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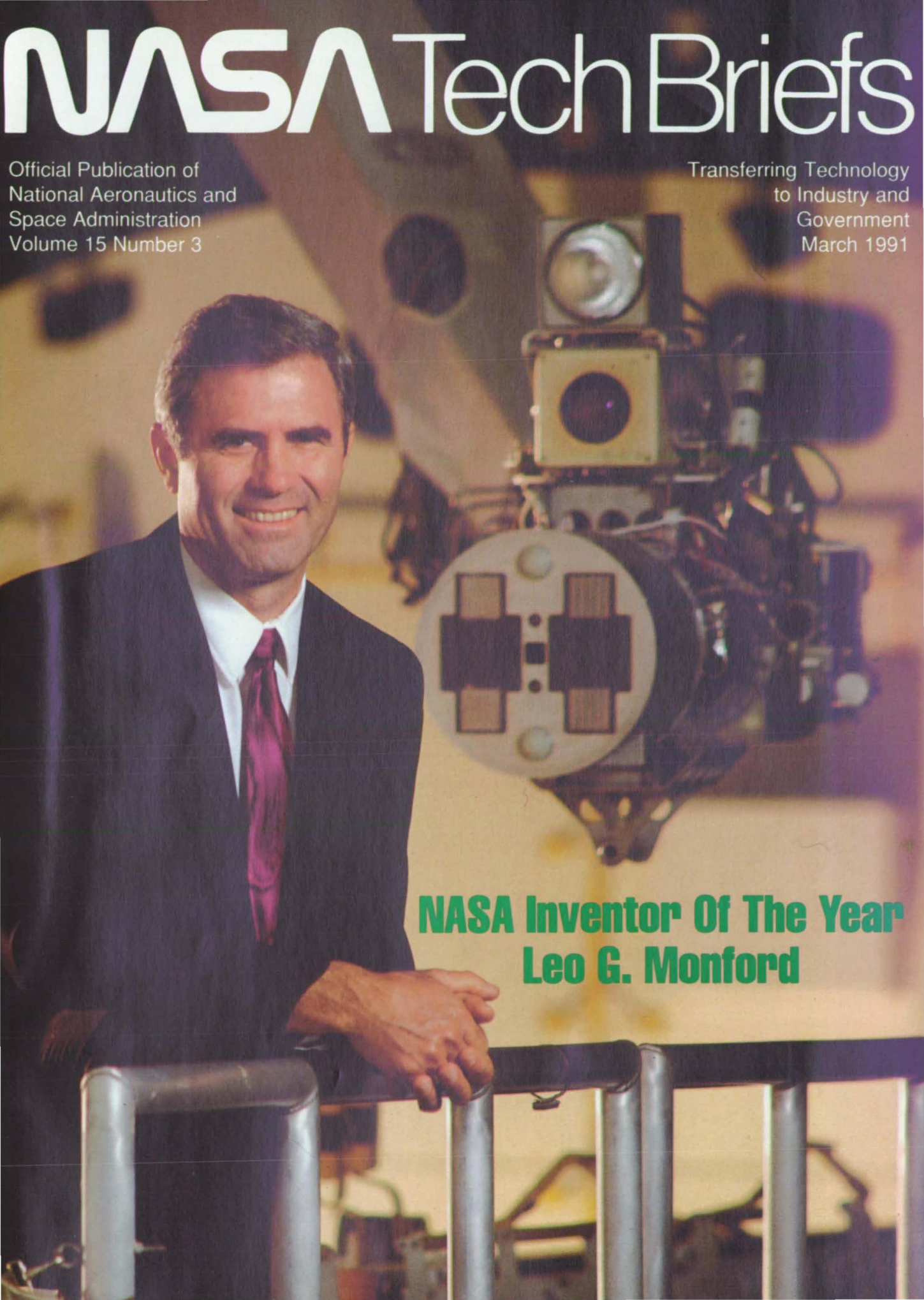
to Industry and
Government
March 1991



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Leo G. Monford

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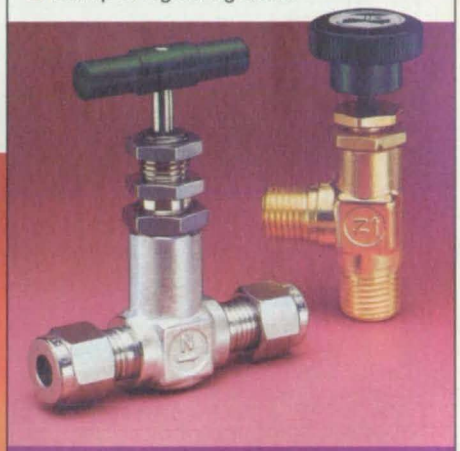

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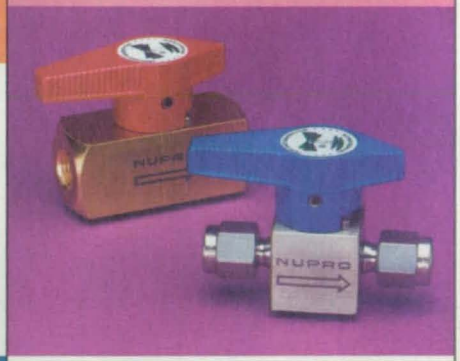

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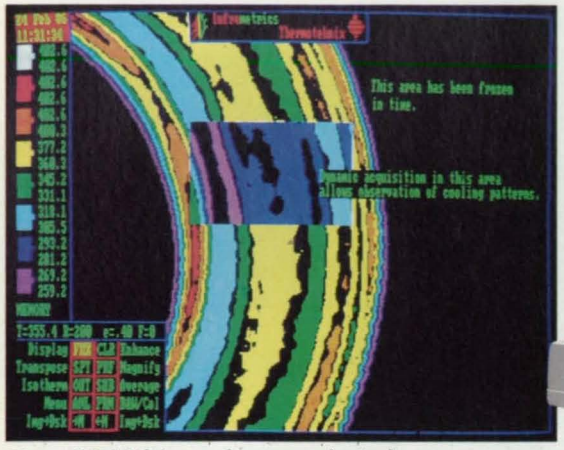
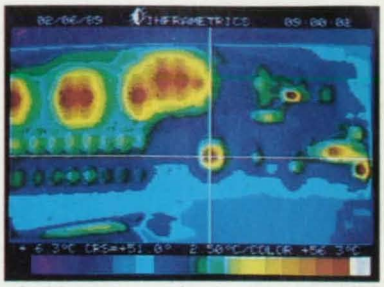


ThermaGRAM® image of an automotive brake rotor.



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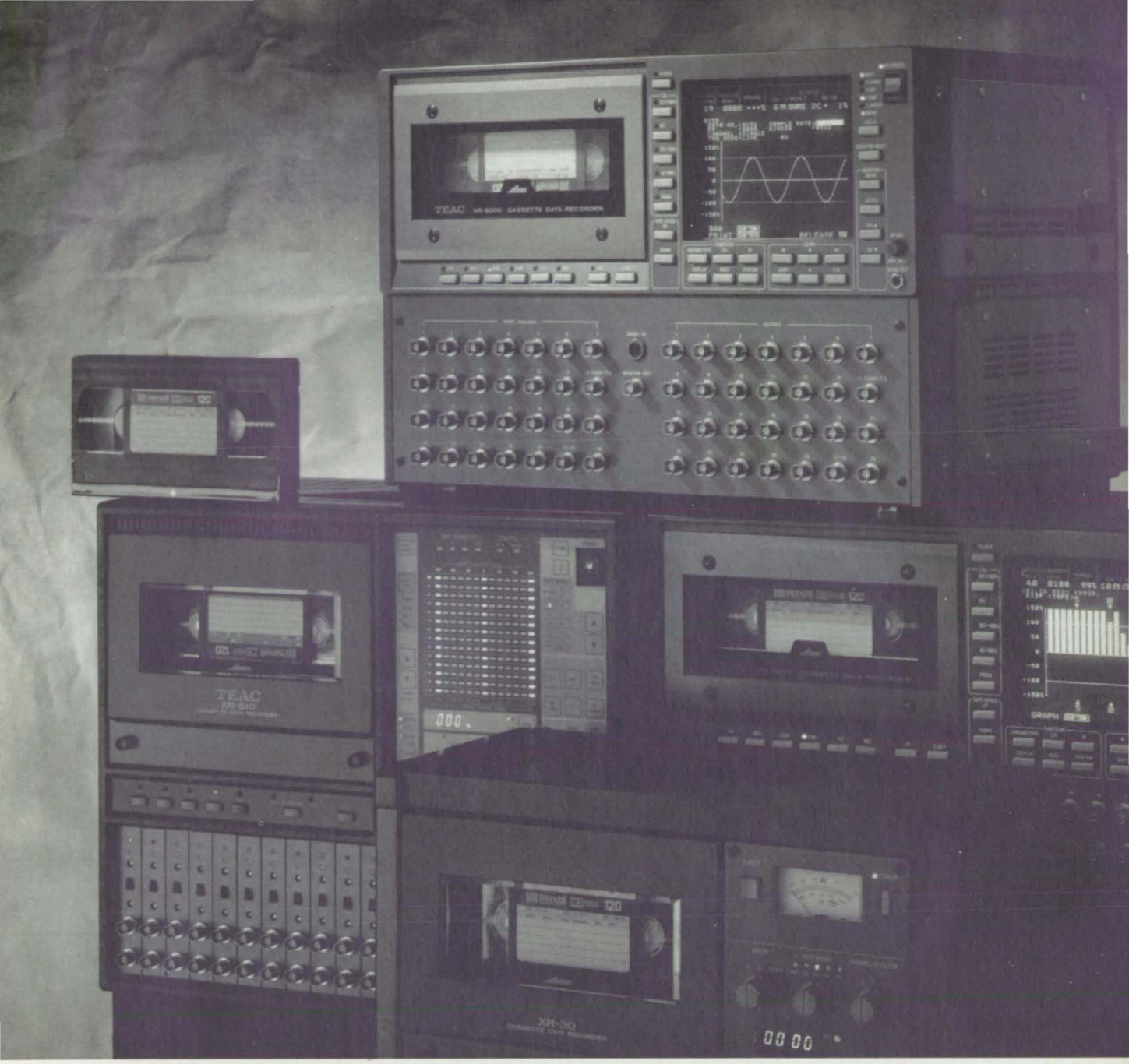

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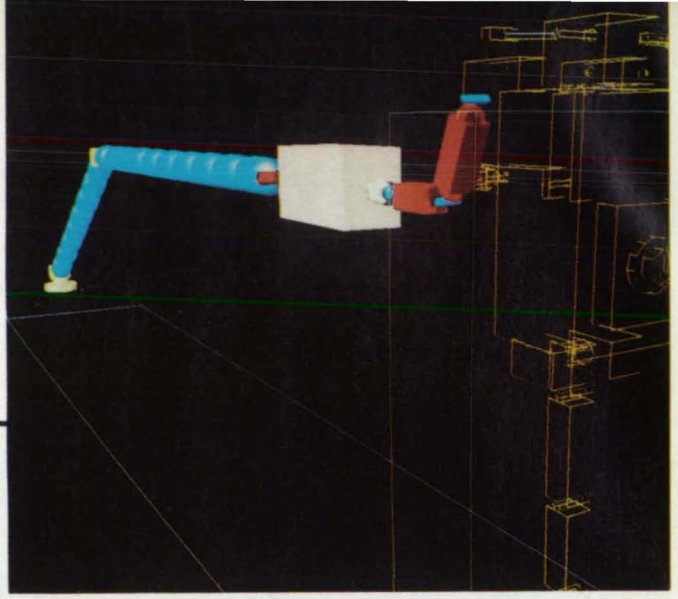

Graphic courtesy CADSI

A new vision-based alignment system promises to greatly improve the dexterity of the space shuttle's remote manipulator arm, shown in blue in this computer simulation. Turn to page 10.

SPECIAL FEATURES

TECHNICAL SECTION

DEPARTMENTS

On The Cover: Leo Monford displays the docking alignment system that earned him NASA's Inventor of the Year title (page 10). The device, which uses a video camera and mirror for precise positioning control, is mounted on a robot arm in the Johnson Space Center's Manipulator Development Facility. Also on the arm is another of Monford's inventions, the Magnetic End Effector.
(Photo courtesy Johnson Space Center)

Photo courtesy Ames Research Center

Researchers at NASA's Ames Center have created a mathematical model of a turboshaft engine for use in real-time computer simulations of the dynamics of helicopter flight. See page 55.

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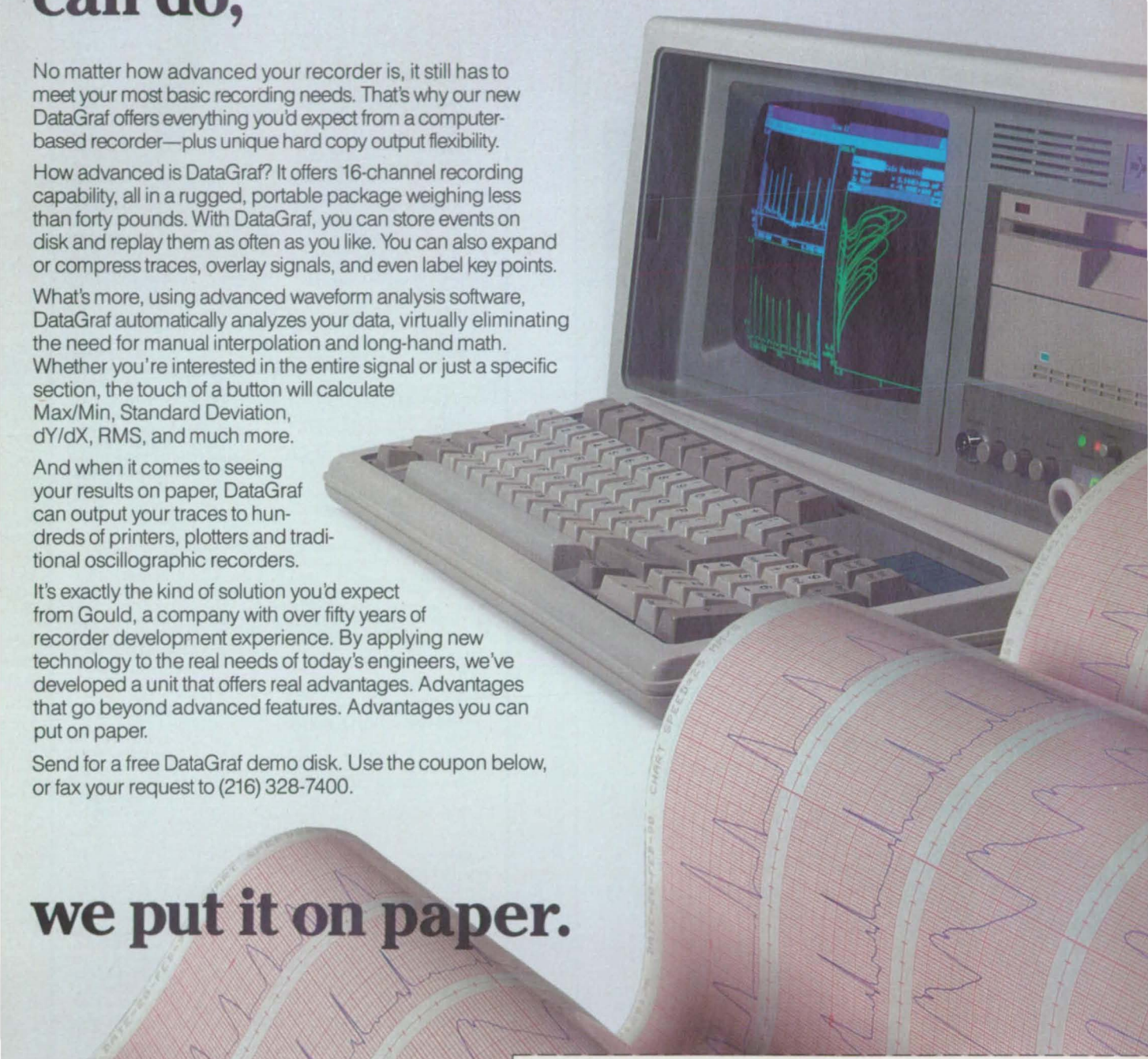

