Division drew upon the company's experience in producing superinsulated, virtually leak-proof cryogenic equipment for storing liquid oxygen and hydrogen fuels in NASA's Apollo, Skylab and Space Shuttle programs.

Drunk Driver Testing

In the mid-1960s, preparing for long duration space missions of the future, NASA conducted a test—performed by McDonnell Douglas Astronautics Company—in which four men were sealed in a realistically simulated space station for 90 days. The experiment had dual purpose: testing the components of an advanced life support system, and obtaining data on the physiological and psychological effects of long confinement. Of particular importance was measurement of the subjects' abilities to perform certain tasks and determination of how much their abilities were impaired

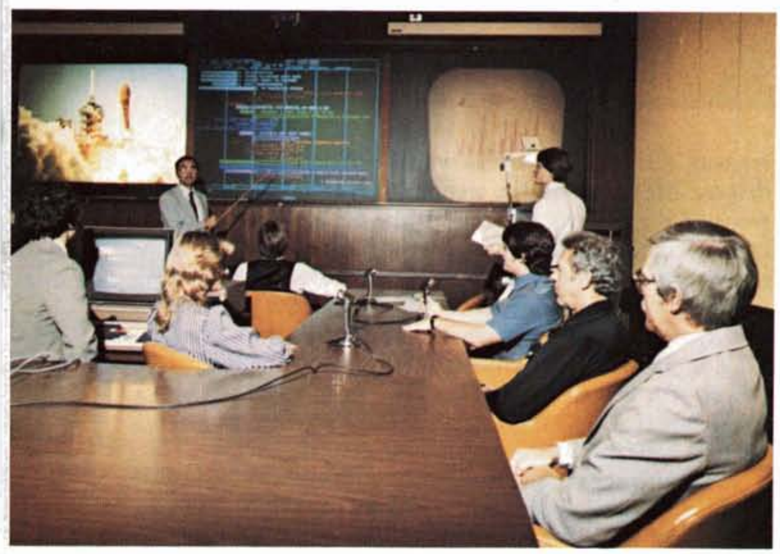
by long term isolation. For these behavioral measurements, Ames Research Center contracted with Systems Technology, Inc., Hawthorne, California for preparation of a series of "tracking tasks" to be accomplished by the subjects and for development of an electronic system for analyzing and rating the subjects' visual/motor responses.

Almost two decades later, that technology has turned up in a system for determining whether a driver is too drunk to drive. Under contract to the National Highway Traffic Safety Administration (NHTSA) of the Department of Transportation, Systems Technology produced a variant of the NASA Critical Tracking Task (CTT) device, the testing component of a Drunk Driver Warning System (DDWS). Last year it was tested experimentally in California; in two of the state's counties, twice-convicted drunk drivers were given a choice of operating a DDWS-equipped test car for six months or taking an alternative sentence involving a fine and treatment.

The device is intended to discourage intoxicated drivers from taking to the road by advising them they are in no condition to operate a vehicle; if they drive anyway, the DDWS system warns police and other drivers. Mounted on the steering column directly in front of the driver (above left), the CTT device tests eye-to-hand coordination and reaction time. When the driver turns on the ignition, the car's hazard lights start blinking; to turn them off he has to pass the test. The test involves watching a needle (above right) on the CTT and keeping it centered—by turning the steering wheel—for less than a minute. It sounds easy, but tests have shown a high failure rate for drivers with blood alcohol concentrations above 0.10 percent.

If the driver fails the test or does not take it and elects to drive anyway, the hazard lights will continue to flash on and off and, in addition, the horn will blow once every second, a clear signal to police and potential victims. In the California experiment, the test cars were also equipped with a monitor that recorded when the ignition was turned on, whether the driver passed the test, and whether the car was driven after a test failure, and at what speed. These records were studied by project personnel every two weeks and the performance of the drivers was analyzed. Study findings are being evaluated by NHTSA.