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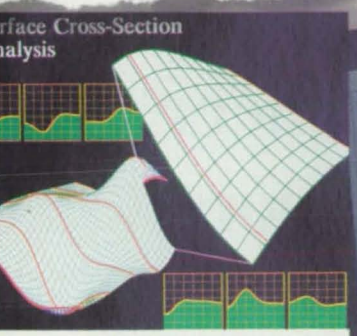

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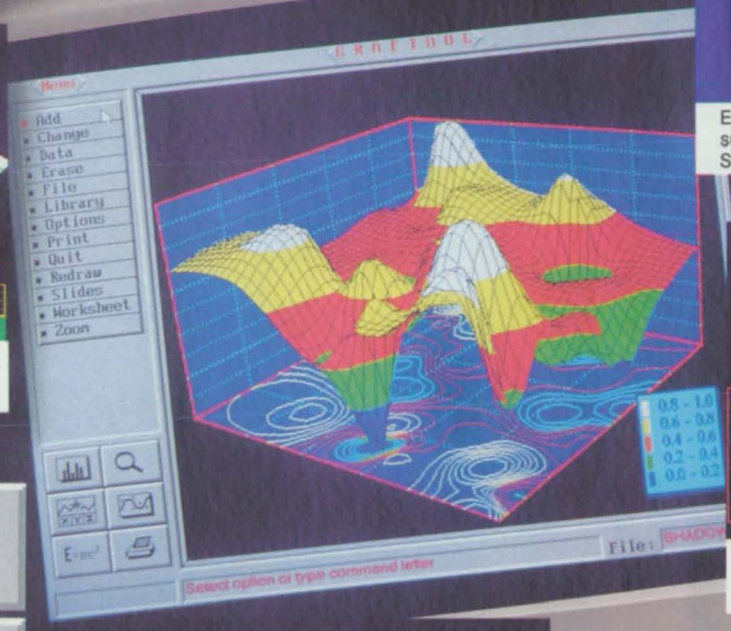

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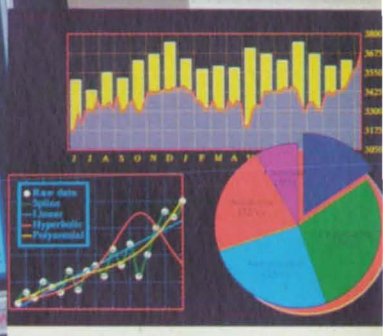

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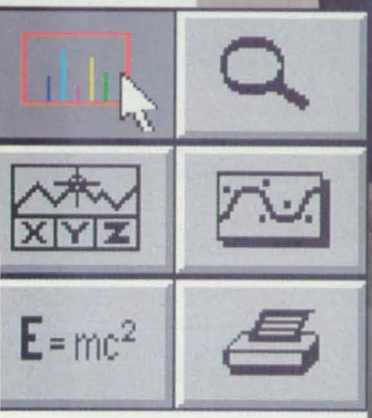

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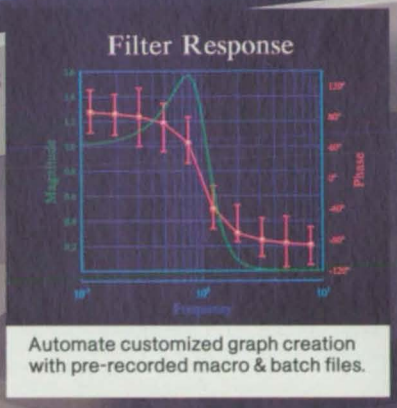

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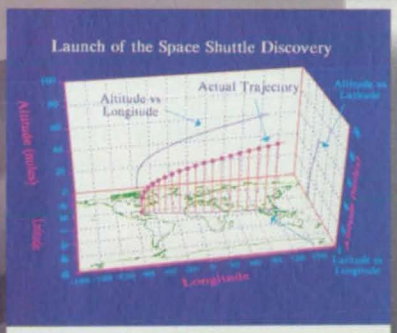

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Photo courtesy Johnson Space Center

Right on TRAC: Monford's invention can be used in space to automate tedious human tasks or make them quicker and easier.

Inventor of The Year

Johnson Engineer Earns Top Honors For Innovative Targeting Technique

Veteran NASA engineer Leo G. Monford has won the agency's1991 Inventor of the Year Award for developing a highly-accurate docking alignment system for the space shuttle's robot arm. His invention, called the Targeting and Reflective Alignment Concept (TRAC), promises to greatly improve the dexterity of robots both in space and on Earth.

TRAC employs a video camera mounted on a robot's end effector, a monitor, and a mirrored target fixture to achieve precise, real-time alignment of two objects in both three-dimensional translation and rotation. "It easily can align to within a hundredth of an inch and to within a tenth of a degree in rotation," said Mr. Monford, who manages new projects in the Johnson Space Center's Space Servicing Systems Office.

The camera lens, monitor, and reflective target are all marked with cross hairs. A remote-manipulator operator, viewing the image from the fixed-focus camera on the monitor, moves the robot arm until the cross hairs on the target and the monitor line up. The operator then uses rotational controls until the camera sees its own image in the mirror and the cross hairs on its lens appear at the center of the monitor. The size of the camera image is proportional to the distance between the camera and the mirror, so size indicia on the monitor indicate the range between the camera and mirror, and thus between the arm and the target object.

Since the camera can see only directly in front of itself, it will not view its own image until the end effector and target are perpendicular to each other. When the camera sees itself and the three sets of cross hairs line up, the alignment process is complete.

"The beauty of this system is its simplicity," said the 46-year-old inventor. "It's lightweight, inexpensive, and easy to operate."

Unlike the shuttle's present alignment system, which utilizes a target with a protruding post, Monford's device allows a flat target to be used as a grappling aid. This is important because many proposed operations for the shuttle's Remote Manipulator System or a similar arm on space station Freedom involve stacking and unstacking objects for construction purposes.

Reseachers at Texas A&M, Monford's alma mater, are working to automate TRAC. Instead of cross hairs, the automated system uses corner cubes on the target that reflect light back only in the direction of its origin, similar to bicycle reflectors, and a light-emitting diode (LED) on the camera lens. A computer lines up the flood-lit corner cubes to determine when the arm is perpendicular to its target. When the camera sees the LED's reflection on its lens, the computer knows the alignment is exact.

Although developed for space use, "TRAC can be applied anywhere that precise alignment and docking is needed," stated Monford. The U.S. Navy is considering using TRAC for underwater operations, where precise maneuvers are often extremely delicate and difficult. And Texas A&M wants to use the invention to develop a high-accuracy robotic system for waterjet cutting. Other potential applications include telerobots in hazardous environments and factory machinery; TRAC could help a forklift operator to properly position the vehicle's forks with respect to rows and columns of stacked pallets.

The first practical application of TRAC will be on shuttle flight STS-37 this April, as part of an effort to measure the stiffness of the remote manipulator arm. On a 1992 shuttle mission, TRAC will be demonstrated in concert with Jet Propulsion Laboratory's Force Torque Sensor, designed to record forces and moment on the arm, and the Magnetic End Effector (MEE), another of Monford's inventions. A potential replacement for the Standard End Effector,

which employs cables to snare a protruding grapple fixture, the MEE uses electromagnetic force to latch onto a metal plate attached to the payload. The plate shares the advantage of flatness with the alignment target, and the MEE's centerline camera would allow the docking plate to double as the target plate for the TRAC system.

The MEE "will totally revolutionize the way we grapple things in space," said Monford. Smaller and lighter than the current technology, the MEE is two-fault tolerant in both grappling and releasing payloads and has no moving parts subject to wear. Proposed MEEs would give different sized arms the capability to grapple common target plates, add the ability to transfer both power and data to payloads, and provide a method for attaching a variety of power tools that could limit the amount of extravehicular activity by astronauts.

An Idea Generator

Monford, a Johnson Center employee since 1963, decided as a teenager he wanted to work for NASA. "While I was in high school it was announced that we were going to enter the space race," he recalled. "I couldn't imagine anything more exciting to be involved with for a career." He started as a coop in the center's measurements laboratory, and has spent the majority of his career designing electronic systems. In addition to TRAC, he holds patents for an audio digitizer, a digital communications system, a binary concatenated coding system, and a radiometric temperature reference, with three other patents pending, including the MEE.

"I'm an idea generator," he said. "My job is to come up with innovative thoughts and technologies and stimulate others into producing those products."

He began working on TRAC and the Magnetic End Effector three years ago after taking over as project manager for the Force Torque Sensor. These inventions "all answer the need for greater dexterity" in space robotics, according to Monford. "Right now we only use the shuttle arm to deploy and retrieve satellites," he said. "We need to develop the capability to service and maintain these payloads using automated systems."

Monford said his job is "extremely" gratifying. "Imagine conceiving of an idea like TRAC and then actually seeing it fly on the shuttle," he said. "It's a wonderful feeling." ❑

NASA's STARS:

The 1991 Award Finalists

NASA's Office of General Counsel, sponsor of the Inventor of the Year competition, chose Leo Monford from a field of seven finalists whose inventions were patented and/or commercially available during 1990. The other nominees' leading-edge work—spanning such fields as high-speed computing, materials science, robotics, and life science—is spotlighted on the following pages.

★ ★ ★ ★ ★ ★ ★

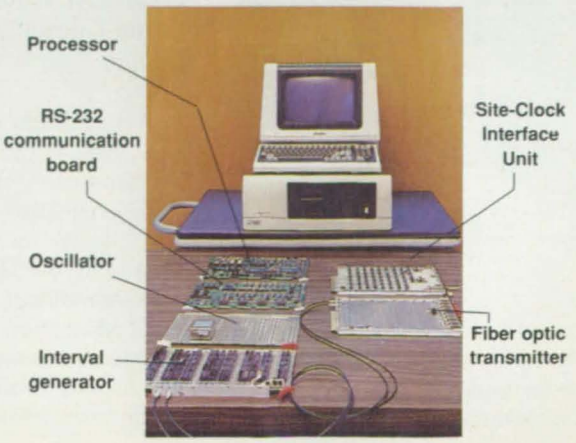
Daniel J. Crawford and Donald R. Bennington
Langley Research Center
Hampton, VA

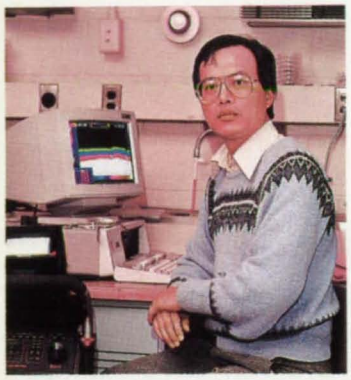
Invention: Real-Time Simulation Clock

Langley's nominees have developed a clock to synchronize events during real-time flight simulation. The invention is a key part of the center's Advanced Real-Time Simulation (ARTS) system, which employs eight high-speed digital networks to simultaneously run up to six independent simulations. It provides a simple, straightforward way to synchronize these demanding applications, according to the inventors.

The system's central clock generates timing data which is transmitted to Site-Clock Interface Units (SCIUs) at each remote simulation site. A fiber optic network consisting of time-distribution drivers and fiber cables connects the central clock to the SCIUs. The heart of the central unit is a highly accurate temperature-controlled oscillator that produces a 5-MHz signal. The unit also features an Intel 80/24 single-board computer and 534 communication board for RS-232 communication with the system's mainframe computers, and a time-interval-generating board.

The clock incorporates several self-monitoring features and can be quickly repaired by board swapping. Clock signals are daisy-chained through the fiber optic transmitter boards and then returned to the clock; a signal interruption triggers the flashing of a status alert on the front panel display. Further, the system has redundant interval counters that are continuously compared to its primary pair.





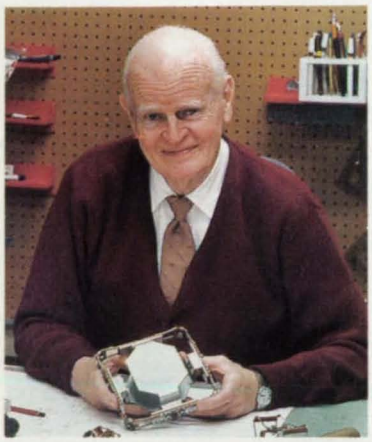
Dr. Ching-cheh Hung
Lewis Research Center
Cleveland, OH

Invention: Graphite Fluoride Fiber Polymer Composite Material

Dr. Hung has created a new composite material which could dramatically improve the electrical performance and reliability of printed circuit boards. Offering five times the thermal conductivity of fiberglass, the material utilizes improved graphite fluoride fibers which are produced by contact reaction between intercalated graphite fibers and fluorine gas. These fibers are bound by an epoxy.

The material's physical properties can be tailored to meet specific engineering requirements by controlling the fluorine content. Its coefficient of thermal expansion (CTE) can be adjusted to match that of silicon, for example, making it a more efficient alternative to fiberglass in printed circuit boards. The fibers can also be tailored for use in satellite reflector antennas, which require a zero CTE.

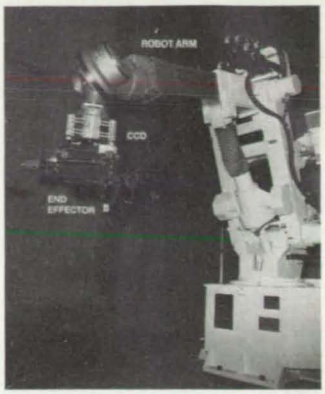
Moreover, since it releases fluorine at 300° C or higher, the graphite fiber can be used as a material to store fluorine and to conduct fluorination. This application may simplify the fluorination process and reduce the risk of handling fluorine, according to Dr. Hung. His invention could also serve as a lubricant, a cathode material in lithium batteries, an insulator for alternator windings, or a filler material which bonds to metal matrices to form a composite with strong transverse tensile strength.



James J. Kerley
Goddard Space Flight Center
Greenbelt, MD

Invention: Robot Cable-Compliant Device

A mechanical joint that makes robotic movements more closely resemble human motion earned Mr. Kerley the Goddard nomination. Featured at the Technology 2000 exposition last November, the device provides six degrees of freedom, variable and adjustable compliance, a high level of damping, shock and vibration protection, and position feedback for correcting misalignments between a tool and a work object. Moreover, it can be used in environments characterized by very delicate or extremely heavy loads.



Kerley's robotic joint intervenes between a robot arm and a tool.

The invention includes two brackets with U-shaped cross-sections, one of the brackets being connected to a robot arm and the other to a tool. Additional angle brackets are displaced from the other brackets at corners of the robotic joint. The brackets are connected by cable segments positioned in one or more planes which are orthogonal to the direction of the tool as it approaches a work object. The joint's compliance can be adjusted by varying the tension or stiffness of the cable segments and by varying the cable characteristics, such as their length, material, angle, and stranding.

The compliant joint "adds another dimension to the robotics field as it makes the robotic action more like that of the human arm," said Mr. Kerley, who has applied the technology to mechanical aids for the elderly and disabled, including a wheeled walker that frees the user's hands and a remotely-controlled robotic helper for the severely handicapped.