Management Information System



At left, Kennedy Space Center engineers are preparing displays of Space Shuttle launch information for presentation at the group meeting shown at lower left. They are using a new Automated Management Information Center (AMIC) that employs innovative microcomputer techniques to create color charts, viewgraphs or other data displays in a fraction of the time formerly required. Developed under KSC contract by Boeing Services International Inc., Seattle, Washington, AMIC can produce an entirely new informational chart in 30 minutes or an updated chart in only five minutes, dramatic improvements in what have been labor-intensive and time-consuming tasks. The data displays can be used for live teleconferencing with officials at other sites involved in space operations.

AMIC stemmed from a NASA need to reduce the time necessary to generate information for decision making at top management levels. At NASA centers, hundreds of people are involved in producing and controlling the thousands of documents essential to space operations management. Many of these documents are still produced manually where AMIC is not available. Manual preparation of such documents, plus delivery time to get them to users at other centers, can take as long as two weeks. The old system worked well, if slowly, in the pre-Shuttle era, but it is not fast enough for the advanced space operations contemplated, with Shuttle flights eventually reaching a twice-monthly rate.

Thus, KSC initiated the AMIC program to provide decision-makers a management tool based on the latest computer technology. KSC and Boeing Services International assembled data from a number of sources to form a single non-duplicated data base, then devised means to compress information from the data base and display it in almost any format preferred by the user. The system is not only faster and more reliable, it also offers substantial savings compared with manual methods of document preparation.

The success of the KSC prototype led to the system's adoption by other NASA and military space centers. In 1982, AMIC sites were installed in the Space Shuttle program offices at KSC, at Johnson Space Center and at Marshall Space Flight Center; a common communications network linked the three centers. Last year, the AMIC network was expanded to include NASA Headquarters, the Air Force Space Division at Los Angeles, California, and the USAF's Shuttle facility at Vandenberg Air Force Base, California. Additional government installations are likely, and AMIC also has considerable potential as a management system for business firms; some large retail corporations have learned of AMIC and expressed strong interest.

Technology Utilization

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

Recycling Technology

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

The wealth of aerospace technology generated by NASA programs is a valuable resource, a foundation for development of new products and processes with resultant contribution to expanded national productivity. In a dormant state, however, the bank of technology represents only *potential* benefit, like oil in the ground. One of NASA's jobs is to translate the potential into reality by putting the technology to work in new applications.

The instrument of this objective is the Technology Utilization Program, the aim of which is to get aerospace technology out of the storehouse and into the mainstream of the national economy, thereby producing bonus return on the aerospace investment. The program seeks to broaden and accelerate the transfer of aerospace technology to other sectors of the economy by promoting awareness of the technology available for transfer and by making it readily accessible to those who want to take advantage of this resource. Established in 1962, the program has been remarkably successful; thousands of technology transfers have been effected.

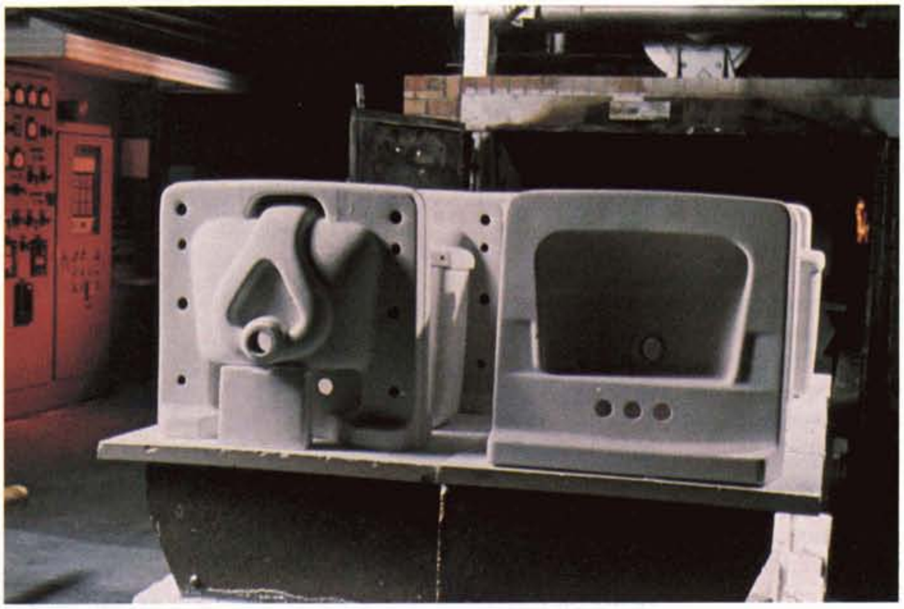
Focal point of the program is NASA's Technology Utilization and Industry Affairs Division, headquartered in Washington, D.C. That office coordinates the activities of technology transfer specialists located throughout the U.S. at NASA field centers, dissemination centers and other offices. These specialists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