Dr. Daniel C. Carter, William K. Witherow, Marc L. Pusey, Vaughn H. Yost, and Diana Hecht
Marshall Space Flight Center
Huntsville, AL

Invention: X-Ray-Sensitive Area Detection Device

Clockwise from bottom: Marc Pusey, William Witherow, Vaughn Yost, Daniel Carter, and Diana Hecht

Area detector systems are important tools for experimentation and research in such diverse fields as crystallography, medical radiography, electron microscopy, biophysics, and astronomy. To date, however, these systems have suffered from several drawbacks: They have low spatial resolution, experience high levels of distortion, and require prolonged ex-

posure to develop a satisfactory picture, making them unsuitable for studies of rapidly deteriorating samples. The Marshall invention answers the need for a faster, more sensitive method.

Using new imaging phosphors from Eastman Kodak and Fuji, the Marshall nominees have developed two-dimensional x-ray area detectors with near-real-time capabilities. Irradiation of the phosphors with x-rays produces F-centers with a half-life of approximately ten hours, essentially storing a "latent image." These F-centers can be stimulated by an He-Ne laser to generate luminescence (400 nm) proportional to the x-ray exposure. The phosphors offer up to 60 times the sensitivity of standard x-ray film, high signal to noise ratios, virtually unlimited counting rate capacity, and reusability.

Dr. Carter earned top inventor honors last year for his innovative work in protein crystallography (*NTB vol. 14, no. 3*). Using computer analysis techniques, he uncovered the three-dimensional structure of human serum albumin, the principal protein of the blood plasma.

★ ★ ★ ★ ★ ★ ★

Laurence deQuay
John C. Stennis Space Center
Stennis Space Center, MS

Invention: Hybrid Butterfly Valve

Mr. deQuay has designed a new type of valve that combines the compactness, light weight, and full flow capability of butterfly valves with the throttling and sealing advantages of globe and needle valves. His invention eliminates the seat wear and leakage problems encountered with conventional butterfly valves.

The hybrid valve has a stationary seat and a valve closure disk which can rotate with a shaft having an axis transverse to the fluid flow path through the valve body. The disk is supported by brackets that feature an elongated slot through which the shaft extends, with the brackets able to move linearly relative to the shaft. Cams fastened to the shaft initiate a 90 degree rotation of the shaft from fully open to a position wherein the disk is aligned with the seat. Guide members carried by the disk within a slot in the valve body ensure that the disk's rotary and longitudinal motions occur separately and in the correct sequence. They also enable uniform loading of the valve seat and thus reduce or eliminate seat wear. Rollers carried by the support brackets aid in reducing frictional forces resisting valve actuator torque and in guiding the disk's movement so that it seats uniformly around the seat circumference with maximum sealing force.

The invention can be used with all types of fluid transfer control systems. It is designed primarily for cryogenic and gas systems in which shutoff valves are repeatedly cycled and stressed thermally, and where minimum valve mass and weight is critical.

★ ★ ★ ★ ★ ★ ★

Dr. Chul Park and Carol B. Davies
Ames Research Center
Moffett Field, CA

Invention: Raked Circular-Cone Aerobraking Orbital Transfer Vehicle

These researchers collaborated on an innovative design for an aeroassisted space transportation vehicle (ASTV), a reusable upper stage vehicle for operations in orbit. NASA and industry have proposed using ASTVs to ferry satellites between low-Earth orbit and a higher orbit, such as geosynchronous Earth orbit. When descending to low-Earth orbit, the ASTV would pass through Earth's atmosphere in order to decelerate by means of the drag produced by the craft's frontal surface, or forebody, instead of using a retro-rocket. This technique, called aerobraking, would eliminate the need to carry fuel to operate a retro-rocket, enabling the ASTV to carry additional payload instead.

Basic research on the ASTV over the past decade has revealed potential problems that must be overcome for the vehicle to reach the production stage. Questions exist as to whether the ASTV will fly stably through the air; how hot the spacecraft and its cargo will get during the flight; and what can be done if it is struck by a passing meteoroid or space debris. Park and Davies have produced the first design that solves these problems.

In the Park-Davies concept, the vehicle's shape roughly resembles a circular cone with the pointed tip rounded off and the tail raked off at an oblique angle. The forebody is covered with heat-shielding tiles similar to those on the space shuttle. The rocket engines protrude through the open hatches on the heat shield. Satellite cargo is to be carried on the back of the vehicle, protected by a pair of covers that will keep the cargo cool and also serve as ballasts when one engine is disabled or a fuel tank leaks. Based on research at the Ames Center and elsewhere within NASA, this vehicle will be stable during the atmospheric flight, remain cool enough to protect its valuable cargo, and have several means of surviving a meteoroid hit.

Building an ASTV that incorporates all aspects of the design is still many years away, according to Dr. Park. When such a vehicle is completed and tested by NASA, he said, it could be turned over to U.S. companies to operate for profit. ❑

For information on licensing any of the inventions described in this article, contact the patent counsel at the NASA field center that sponsored the research (see page 16).

New Product Ideas

New Product Ideas are just a few of the many innovatrions described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 16). NASA's patent-licensing program to encourage commercial development is described on page 16.

Forming $YBa_2Cu_3O_{7-x}$ Superconductors on Copper Substrates

An experimental process forms a layer of the high-critical-temperature ceramic superconductor $YBa_2Cu_3O_{7-x}$ on the surface of a copper substrate. The process offers a possible solution to the difficult problem of finishing ceramic superconductors to required final sizes and shapes.
(See page 38)

Modular, Multilayer Perceptron

A combination of a proposed modular, multilayer perceptron and an algorithm for its operation would be able to recognize new objects after relatively brief retraining sessions. Each object to be recognized would reside in a subnetwork of the full network, so that it would not be necessary to retrain the full network.
(See page 31)

Leading-Edge "Pop-Up" Spoiler for Airfoil

A "pop-up" spoiler at or very near the upper leading edge of the stabilator enables the pilot to regain control of the helicopter. The deployed spoiler very quickly eliminates inadvertent aerodynamic lift of the stabilator.
(See page 52)

Removing Spilled Oil With Liquid Nitrogen

A proposed new technique for cleaning up oil spills is the use of liquid nitrogen to solidify the spill so that it can be carried away in solid chunks. Liquid nitrogen offers probably the best tradeoff among extreme cold, cost, availability, and lack of impact on the environment among the various cryogenic fluids available.
(See page 38)

Lateral-Grating DFB Laser

A new distributed-feedback laser design achieves improved wavelength discrimination and increased coupling. In this configuration, lateral modes in a plane parallel to the active layer interact with the grating, allowing many new effects.
(See page 22)

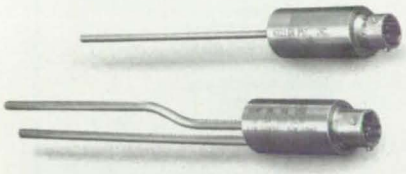
Stereoscopic Video Weld-Seam Tracker

A stereoscopic seam tracker designed for automatic welding system, can track the nearly invisible seam between butted, machined edges of plates. Unlike eddy-current seam trackers, the new unit is designed for use in a production environment.
(See page 29)

ELECTRONIC PRESSURE SCANNERS

Compact, multi-channel devices provide a transducer-per-channel for gas and/or liquid pressure measurement. Users get a single, rugged, mountable package for multiple pressure measurements–without having to buy separate transducers. Save money, space and time. ESP-16BP scanners handle gas pressure measurements in harsh environments and are available with 8 or 16 channels. ESP-4AM scanners provide 4 channels for measurement of liquid pressure or high-pressure gases. PSI, 800-678-SCAN.

Circle Reader Action No. 555



CRYOGENIC PRESSURE SENSORS

Compact, rugged pressure sensors measure liquids or gases at temperatures from ambient down to 1.5° Kelvin (-272°C). Sensors available for pressure ranges from 0-31 through 0-500 psi for absolute or differential pressures. Power dissipation is typically less than 6 mW. Sensors can be installed or even submerged within cryogenic systems. Factory calibration at cryogenic temperatures ensures high accuracy between 1.5° and 373°K. Available with digital readout and RS232 link. Keller-PSI, (619) 967-6066.

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SUBMERSIBLE DEPTH TRANSDUCERS

Rugged Series 200 low-cost depth transducers are designed for ground water and tank level measurements at depths to 500 ft. Series 200 SUB transmitters are priced lower than competitive units, yet offer more capability, and standard ranges are available from stock. Features include all-welded 316 SS construction with polyurethane jacketed vented cable. Transmitter and cable are sealed to ensure watertight operation. New low-cost Series 700 depth sensors are designed for sewage lift stations and other wastewater applications. Keller-PSI, (619) 967-6066.

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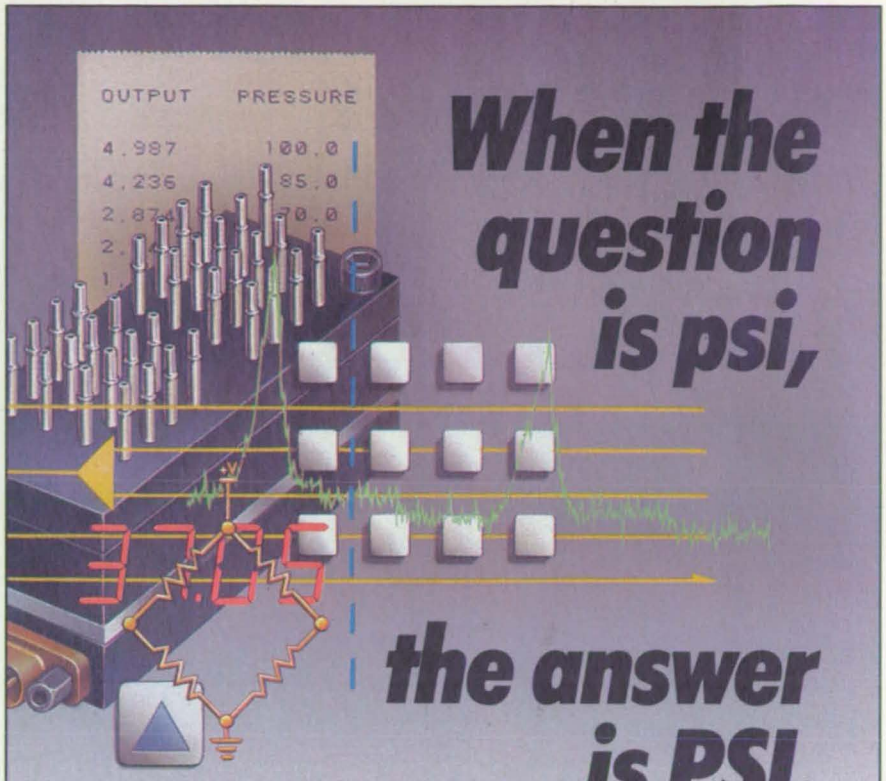

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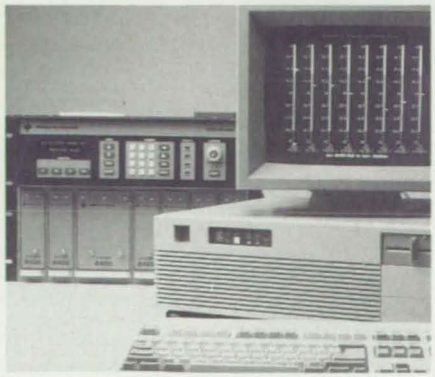

PC-COMPATIBLE TURNKEY PRESSURE ACQUISITION

The AutoNet 8400 pressure acquisition configuration combines electronic pressure scanning with real-time graphic display of data. Measures pressures from 0.4 to 500 psi (dry gas) and 1.5 to 6000 psi (liquid), and is implemented on IBM 386 or compatible PC. Equipped with software for real-time graphic display of pressure tests–users don't need to write own software driver. Parallel processing data acquisition operates over multiple channels at high speeds, with data storage on hard disk. PSI, 800-678-SCAN.

Circle Reader Action No. 558

HOW YOU CAN BENEFIT FROM NASA's TECHNOLOGY UTILIZATION SERVICES

If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low-and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by the TU Network as a whole. In fact, when all of the components of NASA's Technology Utilization Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

We've outlined below NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network.

How You Can Utilize **NASA's Industrial Applications Centers**—A nationwide network offering a broad range of technical services, including computerized access to over 100 million documents worldwide.

You can contact NASA's network of Industrial Applications Centers (IACs) for assistance in solving a specific technical problem or meeting your information needs. The "user friendly" IACs are staffed by technology transfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized data bases, ranging from NASA's own data base to Chemical Abstracts and INSPEC, are accessible through the ten IACs located throughout the nation. The IACs also offer technical consultation services and/or linkage with other experts in the field. You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

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If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology. **Technology Application Team, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709; *Dr. Doris Rouse, Director,* (919) 541-6980**

How You Can Access Technology Transfer Services At NASA Field Centers: **Technology Utilization Officers & Patent Counsels**—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in NASA Tech Briefs, request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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Electronic Components and Circuits

Hardware, Techniques, and Processes

Reduced-Wiring Tactile Sensor

Analog signals would be transmitted via fewer connections than would be needed for digital signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

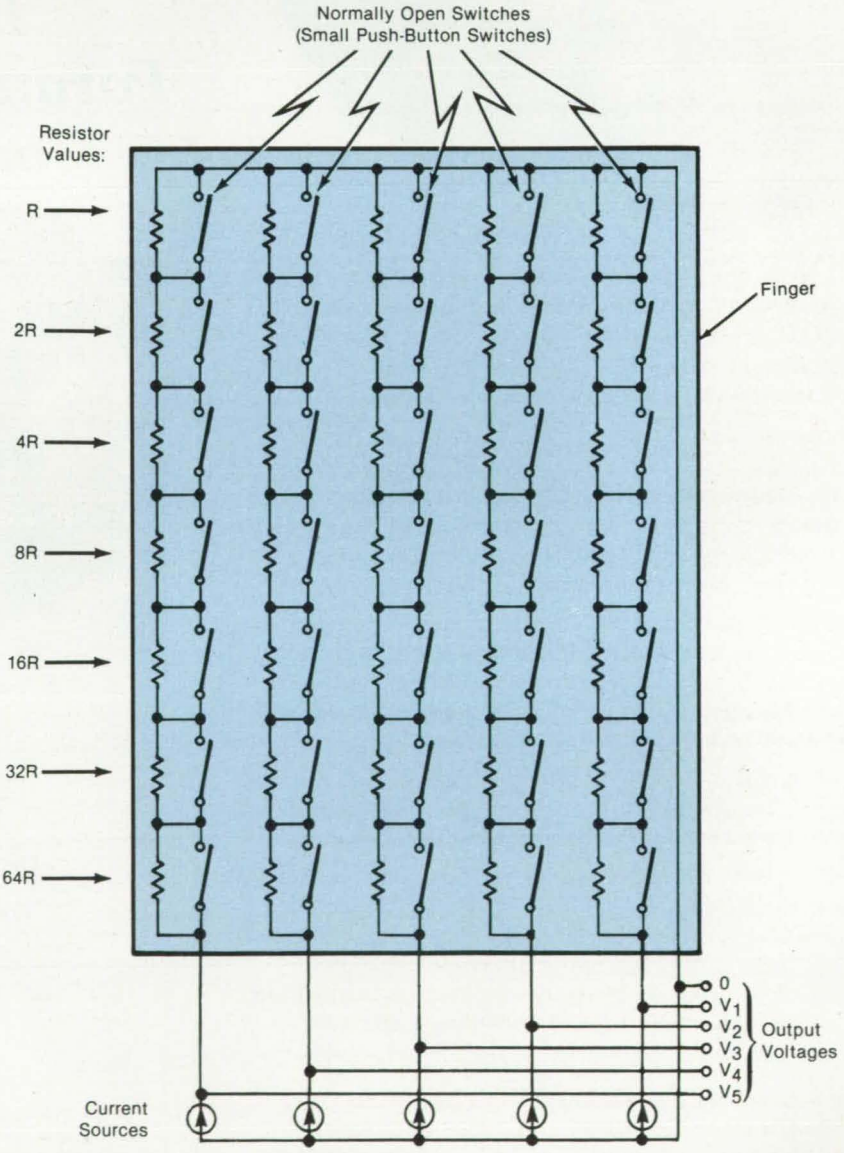
A proposed tactile sensor on a robot finger would put out multiplexed analog signals that could be transmitted to a control computer on fewer wires than would be needed to transmit equivalent digital signals. The analog output would represent data on the contact area of the object being gripped, on the position of the object, and on the direction and rate of slippage if any.

The sensor would consist of chains of normally open switches and resistors on the surface of the finger (see figure). Each resistance would be double the preceding resistance in each chain. Constant-current sources would supply power to the chains.

When an object touched the finger, it would turn on the switches in the contact area. Each switch turned on would short-circuit the resistor in parallel with it, changing the net resistance of the affected column. The voltage drop along each chain would change accordingly. Each possible combination of activated switches would produce a unique set of voltage drops along the chains. The voltages would be fed to the control computer, where an analog-to-digital converter would translate the voltages into digital signals for processing. In a 5-by-7 array like the one shown in the figure, a digital output would need 35 lines — one for each switch in the array, whereas the analog output needs only 5 lines — one for each column.

Movement of the object could be detected easily. If the object slipped downward in the figure, the voltages along the affected columns would increase; if it slipped upward, the voltages would decrease. Left or right slippage would appear as changes in the voltages along adjacent chains.

For a practical unit, an inexpensive miniature sensor pad, much like the keyboard on a pocket calculator, could integrate the components. The number of rows and columns could be increased or decreased, depending on the resolution needed for control of the robot. The upper limit on the number of resistors in each chain would be determined by such factors as the noise in the current source, the bit resolution available in the analog-to-digital converter, and the electromagnetic interference picked up in the cable from the sensor to the computer.



This **Array of Resistors and Switches** would act as a tactile sensor that would produce a unique combination of voltages according to the location of a gripped object.

This work was done by Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 88 on the TSP Request Card.*
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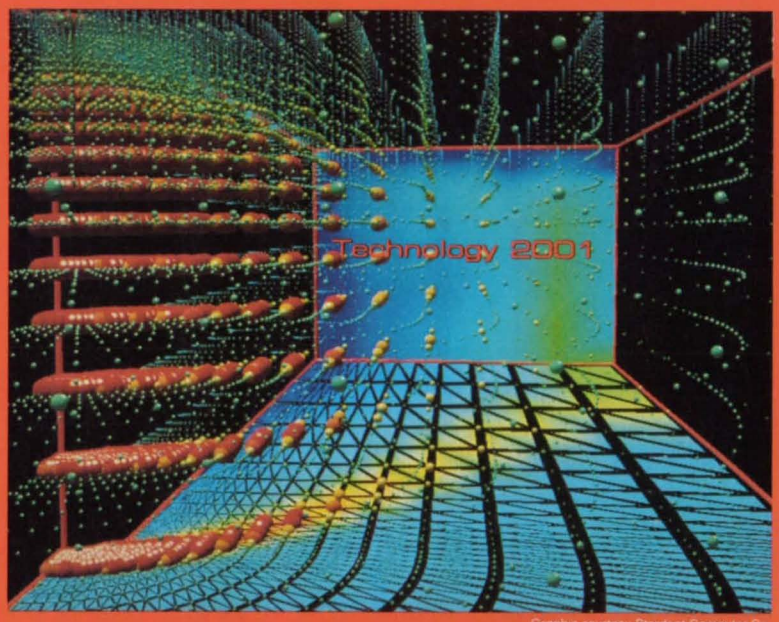

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Dc-to-dc Converter Uses Reverse Conduction of MOSFET's

Efficiency is greater than with bipolar transistors and antiparallel diodes.

Lewis Research Center, Cleveland, Ohio

In present high-power, phase-controlled, full-bridge, pulse-width-modulated dc-to-dc converters, the switching devices are bipolar transistors with antiparallel diodes. In a Lewis modified version, the switching devices are power metal oxide/semiconductor field-effect transistors (MOSFET's). The modification decreases the dissipation of power during switching by eliminating the ~ 0.7-V forward voltage drop in the antiparallel diodes. As a result, energy-conversion efficiency is increased.

Figure 1 shows the unmodified circuit, with representative waveforms. The right (Q_3, Q_4) and left (Q_1, Q_2) sides of the bridge are driven by square waves so that each transistor switch on each side is on half the time while the other transistor switch on the same side is off, and vice versa. The output is regulated by shifting the phase of the Q_3, Q_4 square wave with respect to that of the Q_1, Q_2 square wave. The antiparallel diodes conduct the reverse currents generated, at the reversals of polarity, from energy stored in the transformer and parasitic inductances.

Figure 2 shows the modified circuit. No antiparallel diodes are needed for two reasons: (1) Each MOSFET contains an intrinsic antiparallel diode, and (2) when a gate-to-source potential of about 15 V is applied, a MOSFET can conduct drain-to-source current in either direction, with a low "on" resistance that results in a voltage drop substantially lower than the 0.7-V drop of the intrinsic antiparallel diode. Typically, the reverse current, shown at the bottom of Figure 2, causes a drain-to-source voltage drop of only 0.1 V. The 0.6-V decrease in the voltage drop can increase the power efficiency significantly in a high-power, low-input-voltage circuit.

This work was done by Robert P. Gruber and Robert W. Gott of **Lewis Research Center**. *For further information, Circle 46 on the TSP Request Card.*
LEW-14944

Figure 1. **The Unmodified Circuit** includes bipolar transistor switches, with diodes connected in parallel at reverse polarity, to shunt inductive switching transients.

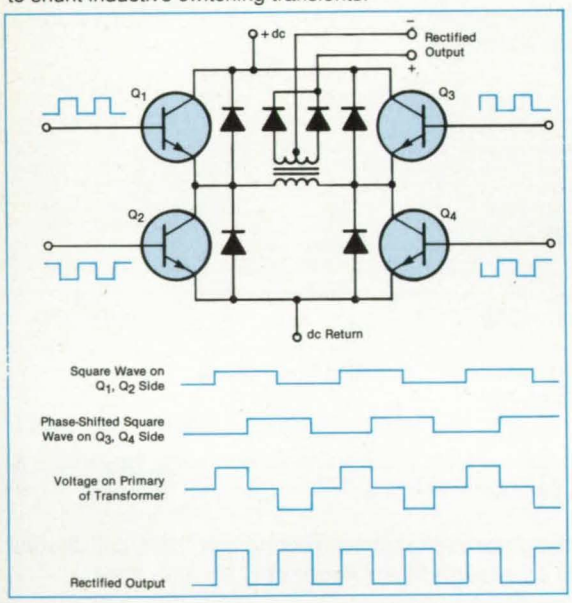
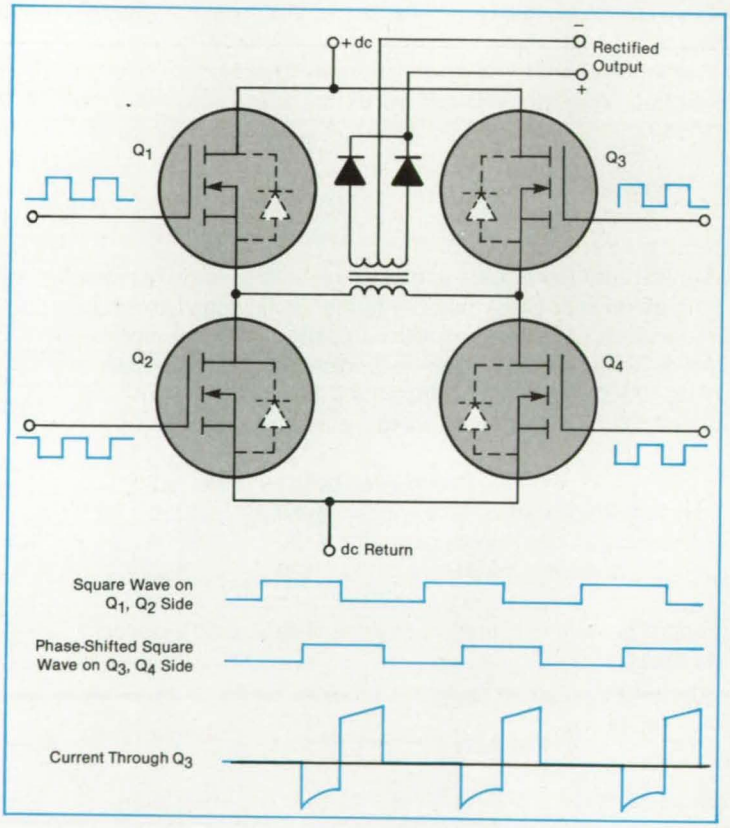


Figure 2. In the **Modified Circuit**, the switching devices are power MOSFET's instead of bipolar transistors. The reverse-conduction transient voltage drop in the MOSFET at the beginning of the "on" period is less than the transient forward voltage drop in the antiparallel diodes of the unmodified circuit.



Lateral-Grating DFB Laser

A novel distributed-feedback laser design achieves improved wavelength discrimination and increased coupling.

Langley Research Center, Hampton, Virginia

Heretofore, a typical semiconductor laser has consisted of semiconductor material with opposed reflective end faces and an active layer positioned between two cladding regions of opposite conductivity. Various laser structures have been developed to enhance particular operating characteristics. For example, in such buried-heterostructure lasers as those of the buried-crescent type, index guiding lowers threshold currents, thereby reducing heating at junctions and, consequently, enabling operation at higher temperatures. Such other lasers as those of the distributed-feedback (DFB) type provide single-wavelength outputs that are stable with temperature, time, output power, and rate of modulation.

A typical DFB laser includes an active layer positioned between two planar cladding regions. Periodic grating corrugations, which are parallel with each other in the

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lateral direction, are located in a layer either above or below the active layer. The distance between successive corrugations determines the wavelength emitted. These grating corrugations provide spatial variations in the index of refraction, thus producing optical feedback and eliminating the requirement for reflective end faces as in buried-heterostructure or buried-crescent lasers.

In a DFB laser of the usual configuration, the grating is placed in a plane parallel to the active layer, so that the mode of lowest order in the direction perpendicular to the plane is the one that interacts with the grating. In a new DFB laser, the lateral modes in the plane interact with the grating. The interaction can be with the mode of lowest order or with one of higher order. In the latter case, many new effects are possible, because the modes of higher order have directional properties that interact with those of the grating.

This structure offers several significant advantages. For example, a greatly improved spectrum discrimination can be achieved, making it possible to obtain a narrow beam, even from a relatively wide laser structure. If the interaction is with the mode of the lowest order, the grating interacts with both sides of the wave, instead of only one side. This effect results in a greatly increased coupling constant, thus requiring much smaller interaction length. In addition, the double grating acts similarly to a phase shifter in the cavity, in that it eliminates the second emission spectral line; this is because the two gratings must inevitably be slightly shifted relative to each other, so that jointly they cannot support two emission spectral lines.

A lateral-grating DFB structure has been successfully fabricated. A lateral finger pattern was made by transforming a surface grating to the lateral grating and then transferring the pattern to the material by chemical etching. The figure illustrates one lateral-grating-DFB-laser configuration. After the ridge and corrugations are fabricated, the whole ridge is overgrown with a p-type layer in order to fabricate a laser of the buried-ridge type. In comparison with conventional DFB lasers, this new structure offers several advantages that should enhance its application. Different effects are obtained, depending on whether the grating interacts with the mode of lowest or higher order. Such improved performance characteristics as better wavelength discrimination and increased coupling are achieved because the grating interacts with both sides of the wave.

This work was done by James T. Andrews and Ivan Ladany of the David Sarnoff Research Center for **Langley Research Center**. *No further documentation is available.*

Title to this invention, covered by U. S. Patent No. 4,837,775, has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning licenses for its commercial development should be addressed to

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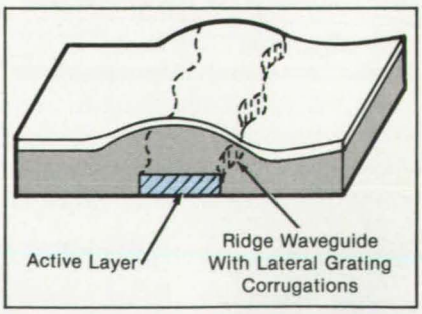

The **Ridge Waveguide With Lateral Grating Corrugations** is overgrown with a p-doped layer to form a buried-ridge type of laser. This is one of several configurations possible under the new laser concept.

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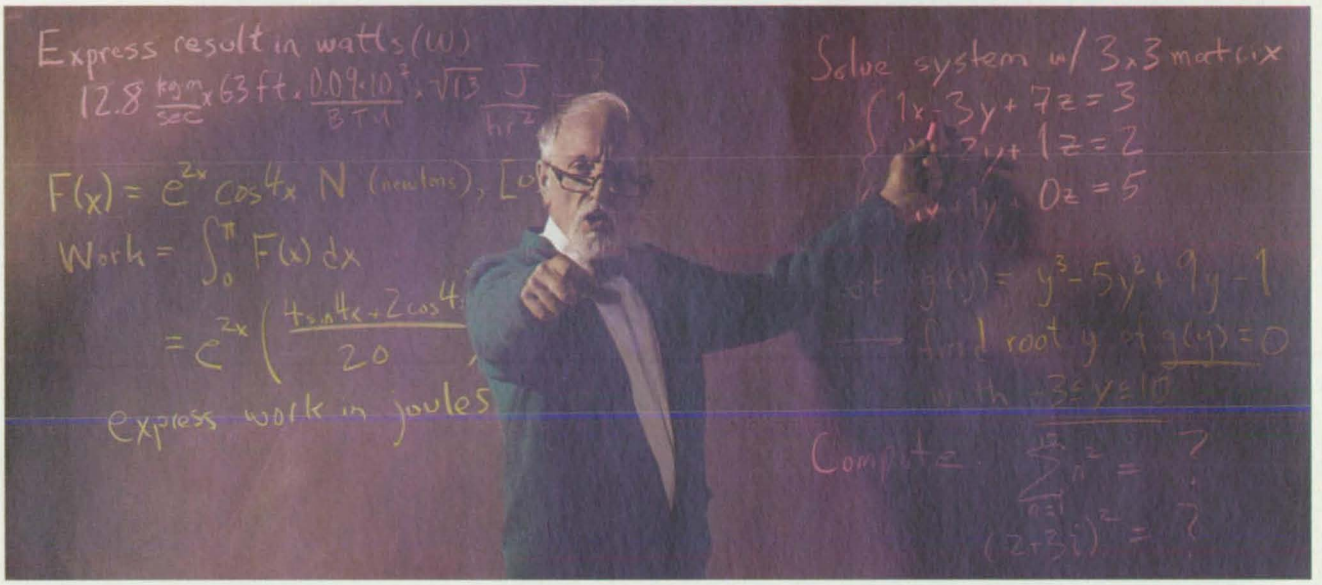

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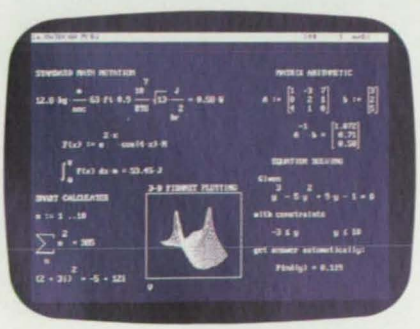

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Circle Reader Action No. 682

Electronic Systems

Hardware, Techniques, and Processes

Optoelectronic Ranging Sensor for Robotic Vehicle

Distance would be inferred from texture and changes thereof in the scene.