A key element of the Technology Utilization Program is a network of user assistance centers that provide information retrieval services and technical help to industrial and government clients. The network's principal resource is a computerized storehouse of technical knowledge that includes more than 10 million documents. How this technology is put to work to the benefit of the individual client and the nation as a whole is exemplified by a project wherein one of the centers—the NASA/University of Kentucky Technology Applications Program (NASA/UK TAP)—provided help in the installation of an advanced cogeneration system at the Ferguson, Kentucky plant of Crane Company, manufacturer of ceramic fixtures.

A cogeneration system is one in which energy ordinarily wasted in an industrial process is recovered and reused to create a second form of energy. The system at Crane Company captures hot stack gases from the plant's four ceramic kilns and uses them to produce electrical power for plant operations. Built by Sundstrand Energy Systems, Rockford, Illinois, the Crane installation was the first industrial application in a cogeneration pilot program jointly sponsored by Sundstrand and the Department of Energy. Key to the system's flexibility is an Organic Rankine Cycle (ORC) engine originally developed by Sundstrand to provide electrical power for spacecraft.

In the Crane installation, an exhaust manifold collects waste heat from the kilns and directs it to a vaporizing system, where the heat is used to vaporize a working fluid (toluene). The vaporized toluene is then employed to drive a turbine connected to the 750 kilowatt ORC generator, which produces electricity and feeds it into the plant distribution system. This technique reduces the demand on the local utility and allows Crane Company to generate 20–40 percent of its own electricity.

NASA/UK TAP played an important supporting role in the installation of Crane's energy recovery system, in response to the company's request for assistance in developing improved energy conservation and utilization practices. The idea of using an ORC engine as the key component of an industrial cogeneration system evolved from NASA/company cooperation. NASA/UK TAP conducted a search of the computerized data bank for relevant data and was able to provide important information used by the firm to evaluate each of the components of the ORC system prior to commitment. NASA/UK TAP's input also contributed to problem solving during the installation and initial operation of the system.



At left, bathroom sinks are being conveyed to a kiln at the Crane Company plant in Ferguson, Kentucky. Heat from the kilns is collected by an exhaust manifold (below) and reused to generate electricity for plant operations. A NASA user assistance center played a supporting role in the installation of the advanced energy recovery system.

NASA/UK TAP is one of nine NASA-sponsored application centers affiliated with universities across the country; the network includes seven Industrial Application Centers (IACs) and two State Technology Applications Centers (STACS). The IACs and STACs perform similar services, but where the IACs operate on a regional basis, a STAC works within an individual state. Staffed by scientists, engineers and computer retrieval specialists, these centers provide three basic types of services: search of data banks for technical literature relevant to a client's needs; "current awareness" reports designed to keep clients' personnel abreast of the latest developments in their fields; and technical assistance in applying the information retrieved to the client's best advantage.

Other mechanisms employed in the Technology Utilization Program include Technology Utilization Officers, located at NASA field centers, who serve as regional program managers; a quarterly publication that informs potential users of new technologies available for transfer; seminars and conferences that bring together NASA and industry personnel, a means of introducing non-aerospace firms to NASA, its technologists and its research and development activities; and a software center that provides computer programs adaptable to secondary use. NASA also undertakes, in cooperation with other organizations, applications engineering projects wherein existing aerospace technology is adapted to specified needs of government agencies and public sector institutions. These mechanisms are amplified on the pages that follow.