NASA's Jet Propulsion Laboratory, Pasadena, California

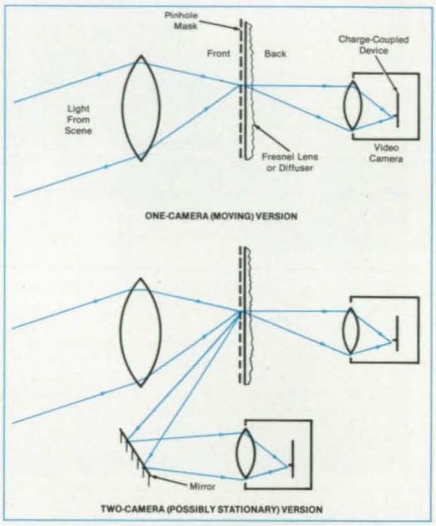
A proposed optoelectronic ranging system for a robotic vehicle would provide information on the distances to points in a natural scene. The system would have no moving parts, require little computation, and consume only a few watts of power. The system would be passive in the sense that it would not include any artificial sources of light, relying instead on sunlight reflected from the scene.

According to the basic principle of operation, pinholes arrayed in a gridlike pattern on an otherwise opaque mask would be used to subsample the very fine detail in the scene (e.g., natural textures at a scale of a millimeter or less). In a typical scene, this detail contains the majority of the information about whether or not a given point in the scene is in, near, or out of focus and is, therefore, a potential source of information as to whether or not the point in question lies at the focal distance. Essential to this concept is the fact that natural sunlight is so bright that even with sparse subsampling, there remains sufficient signal-to-noise ratio to justify the analysis of the patterns of high spatial and/or temporal frequency in the sampled light.

The pinhole mask would be placed at the prime focus of a lens of large aperture, short focal length, and high quality. The size of the pinholes would be at or near the size of the diffraction-limiting spot of the lens — typically, about 2 μm. A diffuser or Fresnel lens would be placed behind the pinhole mask to direct the light coming through the pinholes onto a charge-coupled-device video camera. The distance from the mask to the camera and the focus of the camera lens would be adjusted so that each pinhole would be imaged on one (and only one) picture element of the charge-coupled-device array.

As the vehicle moved, differences among the outputs of each of the picture elements of the camera would be computed for successive frames, and the magnitudes of the differences would be averaged spatially and temporally in such a way as to obtain a significant signal only from those picture elements at which the terrain was in focus. The concept that underlies this approach is that the intensity of light passing through a pinhole could vary rapidly and by a large amount only if the point of the terrain corresponding to the pinhole were in focus. Thus, if the camera were moved between frames by an amount approximately equal to or greater than the projected size of the pinhole on the terrain, then the frame-to-frame differencing would produce the full brightness texture at the pinholes where the scene was in focus, but would produce little or no brightness texture where the image was blurred by lack of focus.

In an alternative version, one camera would be focused on the back side of the pinholes as before, while another would be focused on small reflective rings around the pinholes on the front side. The area of a ring would equal the area of a pinhole. Spatial and/or temporal differencing would be performed, but according to a different plan. In this version, motion would not be essential, and focus or the lack thereof could be deduced on the basis of the strong nonlinear component in the spatial variation of brightness over the rings and pinholes in focus versus the nearly linear variation out of focus. In yet another variation applicable to both versions, the pinhole array could be corrugated in such a way that alternate rows of pinholes were on different focal planes, representing different distances.



The **Passive Optical Ranging Sensor** would provide a measurement of distance by the use of a pinhole mask to sample texture in the scene and thereby determine whether the portion of the scene corresponding to each pinhole is in focus (that is, whether is lies at the focal distance).

This work was done by Brian H. Wilcox of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 145 on the TSP Request Card.*
NPO-17959

Improving Sparse-Aperture Interferometric Radiometry

A pseudorandom optimization process would increase the spatial resolution.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method for designing the spatial arrangement of the antennas of a sparse-aperture interferometric radiometry (SAIR) system would increase the spatial resolution of the images produced by the system. The method was conceived to improve a proposed remote-sensing SAIR system to be placed in geosynchronous orbit; it could also be applied to other SAIR systems intended to stare at stationary targets for relatively long times.

SAIR has evolved in part from the interferometric technique used by astronomers to increase the resolutions of their microwave radiometers. This technique involves the cross-correlation of signals received by pairs of small antennas at different locations. Each cross-correlation samples a point in the visibility function, which is the Fourier transform of the spatial distribution of the brightness temperature

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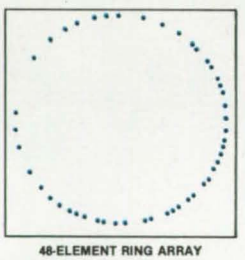
over the field of view. An inverse Fourier transform is applied (typically in software) to the visibility-function measurements to reconstruct the spatial distribution of the brightness temperature (that is, the desired image). Each point in the inverse transform is equivalent to the output signal that would be obtained from a fictitious single independent antenna beam pointed at a particular spot in the field of view. All such beams are present simultaneously if the visibility-function measurements are taken in parallel.

In SAIR as in astronomical interferometric radiometry, a few antennas are placed strategically at large separations to attain resolution approaching the resolution that would otherwise normally be attainable only by use of a huge antenna that has an aperture as wide as the maximum separation. Measurements of the visibility function can be prescribed by the appropriate Nyquist sampling criterion. The extent of the field of view determines the maximum allowable spacing between adjacent visibility samples, and the maximum-visibility sample determines the spatial resolution of the image. In this context, undersampling gives rise to aliased responses in the image, which are analogous to grating lobes in the equivalent antenna pattern.

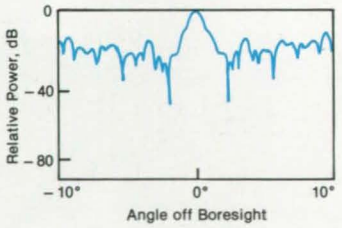
As SAIR is now envisioned, visibility samples would be taken by either or both of two methods. In the "snapshot" method, a complete (in the sense that it would satisfy the Nyquist criterion) sampling would be performed by cross-correlating signals from all possible pairs of antennas instantaneously. In another method, samples would be taken while the antennas moved with respect to the field of view.

The proposed geosynchronous SAIR system would include a ring array of "flood-beam" antennas. The signals from all possible pairs of antennas would be cross-correlated simultaneously. The diameter of the ring would determine the spatial resolution of the image, and the distribution of the antennas around the ring would determine the sampling characteristics. The positions of the antennas around the ring (see figure) can be determined by an optimizing algorithm that pseudorandomly maximizes some measure of the performance of the SAIR system. In this case, the angular rotation of the ring required to sample all necessary visibility samples is minimized. This in turn minimizes the refresh time between successive images of the Earth.

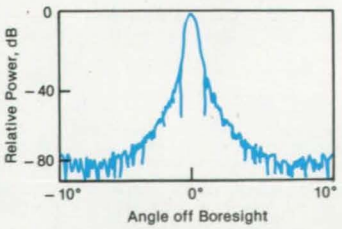
This work was done by Christopher S. Ruf of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 29 on the TSP Request Card.*
NPO-17886



48-ELEMENT RING ARRAY



BEAM PATTERN IN "SNAPSHOT" MODE



BEAM PATTERN IN ROTATING MODE

The 48 Antennas in This Ring Array would be spaced apart in an uneven pattern that would enable the array to take most of the visibility samples in the "snapshot" mode in one angular position. The ring would then be rotated 35° to obtain the missing visibility samples, resulting in an improved beam pattern.

Stereoscopic Video Weld-Seam Tracker

An electronic system locates nearly invisible butt joints.

Marshall Space Flight Center, Alabama

A stereoscopic video camera and laser illuminator operates in conjunction with an image-data-processing computer to locate a weld seam and to map surface features in the vicinity of the seam. This equipment, which has been developed to the prototype stage, is intended to track seams to guide the placement of the welding torch in an automatic welding system and to yield information on the qualities of welds. It is more sensitive than prior optical seam trackers and, unlike eddy-current seam trackers, is suitable for use in a production environment. It can even track the nearly invisible gap between the butted machined edges of two plates.

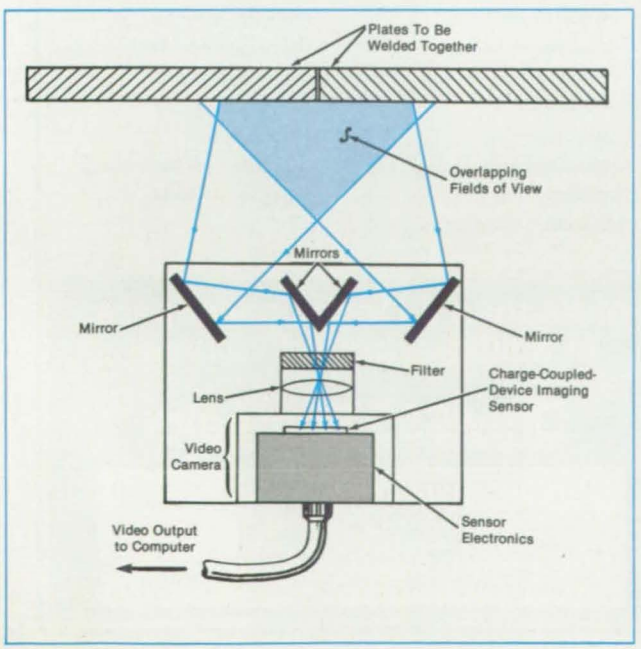
The video camera includes a charge-coupled-device (CCD) imaging sensor in the focal plane of the stereoscopic viewing optics. The view from the left side is imaged on the right side of the CCD, while the view from the right side is imaged on the left side of the CCD (see figure). The output of the CCD is digitized and fed to the computer, which identifies identical features in the right and left images and computes the locations of these features in the workspace according to the geometric transformations that describe the relationships between the two views. The parameters of the transformations are obtained by calibration and occasional recalibration, which the equipment performs automatically while the camera views targets of known position and structure.

The equipment operates in two modes. In one mode, the region of the weld joint is illuminated with a broad beam of laser light, and the image data are initially subjected to gray-scale processing to identify and locate the seam. In the other mode, the scene is illuminated with fanshaped beams to illuminate lines on the surface, and the resulting images are processed to extract information on such surface features as V-grooves, J-grooves, and multipass welds.

The camera can scan a field of view from 0.5 in. to 2.0 in. (13 to 51 mm) wide and 0.5 in. to 2.0 in. deep with a resolution of 2.0 to 8.0 mils (0.05 to 0.21 mm). It acquires 30 frames per second, though the sampling rate may be lower inasmuch as it depends on the computer. For maximum flexibility, the lasers can be controlled manually or by computer. For safety, there is a "laser on" indicator, and the lasers are turned off automatically by the computer when the camera is not in use. The camera-and-laser assembly measures only 3 by 3 by 2.75 in. (76.2 by 76.2 by 69.9 mm) and weighs only about 1.5 lb (0.7 kg). Other than the occasional recalibration and cleaning of protective glass windows on the laser and camera, the equipment requires little maintenance.

This work was done by Larry Z. Kennedy of Applied Research, Inc., for **Marshall Space Flight Center**. *For further information, Circle 73 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-26116.



The **Stereoscopic Seam Tracker** can track the nearly invisible seam between butted, machined edges of plates. It is designed for use in a production environment.

Multiple-Symbol Differential Detection of MPSK

Performance would approach that of ideal coherent detection.

NASA's Jet Propulsion Laboratory, Pasadena, California

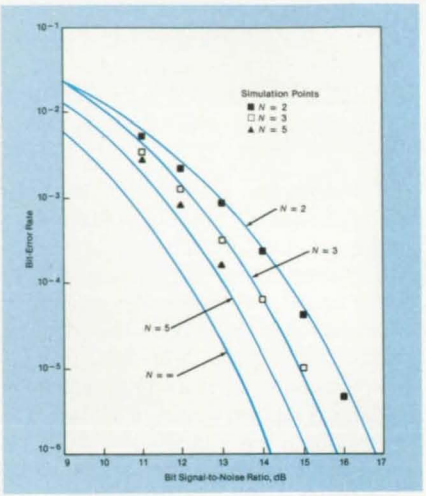
Multiple-symbol differential detection has been proposed for the reception of radio-frequency signals modulated by multiple-phase-shift keying (MPSK). In comparison with ideal coherent detection, differential detection offers the advantage of less complexity in that it does not require equipment to acquire and track the carrier signal. However, conventional differential detection, which involves the observation of the received signal during intervals of two symbol periods each, requires a higher signal-to-noise ratio to achieve the same bit-error rate obtainable by ideal coherent detection.

In multiple-symbol differential detection, the observation period would be N symbol periods (where N is any integer ≥ 2). Furthermore, whereas a conventional differential detector decides the phase of each received symbol separately, a multiple-symbol differential detector would make a joint decision on $N-1$ symbols considered together, using a maxim-likelihood-sequence-estimating algorithm.

Computer simulations of the proposed scheme have shown that in terms of performance, it would fill the gap between conventional two-symbol differential detection and ideal coherent detection. The amount of improvement would depend on the number of additional symbol periods added to the observation. In the limit as $N \to \infty$, the performance would approach that of ideal coherent detection with differential encoding, and the addition of only a few symbols would make the performance approach this limit (see figure). The multiple-symbol detection scheme is applicable to coded as well as uncoded MPSK, and to other forms of modulation.

This work was done by Dariush Divsalar and Marvin K. Simon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 56 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17896.



The **Bit-Error Rate of an 8-Phase-Shift-Keyed Detector** as a function of the signal-to-noise ratio is shown for N-symbol-period detection schemes ranging from $N = 2$ (conventional differential detection) to $N = \infty$ (infinite observation interval, with performance equivalent to that of ideal coherent detection).

Modular, Multilayer Perceptron

Ability to recognize a new object would be added without retraining the entire network.

NASA's Jet Propulsion Laboratory, Pasadena, California

The combination of a proposed modular, multilayer perceptron and an algorithm for its operation would be able to recognize new objects after relatively brief retraining sessions. (A perceptron is a multilayer, feed-forward artificial neural network that is fully connected and trained via a back-propagation learning algorithm.) In effect, the knowledge pertaining to each object to be recognized would reside in a subnetwork of the full network, so that it would not be necessary to retrain the full network to recognize each new object.

The back-propagation learning algorithm is based on the least-mean-square and gradient-search techniques. In a nonmodular perceptron, it involves the passage of error signals from the outputs back through hidden (inner) neural layers toward the inputs, thus training all parts of the network simultaneously in all its capabilities. After training, the capabilities of the network are fixed; the network cannot thereafter recognize objects that were not part of the training set. To enable the network to recognize additional objects, the network must be retrained with the entire expanded set of objects. Such training is time-consuming and undesirable in many practical situations.

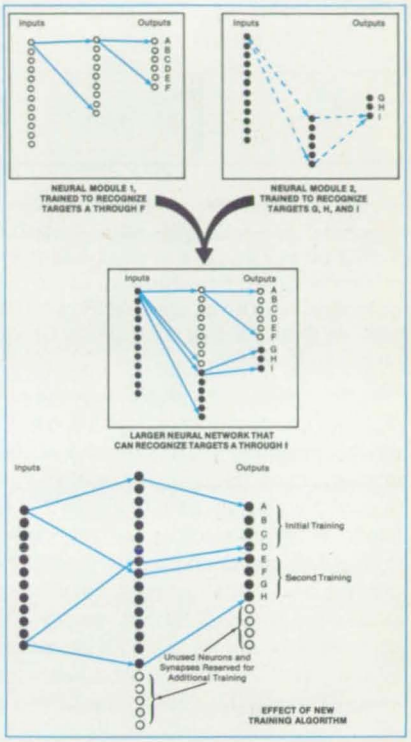
The evolution of the proposed modular perceptron from the nonmodular perceptron is illustrated by example in the figure. Neural modules 1 and 2 would be trained to recognize objects A through F and G through I, respectively. The juxtaposition of the arrays of input neurons of these two modules would form a large neural network that could recognize objects A through I, without having to retrain either module. The behavior of this network would be the same as that of a nonmodular network that had been trained with targets A through I simultaneously.

This modular concept enables the development of the new training algorithm, which would eliminate the need to retrain the whole network when objects are added. During a particular learning event in the initial training, only those neurons and synapses in a particular section of the network would be used, and this section would be kept as small as possible. When a new training set of objects to be recognized was needed later, the algorithm would allocate only just enough synapses and neurons from the pool of unused synapses and neurons to accept the new training set. During each such training session, the algorithm would provide adequate protection for synapses and neurons in the part of the network used in the previous training sessions. Subsequent training sessions could continue until all the synapses in the network were exhausted.

The training algorithm could impart a self-training capability for the acceptance of a new object into memory. If an object not in the original training set appeared, the activities of all the assigned output neurons for known objects would be near zero. This condition could activate the network for a short training process to remember the new object and assign it to one particular output neuron, the activity of which would become high when the new object appeared again. The network would not understand what the new object was, but its ability to distinguish different objects would increase with experience.

This work was done by Li-Jen Cheng and Tsuen-Hsi Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 34 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17860.



A **Larger Neural Network** assembled from modules 1 and 2 could recognize targets A through I without retraining of either module. The new training algorithm would eliminate the need to retrain the whole network when adding the ability to recognize new objects.

Docking System With Video Feedback

No communication between the vehicles is necessary.

Marshall Space Flight Center, Alabama

A video-sensor/electronic-feedback control system is being developed to provide automatic control of the final stage of approach of an active vehicle to a passive vehicle or object. One of the advantages of the system is that it requires no communication between the two vehicles. The system was conceived for use aboard a chasing spacecraft to control its maneuvers in docking with a chased spacecraft, but the concept of the system may also be useful in controlling the coupling of aircraft in flight or vessels on water or in controlling the approach of a robot to an object to be manipulated.

The passive vehicle is equipped with an optical docking target (see Figure 1) that includes three retroreflective patches at known positions along a line. The patches are made in different sizes to remove a ±180 °C ambiguity in the angle of roll about an axis perpendicular to the plane of the target. The active vehicle is equipped with a source to illuminate the target and with a tracking sensor in the form of a monochrome video camera. Image-processing circuitry connected to the camera computes the relative azimuth and elevation of each patch. From these data, the system computes the relative position and orientation of the two vehicles.

The active vehicle is also equipped with an autonomous docking-process controller, which is a digital processing system that generates commands for the motion actuators (e.g., thrustors in the original spacecraft application, control surfaces on an airplane, or motors in a robot). The control algorithm is designed so that the commands tend to eliminate the errors in the relative attitude, maneuver the active vehicle onto the docking axis, and reduce the relative distance along this axis at a predetermined, continuously-decreasing velocity simultaneously.

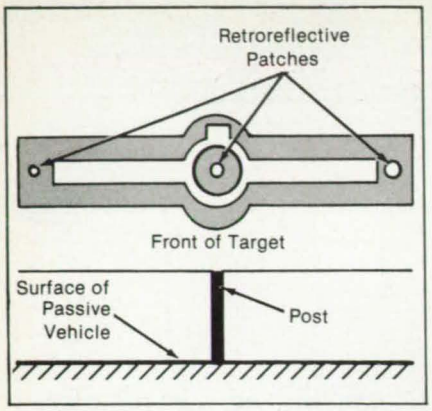


Figure 1. The **Docking Target**, mounted on a post on the passive vehicle, has three reflective dots, the positions of which can be measured in an image to determine the relative position and orientation of the target and vehicle.

There are six control channels, one for each of three degrees of translational freedom and three degrees of rotational freedom of the relative motion. Figure 2 illustrates, in simplified schematic form, the control scheme for one such channel. The position and orientation data are sampled at discrete times. Random noise in the sampled data is partly low-pass filtered out by taking pairwise moving averages of the samples. Next, the rate of change of the reading in each channel (in effect, the relative translational or rotational velocity for the degree of freedom represented by that channel) is estimated by taking the difference between the present and immediately preceding pairwise average and dividing by the sampling period. This rate estimate is then pairwise-moving-average-filtered.

The filtered signals that represent the position and orientation and the rate of change of position and orientation are multiplied by feedback gain coefficients, then differenced to provide a continuous rate-error signal. These signals are passed through dead-band processors and hard-limited to accommodate (in the spacecraft application) the minimum and maximum allowable firing times of the thrustors per cycle. In addition, if the measured rates exceed predivined limits, rate-limiting processors issue commands to reduce the rates.

This work was done by Richard Dabrey of **Marshall Space Flight Center**. *For further information, Circle 18 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-28421.

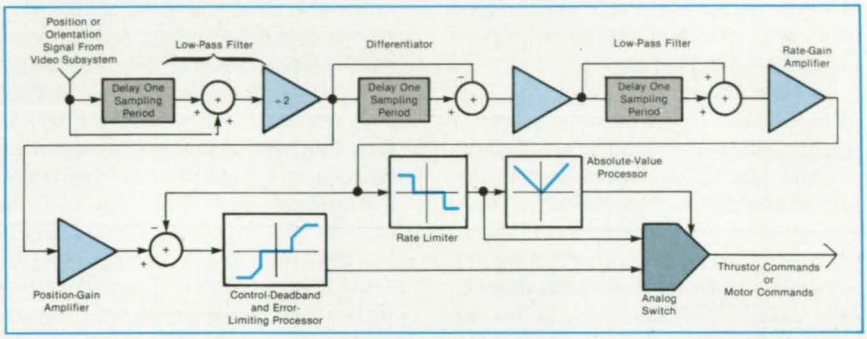


Figure 2. This **Control Channel** (one of six similar channels) processes video-sensor feedback into motion-control signals (thrustor commands in a spacecraft or motor commands in a robot).

Physical Sciences

Nonintrusive Measurement of Temperature of LED Junction

The temperature is inferred from the spectrum of the emitted light.

Goddard Space Flight Center, Greenbelt, Maryland

The temperature at the junction of an operating light-emitting diode (LED) can be determined without breaching the LED case to place a thermometer or other probe in contact with the junction. Instead, the temperature can be inferred from the spectrum of the emitted light. It is important to determine this temperature because overheating shortens the operating life of an LED and one may need temperature data to make an engineering compromise between output power (and temperature) on the one hand and operating life on the other hand.

Intrusive (that is, probe) techniques are undesirable because, of course, they disturb the very thermal operating conditions that they are intended to measure. Previous attempts at nonintrusive determination of junction temperature included measurements of temperatures of the lead wires of a noninstalled LED and measurement of the voltage drop across a LED. The lead-wire-temperature technique has been found to be subject to large systematic errors, and the voltage-drop technique has been found not to account adequately for the thermal dissipation of electrical power at places other than the junction at typical operating currents.

The spectral method of determining the temperature of the junction is based on two relevant characteristics of an LED. One is that the gap between the valence and conduction electron-energy bands in the LED material decreases with increasing temperature, causing the wavelength of an emitted photon to increase with temperature. The other relevant characteristic is that as the temperature increases, non-

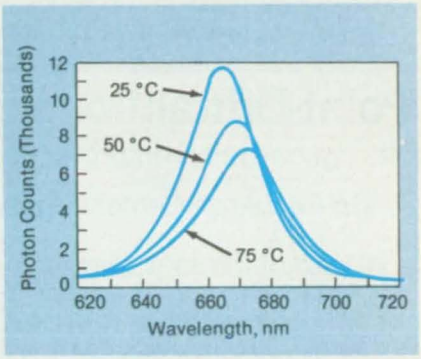


Figure 1. **Spectra of a Light-Emitting Diode** in air were measured at three different case temperatures while the diode was excited by a current of 1 mA. (This current was estimated to heat the junction only 0.6 °C above the temperature of the case.)

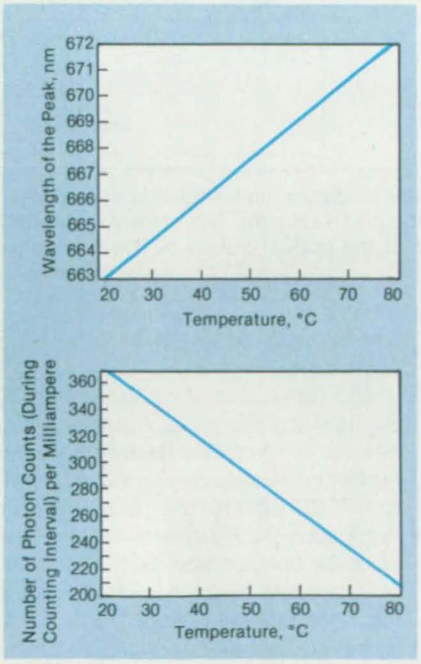


Figure 2. **Two Plots That Characterize the Spectra** of Figure 1 can be used to determine the temperature of the junction of the light-emitting diode.

radiative processes dissipate more of the input electrical energy as heat and less as photons in the band-gap wavelength region; that is, the optical and quantum efficiencies decrease with increasing temperature. In principal, either characteristic alone could be used to determine the temperature. However, it is desirable to use both to obtain an indication of an uncertainty.

To apply the spectral method to a given LED, it is necessary to take calibrating spectral measurements while maintaining the case of the LED at various known temperatures (see Figure 1). During these measurements, one excites the LED with a known forward current low enough to cause a negligible rise in the temperature of the junction above the temperature of the case, so that in analyzing the spectral data as a function of temperature one can assume that the temperature of the junction equals the known temperature of the case. From the spectral data one can obtain a plot of the wavelength of the peak in the spectrum as a function of the temperature and a plot of ratio of power in the optical peak to the current (proportional to the optical efficiency), also as a function of temperature (see Figure 2).

Thereafter, either of the plots can be used with spectrophotometry to determine the temperature of the junction, even when the current is large enough to cause significant heating. For example, experiments have shown that when the LED represented by the plots in the figures is mounted on a circuit board at a temperature of 25 °C and excited by a current between 0 and 50 mA, either plot gives the temperature of the junction within about 2 °C of its correct value.

This work was done by Henning Leidecker and Charles Powers of **Goddard Space Flight Center**. *For further information, Circle 158 on the TSP Request Card.*
GSC-13339

Point-Diffraction Interferometer for Flow Experiments

The optical train is improved to accommodate higher laser powers.

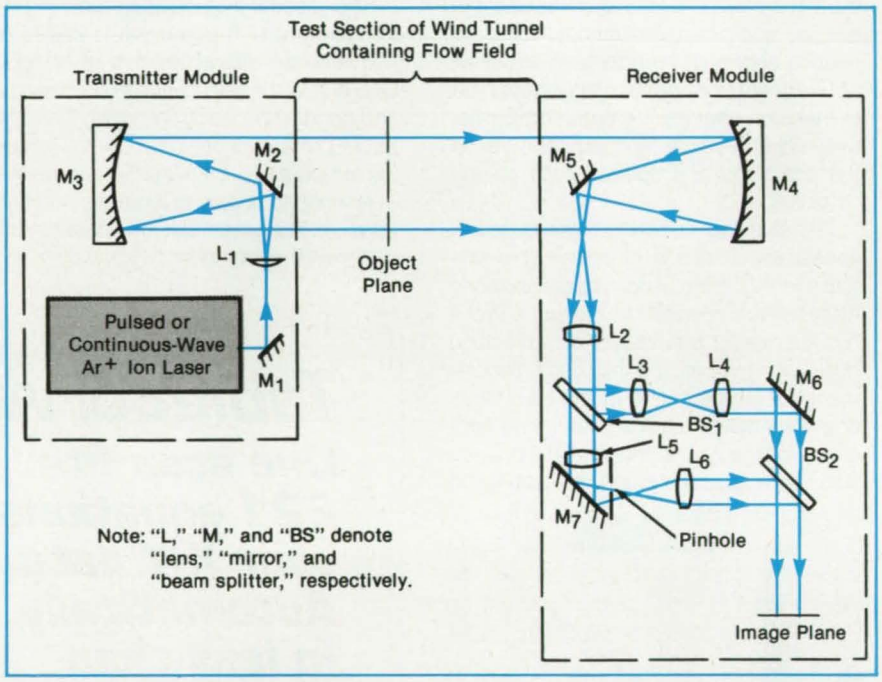
Ames Research Center, Moffett Field, California

An improved point-diffraction interferometer can be used in both the real-time visualization and the recording of supersonic and transonic flow fields about airfoils and other test bodies in wind tunnels. Unlike point-diffraction interferometers designed for testing lenses and other optical components, an instrument to be used in recording flows must use short exposures. This, in turn, requires higher laser powers. The optical train of the new instrument is designed to handle the higher laser powers and to use the available light efficiently.

The improved point-diffraction interferometer is illustrated schematically in the figure. The portion of the optical system to the left of the receiver module is identical to that of a Schlieren system. The laser light is spatially filtered and expanded to fill the lenses and mirrors of the transmitter system and form a collimated beam, which passes through the field to be tested.

In the receiver module, mirror 4 focuses the light after it passes through the test section. After collimation by lens 2, the beam is split by beam splitter 1 into a transmitted beam and a reflected beam, traveling along different optical paths. The transmitted beam is spatially filtered and diffracted by a pinhole to remove the high spatial frequencies produced by the refractive flow field in the test section. This diffracted beam acts as the reference wave. The reflected beam retains the wave-distortion information produced by the gradients of refraction in the flow field. The two beams are recombined in beam splitter 2 to produce the interferogram.

The system can be aligned in the manner of a common Mach–Zehnder interferometer. However, the optical components in the receiver module can be made very compact and are mounted rigidly so that vibration need not be more serious than in a Schlieren system. The use of two separate paths allows the reduction of energy incident upon the aperture. This optical configuration permits the use of commercially available pinholes that can withstand the necessary high laser-beam energies. Because of the losses involved in the filtering process, a variable beam splitter can be used instead of an absorbing substrate to maximize the use of the available light. Additional attenuation can be introduced to maximize the visibility of the interference fringes and, hence, the signal-to-noise ratio. Both the transmitted and reflected outputs of beam splitter 2 can be used to form the final interferogram images. One image can be used for real-time viewing while the other is being recorded.



The **Improved Point-Diffraction Interferometer** produces interferograms of the flow in the test section, for both viewing in real time and recording. The system is relatively insensitive to vibrations, but very sensitive to the optical quality of the wind-tunnel windows.

This work was done by William D. Bachalo and Michael J. Houser of Aerometrics, Inc. for **Ames Research Center**. *Further information may be found in NASA CR-177467 [N89-16765], "Evaluation and Application of a New Interferometry Technique for Compressible Flow Research."*

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Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Electrostatic Stabilization of Growing Protein Crystals

A proposed technique would produce large crystals in a compact, economical apparatus.

A report presents a concept for supporting protein crystals during growth in microgravity. The technique promises to yield crystals that are larger and more-nearly perfect than are those grown on Earth. The concept combines the best features of the sandwich-drop and the electrostatic-levitation methods of support.

A drop of protein solution would be inserted between a pair of glass or plastic plates, as in the sandwich-drop-support method. An electrostatically charged ring would confine the drop laterally and shape it, as in the electrostatic technique.

The sandwich plates could be coated with a halocarbon film, which would repel the water-based protein solution, preventing it from making direct contact with the plates. The growing protein crystal would therefore not be subject to unwanted nucleation from contact with the plates. Experiments have shown that halocarbon films satisfactorily inhibit spontaneous nucleation; however, they also destabilize the sandwich configuration, causing the drop to break up or wander. Centripetal electrostatic repulsion by a ring electrode would stabilize the drop without the use of wetting (and hence nucleating) glass surfaces.

Unlike in the conventional electrostatic technique, however, the drop would not be a sphere. It would be cylindrical with rounded edges. The growing crystal could be monitored optically through the flat surfaces more easily than through a spherical surface.