Searching data banks for information relevant to a client's projects or problems is one of three types of services provided to government and industry organizations by NASA's applications centers, located at universities across the country.

Publications

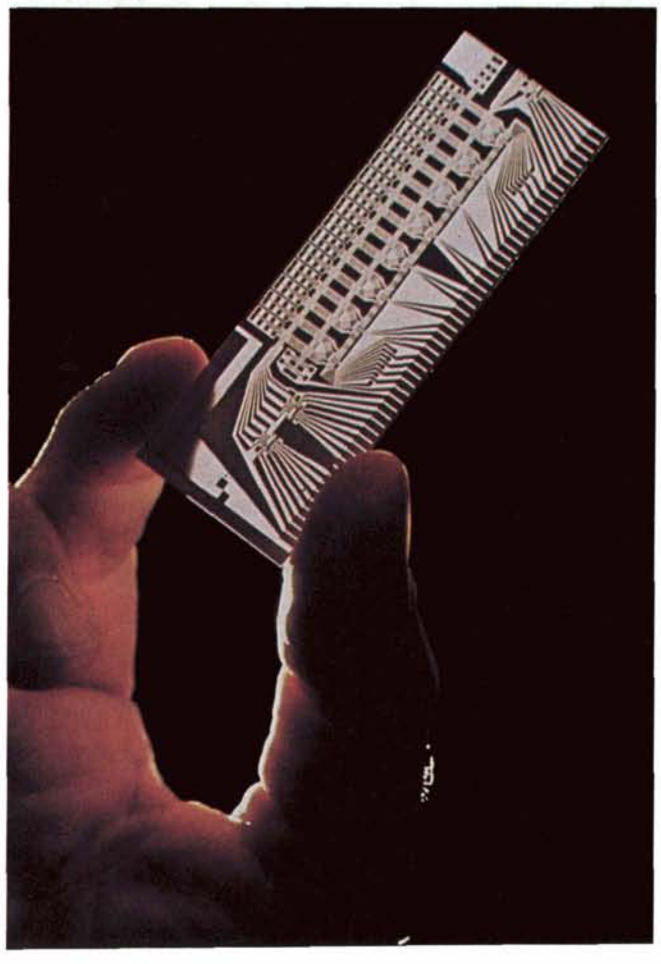
An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This is accomplished primarily through the publication *Tech Briefs*.

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

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

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

A related publication deals with NASA-patented inventions available for licensing, which number almost 4,000. NASA grants exclusive licenses to encourage early commercial development of aerospace technology, particularly in those cases where considerable private investment is required to bring the invention to the marketplace. Non-exclusive licenses are also granted, in order to promote competition and bring about wider use of NASA inventions. A summary of all available inventions, updated semi-annually, is contained in the NASA Patent Abstracts Bibliography, which can be purchased from the National Technical Information Service, Springfield, Virginia 22161.



Conferences and Seminars

The accompanying photos show scenes from a March 1984 technology awareness conference at Langley Research Center; in the bottom photo, Langley director Dr. Donald P. Hearth is welcoming Virginia Governor Charles Robb. Jointly sponsored by NASA and the Small Business Administration (SBA), the Virginia Conference for High Technology Opportunity drew more than 150 representatives of industrial firms—principally small businessess—for briefings by NASA, SBA and state/local government officials. NASA technologists made presentations on the potential for development of innovative products and processes through employment of NASA technology. SBA officials provided guidance for companies interested in government contractual work and discussed how firms may reduce the risk of high technology development by obtaining funding through the SBA's Small Business Innovative Research program. State and local government representatives advised on assistance available to industry from their agencies.

This meeting was typical of an ongoing series of conferences and seminars, sponsored by NASA independently or in cooperation with other organizations, held at NASA centers to make private companies aware of technologies NASA has developed or is developing, and to encourage broader private sector participation in the technology transfer process. One mechanism is the Corporate Associates Program, a joint effort of NASA and the American Institute for Aeronautics and Astronautics (AIAA); AIAA serves as an industrial broker to introduce non-aerospace firms to NASA and the opportunities for innovation that use of NASA technology offers.