The apparatus would be simpler, less costly, and more compact than that for purely electrostatic support because electrodes for vertical support along the axis perpendicular to the planes of the plates would not be needed. The apparatus might also be made to accommodate several drops simultaneously between the same pair of supporting plates. Drops might be inserted and crystals removed through ducts in the plates.

If necessary to ensure adequate containment and shaping, a drop could be given an electric charge of the same polarity as that of the electrostatic ring by a microelectrode protruding from a plate into the solution. The microelectrode might also serve as a point of controlled nucleation of crystals.

Unwanted contact nucleation might be further inhibited by adding transparent conductive film electrodes to the plates. The voltage between the plates would be adjusted to add to the repelling effect of the ultrahydrophobic film.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Electrostatic Levitation Stabilized Sandwich Technique for Growing Protein Crystals," Circle 89 on the TSP Request Card. NPO-17747*

Behavior of $NbSe_3$ Cathode in Rechargeable Li Cell

Ac impedance measurements were made at various stages in the reduction of $NbSe_3$.

A report discusses a series of ac impedance measurements of niobium triselenide

cathodes in lithium secondary (rechargeable) cells. Such cells should provide high energy density because $NbSe_3$ reacts with three equivalents of Li at high positive potential. $NbSe_3$ also has high electronic conductivity, long cycle life, and high diffusivity for Li. Part of a continuing evaluation of this battery system, the reported work was done to improve understanding of the intercalation of $NbSe_3$ with Li and to find out whether the state of charge of $NbSe_3$ can be determined nondestructively from the impedance parameters.

The results of the measurements are presented in four sections. The first presents a Nyquist (complex-impedance) plot for a virgin electrode. The data are for a prismatic 3-mAh virgin $NbSe_3$ electrode (area, 2 cm^2) in 1.5 M $LiAsF_6$/2-methyltetrahydrofuran, with an open-circuit potential of 2.3 V. In the next two sections similar plots show relaxation loops at various states of charge ~ from 0.8 to 0.2. These provide qualitative information about the kinetics of the individual steps in the reduction of $NbSe_3$. For example, at a state of charge of 0.8 (open-cell potential 1.799 V), the relaxation loop corresponding to the first step becomes smaller, indicating that the first step is becoming more facile. As discharge continues, the relaxation loop corresponding to the second step also becomes smaller and merges with the diffusional impedance. As the electrode reaches a state of charge of 0.2, both relaxation loops increase in size as the number of unoccupied intercalation sites in the $NbSe_3$ decreases.

The fourth section describes procedures for calculating various kinetic and interfacial parameters, including the charge-transfer resistance, the double-layer capacitance for the first step in the reduction of $NbSe_3$, the exchange-current density, and the Warburg coefficient, which determines the mass-transfer impedance. The standard exchange-current densities for the first and second step are 0.4 and 1.5 A/(mole•cm^2), respectively; the diffusion coefficients at the corresponding sites are 5.5×10^{-11} and 1.6×10^{-10} cm^2/s, respectively.

The authors conclude that the impedance parameters of $NbSe_3$ do not vary in sufficiently regular fashion to be useful as indicators of the state of charge. The kinetic parameters obtained from the ac-impedance measurements support the finding of an earlier study that in the reduction of $NbSe_3$, one equivalent of Li intercalates at one type of site at a potential of about 1.9 V and two equivalents of Li intercalate at a different type of site at a potential of about 1.7 V.

This work was done by Ratnakumar V. Bugga, Salvador DiStefano, and Clyde P. Bankston of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 95 on the TSP Request Card.*
NPO-17648

Optical Modeling of Segmented Mirror Telescopes

Fabrication and alignment errors are analyzed.

A report describes how to model optical-path-length errors caused by errors in the fabrication and alignment of hexagonal segments of a segmented mirror telescope. This study was motivated by the trend toward lightweight designs of astronomical reflectors composed of such segments, which can be deployed or erected on ground or in space.

The analysis begins with development of a mathematical model to describe the surface errors. The basic equations for the sag of an ideal mirror, the sag of a mirror with fabrication errors, and the effects of alignment errors on sag are presented. Equations of geometric transformation are then derived to describe the six types of misalignment of a mirror segment: two translations perpendicular to the optical (z) axis, a rotation about an axis parallel to the z axis, and two tilts about either of the two axes (x or y) perpendicular to the z axis. Fabrication errors are described in terms of Zernike polynomials in coordinate systems centered on the segments. Surface errors caused by errors in base curvature are also quantified. The

equations for the various errors and transformations are combined along with that for piston error (pure translation along the *z* axis) to obtain an equation for the overall sag error of the surface and the optical path difference, which is approximately twice the sag error.

This is followed by a discussion of the use of the foregoing equations to analyze the optical effects of manufacturing and assembly tolerances and to determine what adjustments (e.g., in piston or tilt) could compensate for some of the optical degradation caused by decenter, rotation, fabrication errors, or differences of radius. The kind of compensation analysis described here amounts to finding the best position and orientation of each segment with respect to the nominal paraboloid by minimizing the sag error over the aperture. It yields data on the best optical performance that can be expected in the presence of the given manufacturing and alignment errors and on the dynamic ranges of the actuators needed to achieve compensation.

The discussion then turns to practical implementation via computer programs. First, it is shown how the boundary of the array of hexagonal apertures can be specified in CODE V, a commercial optical-analysis program that computes wavefront-aberration maps and point-spread functions. Next, there is a description of SMMAT, a program that calculates the sag-error and OPD data, which can be input into CODE V for graphical representation. An example of an application, a tolerance study of NASA's Precision Segmented Reflector (PSR), a paraboloidal mirror with two rings of hexagonal elements, a base radius of curvature of 5.2 m, and an entrance-pupil diameter of 4.33 m, is presented. For the particular case, it is shown that compensation can improve performance by a factor of ~100. The predominant error, after compensation, is found to be the root-mean-square surface error. The quality of the figure of each segment is found to be paramount in achieving high optical fidelity, while such gross alignment errors as rotation and decenter can be tolerated because of compensation in focus and tilt.

This work was done by Paul K. Manhart of Caltech and John M. Rodgers of Optical Research Associates for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Study of Segmented Mirror Surface Errors in Terms of Wavefront Aberrations Due to Fabrication and Alignment Errors Preliminary to Development of the SMMAT Program," Circle 151 on the TSP Request Card.* *NPO-17961*

Using Multiple Grids To Compute Flows

Applications include flows in turbomachinery and about helicopters.

A paper discusses the decomposition of global grids into multiple patched and/or overlaid local grids in computations of fluid flow. Such "domain decomposition" is particularly useful in the computation of flows about complicated bodies that move relative to each other; for example, flows associated with rotors and stators in turbomachinery and rotors and fuselages in helicopters.

The finite-difference numerical solution of the equations of fluid flow requires the generation of a grid in the region of interest. The paper begins by introducing the problem of the generation of grids. It shows how decomposition into multiple grids can simplify the spatial discretization, provide for increased spatial resolution where necessary, enable the use of different sets of equations in different parts of the flow, and simplify the processing of large blocks of data.

The introduction continues with a discussion of the patched- and overlaid-grid approaches to domain decomposition. Examples of each are presented, and relative advantages and disadvantages are discussed. A primary consideration in both approaches is the proper treatment of grid points on the interfaces to ensure the accurate transfer of information between subdomains. In order that discontinuities in flows (e.g., shocks) move freely across interfaces without adverse affects on the accuracies of the simulations, it is required that the interface procedure be numerically stable, spatially and temporally accurate, conservative, and easily applicable in generalized coordinates.

In the next section of the paper, a conservative patched-grid interface scheme is developed for an explicit finite-difference representation of the conservation-law form of the Euler equations of unsteady flow. A nonconservative scheme (which is conceptually simpler than the conservative scheme) for patched and overlaid grids is also developed.

The patched-grid method is then applied to a two-dimensional simplified mathematical model of rotor/stator interaction in which two circular-arc airfoils move relative to each other. A subgrid is attached to each airfoil, and the two subgrids slide with respect to each other along a zonal boundary. The Euler equations are solved numerically on this grid, and the results are presented in the form of pressure contours and other plots.

This work was done by Man Mohan Rai of **Ames Research Center**. *To obtain a copy of the report, "Applications of Domain Decomposition Methods to Turbomachinery Flows," Circle 162 on the TSP Request Card.*
ARC-12321

Materials

Forming $YBa_2Cu_3O_{7-x}$ Superconductors on Copper Substrates

Mechanical processing — always difficult and usually impossible with superconductors — is not necessary.

John F. Kennedy Space Center, Florida

An experimental process forms a layer of the high-critical-temperature ceramic superconductor $YBa_2Cu_3O_{7-x}$ on the surface of a copper substrate. The process offers a possible solution to the problem of finishing ceramic superconductors to required final sizes and shapes — a difficult problem because these materials are so brittle that they cannot be machined or bent.

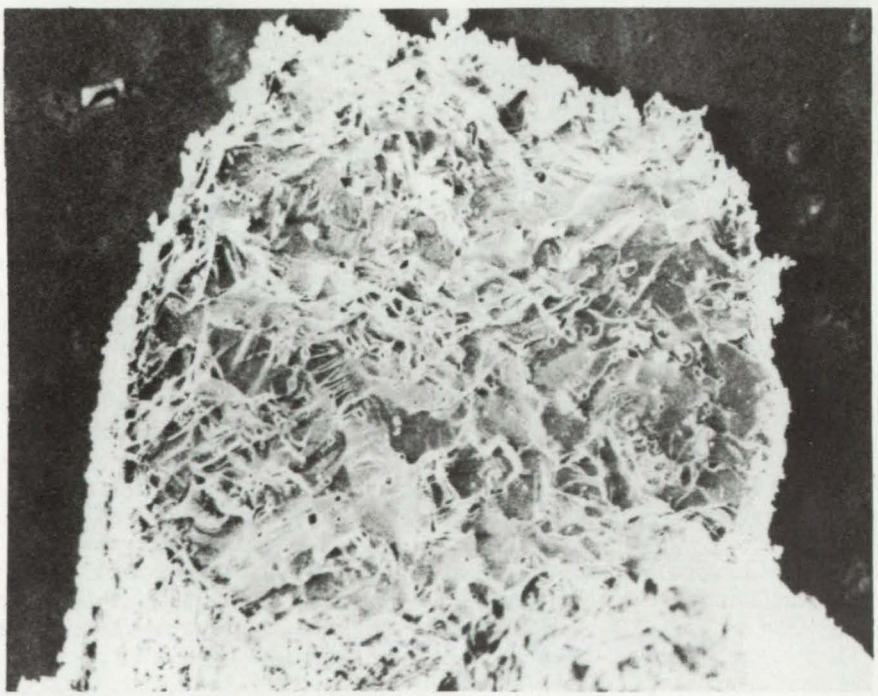
The process is easily justified by basic physical principles. A superconductor is subject to the Meissner effect — the exclusion of magnetic field from the interior of the material. This effect forces any electrical current in the superconductor to be concentrated at the surface. Consequently, in a typical application, there would be no advantage in making a thick superconductive part at great difficulty and expense: it would suffice to form a thin superconductive layer on a normal conductor or insulator, which could provide mechanical support. For example, a superconductive coat could be formed on a copper wire or on a tube. The tube could be cooled below the critical superconducting-transition temperature by pumping liquid nitrogen (temperature $\approx$ 77 K) through it.

The experimental process begins with the mixing of yttrium oxide and barium carbonate powders in the required stoichiometric ratio of 1:2. (The powders are mildly toxic and are prepared in vented hoods.) Next, the powder is packed around the copper wire, tube, or other part in a ceramic boat. The amount of powder and the size and shape of the copper part are not critical. However, contact between the powder and the copper surface is essential and is achieved by firmly pressing the powder into the boat with a spatula. The boat and its contents are fired in an oxidizing furnace. The outer layer of the copper oxidizes; then the yttrium and barium compounds react with the copper oxide by diffusion, forming a layer that contains $YBa_2Cu_3O_{7-x}$ mixed with nonsuperconducting phases (see figure).

Further research will be necessary to evaluate the superconducting qualities of the surface layers and optimize the process. for example, surface layers with thickness of 5 to 10 μm (depending on firing time) have been examined by energy-dispersive x-ray analysis, which showed that at least parts of these layers contained the required proportion of yttrium, barium, copper, and oxygen. It remains to be determined to what extent and in what configurations nonsuperconducting phases/quality superconducting phases are required for optimum superconductivity and what optimum thicknesses are necessary. The effects of variations in the pressure, time, and temperature of the process must also be investigated. for example, variation of the firing time varies the degree of oxidation of the copper; and with an increase in firing time, the yttrium and barium may be drawn further into the copper part.

This work was done by J. Devin MacKenzie and Stanley G. Young of **Kennedy Space Center**. *For further information, Circle 112 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 16]. Refer to KSC-11448.



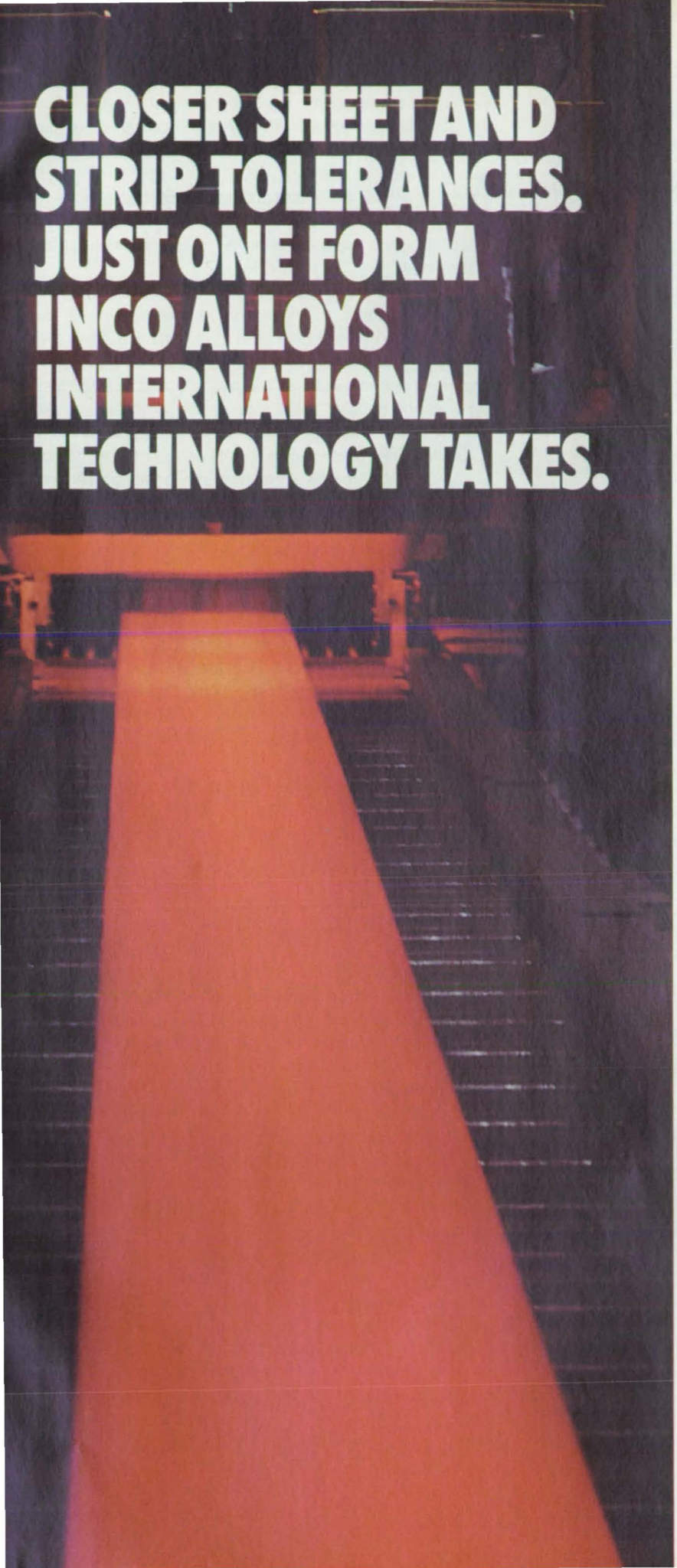
This **Secondary-Electron Image** shows an outer layer of yttrium, barium, copper, and oxygen that was formed on a copper wire.