These meetings usually generate a high volume of industry-initiated post-conference contacts with NASA technologists, efforts to follow up the briefings and pursue further some type of technology transfer—perhaps simply additional information or help in company problem solving, perhaps an active development project. In a number of instances, post-conference contacts have led to Technical Exchange Agreements between NASA and industrial firms; under these agreements, NASA makes available facilities and expertise so that a company can become more familiar with NASA technology and identify areas the company may explore to improve its product line. A related mechanism is a program whereby a company may participate in a major NASA project of special interest to the firm by assigning one of its own scientists or engineers, who works on the project as a guest investigator on loan to NASA. Still another mechanism is the Joint Endeavor Agreement, wherein NASA and private enterprise work together to promote the utilization of space, teaming on projects where a technological advancement appears feasible and where there is indicated potential for commercial application.

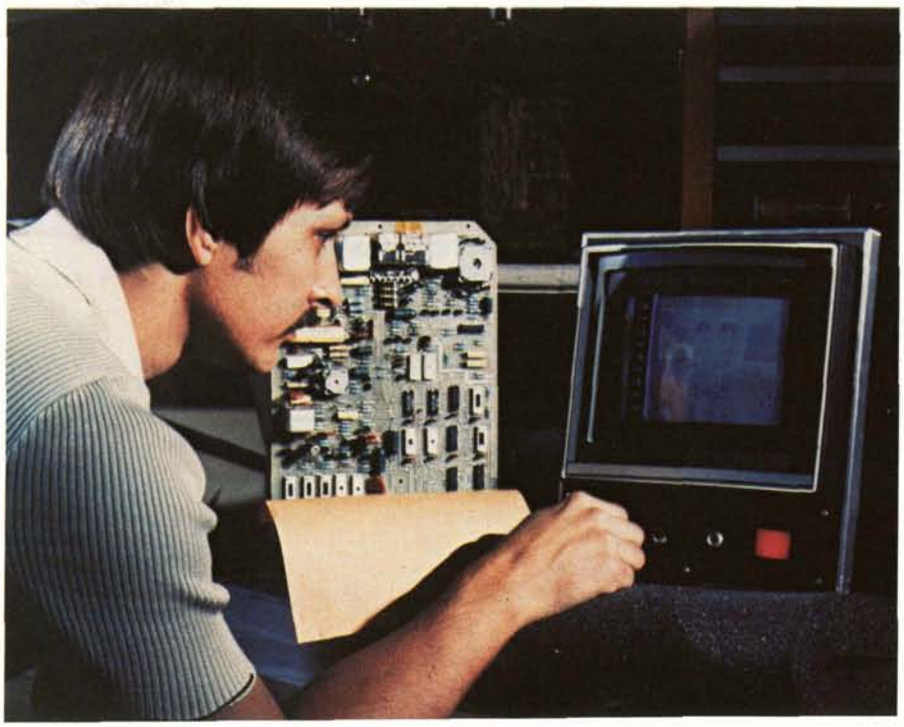
Software Center

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

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

An example of COSMIC's service is its assistance to Western Electric Research Center, Princeton, New Jersey, which conducts research in such areas as chemical processes, organic material processes, lasers, optics and thermal energy. The Western Electric researcher pictured below is engaged in the latter work; he is studying heat transfer processes to develop new manufacturing applications. In the course of this work, the Center employs a COSMIC computer program; called RAVFAC (Radiation View Factor Program), it is used for analyses of high temperature processing in the manufacture of semiconductor wafers.

In one step of the manufacturing process, the silicon wafers are placed in an apparatus that must produce uniform temperature gradients throughout the thickness of the wafer; if the gradients are not sufficiently uniform, circuits produced near the edges of the wafer



are not usable. The RAVFAC program helps assess proposed new designs by calculating heat transfer to determine whether temperature gradients vary from wafer edge to center. Center engineers report that RAVFAC is a powerful analysis tool that offers ease of computing heat transfer data; they estimate that its use saved several man-months that would have been required to develop a new program.

Another example is the help provided FMC Corporation's Construction Equipment Group, Cedar Rapids, Iowa. FMC manufactures the Link-Belt® line of construction equipment, examples of which are pictured; at upper right is a crawler crane, at lower right a wheeled rope truck crane. The company conducts extensive proof lift tests and computerized analyses to insure that the cranes can lift rated capacity loads that range up to one million pounds. In their analysis work, FMC engineers make use of a COSMIC program called Analysis of Beam Column; it is used as part of the required analysis for determining bending moments, deflections and critical loads for latticed crane booms.

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

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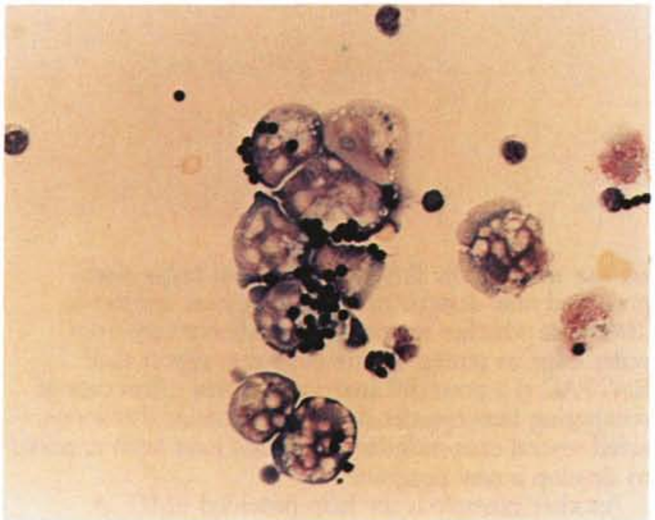
®Link-Belt is a registered trademark of FMC Corporation.



Technology Applications

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

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

An example of an applications engineering project is the contribution of Jet Propulsion Laboratory—principally Dr. Alan Rembaum—to a new cancer treatment that combines conventional chemotherapy with a technique that employs magnetic particles to separate cancerous cells from healthy cells. The basic research leading to this important biomedical development was sponsored by NASA and the National Institutes of Health.

Dr. Rembaum's original goal was to produce pure strains of cells for laboratory use. Over a span of 10 years, he investigated the synthesis and properties of various polymeric "microspheres," which led to the development of the cell separation technique illustrated above. The small black beads are magnetic microspheres coated with a substance that causes them to attach themselves selectively to certain cells within a mixture of cells. When the mixture is passed through a magnetic field, magnetic attraction separates the cells bound to the microspheres from the rest.

Recognition that the separation technique had broader medical applications led to Dr. Rembaum's advanced research as a member of an international team that also included biochemist John T. Kemshead of the Imperial Cancer Research Fund, London, England and chemist John Ugelstad of the University of Trondheim, Norway. The team developed a procedure for treatment of an often fatal type of cancer known as neuroblastoma, which commonly spreads to the body's bone marrow. In the spring of 1983, the trio worked with London doctors on the first human treatments, using magnetic "immunomicrospheres" to clean bone marrow of intruding cancer cells. Developed by Dr. Ugelstad as an extension of Dr. Rembaum's cell separation technique, the immunomicrospheres are made of polystrene plastic surrounding a small core of magnetite. The tiny beads are coated with an antibody that recognizes—and will only attach to—the original antigens on the cancer cells.

In the London treatments, doctors first remove about 10 percent of the patient's bone marrow in the diseased area (only a fraction can be safely removed, because the marrow is the foundation of the body's infection-fighting immune system). The patient is given chemotherapy or radiation to kill the malignant cells in the bone marrow still in the body. At a laboratory, the removed bone marrow samples are mixed with antibodies and passed through a container surrounded by strong magnets. The magnets attract the magnetitite in the immunomicrospheres and hold the cancerous cells against the walls of the container while the healthy cells pass through. The cleansed bone marrow, 99.9 percent pure, is then returned to the patient's body to carry on its immune functions until the bulk of the marrow—damaged by chemotherapy—can regenerate. More than 20 patients have been treated by this method. So far the magnetic microsphere technique has been used on humans only in Europe and only for neuroblastoma, but it has potential for other medical applications, such as diagnostic testing, separation and purification of proteins, labeling of cell membranes and study of the mechanisms of drug actions.

Another example involves application of technology from the Lunar Rover used in the Apollo program to a system that offers severely handicapped people mobility and more productive lives by allowing them to drive highway vehicles. Such a system is being developed by Johnson Engineering Corporation, Boulder, Colorado,

under the joint sponsorship of NASA and the Veterans Administration Rehabilitative Engineering Research and Development Service, Washington, D.C.

During surface explorations of the moon in the early 1970s, Apollo astronauts drove the Lunar Rover using only one hand to accelerate, brake and steer the vehicle. The technology that made that possible is the basis for Johnson Engineering's UNISTIK vehicle control system. The system employs a joystick instead of a steering wheel, brake pedal and throttle pedal, thus can be operated by handicapped persons who have no lower limb control and only limited use of upper extremities. UNISTIK operates all primary controls necessary for driving and controlling a highway vehicle; the driver simply moves the joystick forward to accelerate, backward to brake, from side-to-side for steering, and he can use any combination of these movements. The UNISTIK system is designed as an addition to an ordinary van. The modification consists of installing three actuators, one each for brake, throttle, steering, powered by electric motors; the installation is entirely within the passenger compartment and allows full use of the vehicle's normal controls by able-bodied persons.

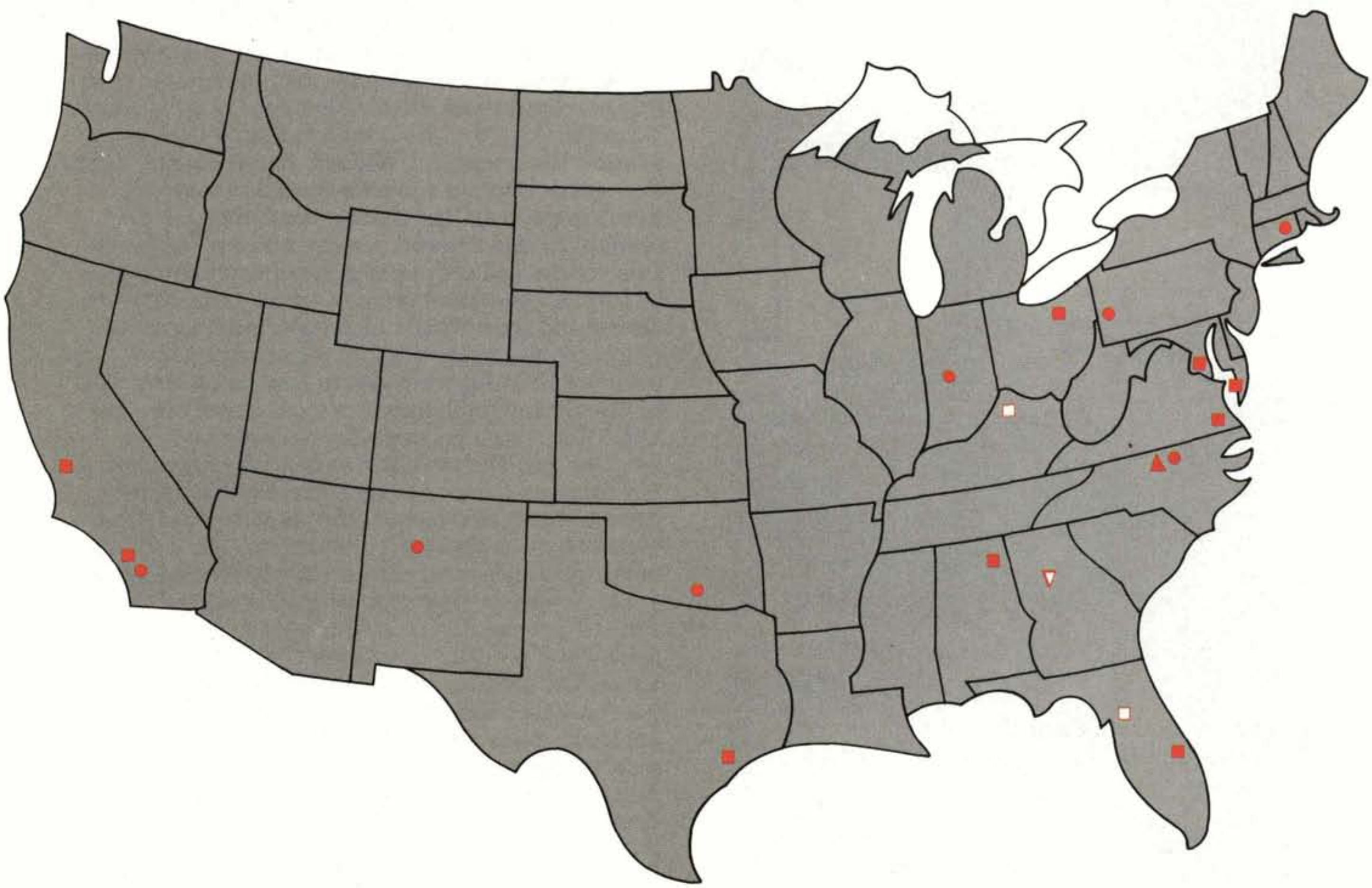
The development project has been underway since 1981 and the prototype UNISTIK system is now undergoing extensive testing in a 1981 Ford van, shown above. The photo at left shows Johnson Engineering's test consultant Tom Wertz, a paraplegic, driving the vehicle from his wheelchair positioned next to the standard operator's seat. NASA and the Veterans Administration are providing funding for the final development phase, which is expected to culminate in production of the UNISTIK system beginning in October 1985.

NASA's Technology Transfer System

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

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

- ■ *Field Center Technology Utilization Officers:* manage center participation in regional technology utilization activities.
- ● *Industrial Applications Centers:* provide information retrieval services and assistance in applying technical information relevant to user needs.
- □ *State Technology Applications Centers:* provide technology transfer services similar to those of the Industrial Applications Centers, but only to state governments and small businesses within the state.
- ▽ *The Computer Software Management and Information Center (COSMIC):* offers government-developed computer programs adaptable to secondary use.
- ▲ *Application Team:* works with public agencies and private institutions in applying aerospace technology to solution of public sector problems.



Field Centers

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

Technology Utilization Officer; *Stanley A. Miller*
Phone: (415) 965-6471

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

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

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

Technology Utilization Officer: *William Chmylak*
Phone: (713) 483-3809

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

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

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia 23665

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

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

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

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

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

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

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, ext. 565

Resident Office
Jet Propulsion Laboratory
4800 Oak Grove Drive
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Technology Utilization Officer: *Aubrey D. Smith*
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National Aeronautics and Space Administration
National Space Technology Laboratories
NSTL, Mississippi 39529

Technology Utilization Officer: *Robert M. Barlow*
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Industrial Application Centers

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Kerr Industrial Applications Center
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Durant, Oklahoma 74701

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NASA Industrial Applications Center
701 LIS Building
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Paul A. McWilliams, Ph.D., executive director
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Daniel Wilde, Ph.D., director
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North Carolina Science and Technology Research Center
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James E. Vann, Ph.D., director
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Technology Applications Center
University of New Mexico
Albuquerque, New Mexico 87131

Stanley A. Morain, Ph.D., director
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State Technology Applications Centers

NASA/Florida State Technology Applications Center
University of Florida
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Gainesville, Florida 32611

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

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

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

Computer Software Management and Information Center

COSMIC
112 Barrow Hall
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Athens, Georgia 30602

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