Removing Spilled Oil With Liquid Nitrogen

Pollutants would be frozen quickly and hauled away.

Langley Research Center, Hampton, Virginia

A novel technique has been proposed to reduce more quickly, contain, clean up, and remove petroleum products and such other pollutants as raw sewage and chemicals without damage to humans, animals, plants, or the environment. Current meth-



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Circle Reader Action No. 569

ods for cleaning up oilspills are usually slow, ineffective, and inefficient, as demonstrated in the well-publicized incident of the oil tanker in Alaskan waters. A significant disadvantage of current methods is that the people and equipment are working with a substance that is liquid, viscous, sticky, gummy, and generally difficult to capture and handle. Because these methods are slow and ineffective, the pollution spill is afforded time to contaminate the general area—water, shorelines, plants, and animals.

The unique and primary aspect of the new technique is the use of a cryogenic fluid to solidify the spill so that it can be carried away in solid chunks. Liquid nitrogen (LN_2), with a boiling point at -320°F(-196°C), offers probably the best trade-off among extreme cold, cost, availability, and lack of impact on the environment among the various cryogenic fluids available. The LN_2 must be transported to the spill site quickly and in large quantities. Both these requirements can be met by the numerous ships that were built a few years ago to transport enormous amounts of liquefied natural gas (LNG). The market for such quantities of LNG did not materialize as anticipated, leaving a number of appropriately outfitted ships lying idle. Two such ships, for example, are currently in the "Mothball Fleet" located in the James River, Virginia. Each ship has the capacity to carry 33 million gallons (0.12 Mm^3) of LN_2.

The technique calls for these and other, faster, ships like retired and modified liners or cruisers to be stationed strategically in national waters with their LN_2 tanks as close to full as feasible. When a spill occured, all ships of both kinds that were reasonably near would sail to the affected area. The crews would place a large, deep boom around the oil and place collapsible sections (relatively deep boxlike structures) within the boom—as many as required to fill the enclosed area. These boxlike structures would be constructed with insulated electrical heater wires. Within each section would be placed a steel cable net with rings or hooks secured above the booms.

As soon as this equipment was in place, copious amounts of LN_2 would be rapidly applied to spilled oil. This would be done on top of the oil, under the oil, and if possible, within the oil. LN_2 would be applied until all of the oil was frozen. At the same time, other crewmembers would begin pumping very large quantities of LN_2 into the area of the rupture in the tanker until the oil was frozen in place, thus plugging the hole and preventing further spillage. The heater elements embedded in the segmented sections of the spill would be turned on, melting thin layers of oil between segmented sections, thereby permitting each frozen section to be removed by a crane. These sections would be taken away by barge and the spillage treated and/or disposed as appropriate.

Where a relatively thin layer of oil existed, a different means of application would be used. In fairly calm waters, a large, flat platform-type structure would be towed, preferably between two ships, at a depth of only a few inches (1 in. = 2.54 cm). At the same time large quantities of LN_2 would be applied to the oil/water surface over the platform. The use of a platform at minimum depth would prevent the formation of strong thermal currents, which otherwise occur when very cold liquid is applied to relatively warm water. (Such currents would prevent freezing on the surface until virtually all the water from surface to bottom was cooled to near the freezing temperature.)

Immediately behind the platform, a chain-link conveyor assembly would lift the solid pieces of frozen oil into a barge for future treatment. In shallow water and on some beaches, LN_2

would be applied and the frozen oil, possibly in the form of large plates, would be lifted into appropriate containers for future processing.

Other applications of this technique could include extinguishing fires at such locations as oil derricks or platforms and at tank farms that contain such petroleum products as gasoline, diesel fuel, and kerosene. Aircraft, fireboats, and the like could be used to apply LN_2, or possibly liquid neon, which is colder and has a much larger liquid-to-gas expansion ratio, forming a giant cloud of nonoxidizing gas. The cryogenic liquid would vaporize almost immediately, the oxygen-starved flame would be extinguished, and a cooled structure, ready to be approached, would result.

This work was done by Daniel B. Snow of **Langley Research Center**. *For further information, Circle 35 on the TSP Request Card. LAR-14227*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Effects of Moisture on Zinc Orthotitanate Paint

Electrical conductivity varies with humidity.

A report presents results of tests of the electrical conductivity and resistance to corrosion of zinc orthotitanate (ZOT) paint. The tests measured the effects of temperature, humidity, and vacuum on the ceramic paint. ZOT paint is used as a temperature-control coating designed to have a low and stable ratio of absorptance to emittance for heat radiation. It also helps to prevent the buildup of static electric charge and thus helps to protect electronic circuitry from potentially damaging static discharges.

The tests included measurements of the bulk electrical resistivity of ZOT paint on aluminum. To reduce or eliminate the buildup of charge, the resistivity should be low. The resistivity was measured at temperatures from 22 to 90 °C, relative humidities of 0 to 100 percent, and in soft and hard vacuums, 10^{-2} and 10^{-7} torr ($\sim$1 and $\sim 1 \times 10^{-5}$ Pa), respectively. Temperature had little effect on resistivity, but humidity had a considerable effect. The resistivity fell from 10^{10} Ω-cm at 0 percent relative humidity to 10^{5} Ω-cm at 100 percent relative humidity. The resistivity rose to 10^{14} Ω-cm in the hard vacuum — higher than allowed by the design criterion for the prevention of electrostatic discharge on the Galileo spacecraft.

The tests also included measurements of resistance to corrosion. Specimens of ZOT paint on aluminum and other specimens on magnesium were exposed to moist environments: 30 °C and 85 °C with 85 percent relative humidity for 2,000 h. The samples were removed periodically so that electrical resistances could be measured and scratch-peel tests could be performed. Some corrosion and increase of resistance occurred in the magnesium specimens, indicating that the magnesium painted with ZOT should be protected from humid environments.

This work was done by Gordon R. Mon, Charles C. Gonzalez, Ronald G. Ross, Jr., Liang C. Wen, and Timothy O'Donnell of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Moisture Interaction and Stability of ZOT Thermal Control Spacecraft Coating," Circle 83 on the TSP Request Card. NPO-17742*

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the annual *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Machinery

Simulating the Performance of a Scramjet

The SCRAM program represents a compromise among speed, accuracy, and ease of modification.

The SCRAM computer program determines, according to a one-dimensional mathematical model, the cycle performance for airframe-integrated subsonic or supersonic combustion Ramjets. The subsonic/supersonic combustion ramjet cycle, which uses hydrogen for fuel and air for oxidation, is essential for the development of a propulsion system for single-stage-to-orbit aerospace vehicles. These vehicles are intended to be launched horizontally, as opposed to the vertical launching of current space vehicles. In addition, they must achieve hypersonic flight to mach 25 for insertion into low orbits around the Earth. The propulsion system of such a vehicle must be reusable, efficient, and cost effective.

The scramjet cycle analysis code simulates, from nose to tail, a hydrogen-fueled, airframe-integrated scramjet in a real gas flow with equilibrium thermodynamic properties. This enables rapid scramjet performance estimates. SCRAM is a reliable, efficient, and speedy ramjet designer's software tool that is usable on all standard computers down to those compatible with IMB PC-AT's.

Developed in the Hypersonic Propulsion Branch at NASA Langley Research Center for the Hypersonic Research Engine and Langley 3-Strut engine programs, the current version of this code has been modified by the NASA Dryden Flight Research Facility of the Ames Research Center to support testing of the engines of the Langley Strutless Parametric Engines and the National AeroSpace Plane (NASP). The current version of SCRAM optimizes the tradeoffs between the needs for speed of computation, accuracy, and future modifications. The program incorporates a five-station-geometry model, with steps of variable size between the stations, to perform a nose-to-tail analysis of the mass-capture stream tube control volume. SCRAM applies the laws of the conservation of mass, momentum, and energy across each step to calculate the changing parameters of the flow. The code incorporates an integral boundary-layer code based on the Spaulding-Chi Method to determine the coefficient of friction, then uses a modified Reynolds analogy to calculate the transfer of heat. Although the code was written primarily for supersonic flows, it has been modified to accommodate subsonic flows, and dual-mode operation of the combustor.

The program is written in FORTRAN 77 and is machine independent. It has a memory requirement of 300 K and originated in 1968.

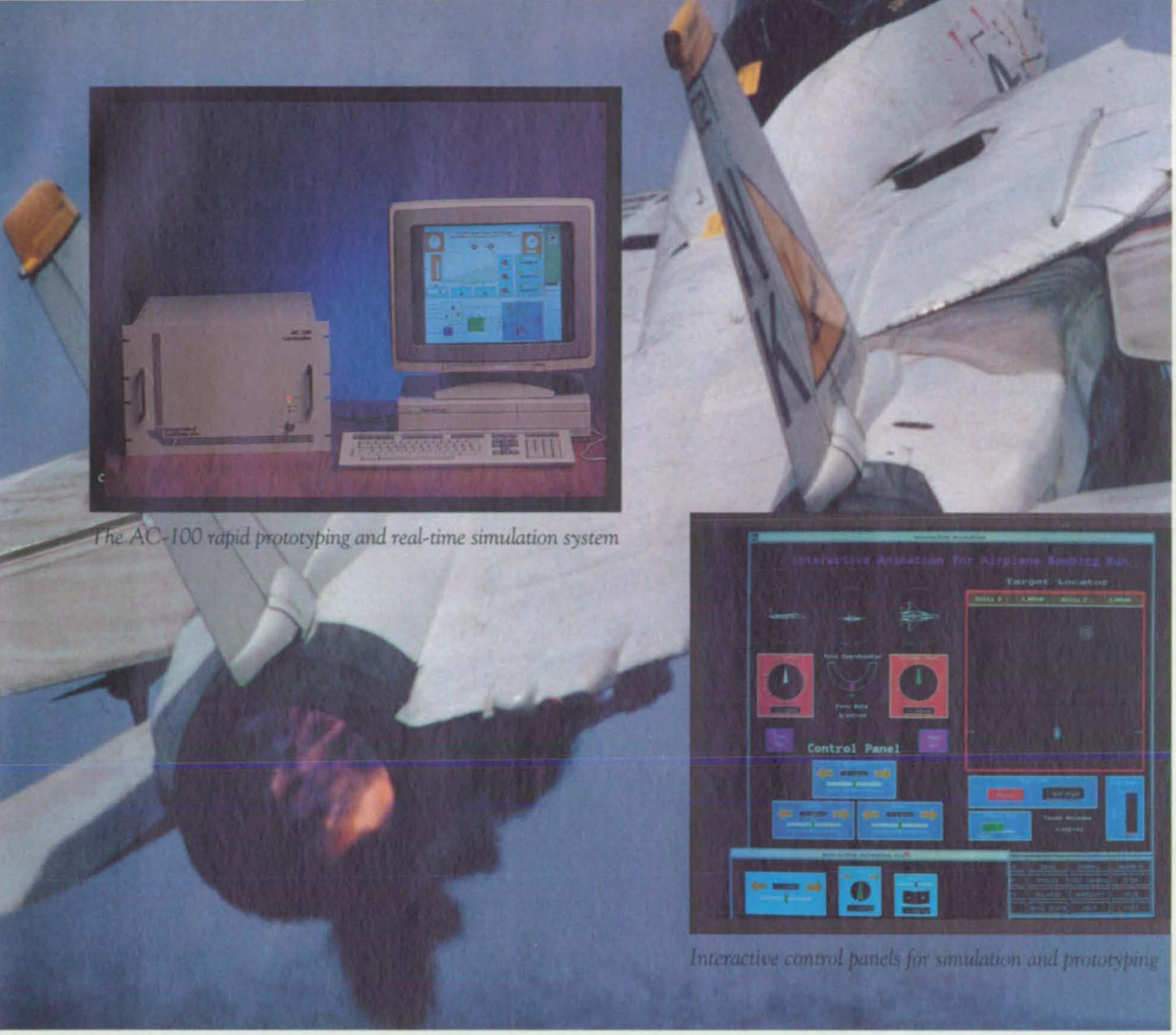
This program was written by James T. Walton of **Ames Research Center.** *For further information, Circle 75 on the TSP Request Card.*
ARC-12338

Computing Rotational/ Vibrational Dynamics of Turbine Engines

This program computes transient and steady-state responses to applied stimuli.

The Turbine Engine Transient Response Analysis program, TETRA 2, was developed to calculate the dynamic response of the structure of a turbine engine to applied stimuli. The loss of a blade at operating speed is usually the primary initiator of a failure that could ultimately lead to shutdown of the engine. In the event of damage to the engine, shutdown, or failure, an assessment of damage cannot discriminate between the damage caused primarily by transients and the damage caused by steady-state operation after the loss of a blade and before shutdown. Therefore, TETRA 2 includes options for the calculation of both transient response and steady-state forced response. TETRA 2 should help the turbine engineer in understanding basic transient and steady-state responses of the whole structure and in identifying the crucial problem areas. This could lead to the design of turbine engines that respond more robustly to applied stimuli.

TETRA 2 is based on a component-element method and a modal synthesis approach. The program allows the use of linear, as well as nonlinear, connecting elements. Both transient and steady-state options can include flexible blade disks and nonlinear connecting elements (including



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deadbands and hardening/softening springs). The component elements consist of elastic and rigid elements described by generalized coordinates, and physical connecting elements that model bearing/frame springs and dampers, rotor-case hub springs, and gyroscopic cross-axis coupling effects. The generalized coordinates are based on the free-free vibrational modes and partially constrained vibrational modes associated with the structures of subsystems of the engine.

The component-element method extends the conventional modal analysis procedure to account for physical-damping and symmetric-stiffness terms, and rotor-case rubs including the effects of force deadbands associated with the structural clearances. The resulting reduced system of second-order differential equations is solved by an explicit numerical-integration scheme to obtain the transient response. The transient option includes the additional capability to calculate response with a squeeze-film bearing module.

The input to TETRA 2 consists of a description of the various subsystems of the structure and of the elements that connect these subsystems. The normal vibrational modes of each subsystem must be calculated outside the TETRA 2 program, usually by a structural-analysis program like NASTRAN (available from COSMIC). Modal input to TETRA 2 includes the modes and the number of modes used to represent each subsystem. The user also specifies the engine-operating conditions such as speed, amount and location of unbalance, and time interval. TETRA 2 summarizes the output in a plot file, which permits such postprocessing as fast Fourier transforms or graphical animation.

The TETRA 2 program is written in FORTRAN 77 for batch execution and has been implemented on a CRAY X-MP computer with a central-memory requirement of approximately 700K. The TETRA 2 program was developed in 1986.

This program was written by V. G. Gallardo, G. Black and M. J. Stallone of General Electric Co. for **Lewis Research Center**. *For further information, Circle 25 on the TSP Request Card.*
LEW-14770

Computing Lives and Reliabilities of Turboprop Transmissions

A modular program performs analyses for components and for entire systems.

The computer program PSHFT calculates the lifetimes of a variety of aircraft transmissions. A generalized life-and-reliability mathematical model is presented for turboprop and parallel-shaft, geared propfan aircraft transmissions. The model is a combination of the mathematical models for reliabilities of all the bearings and gears in the main load paths. These models, in turn, are based on the statistical two-parameter Weibull failure-distribution method and classical theories of fatigue. The computer program developed to calculate the model for the overall transmission is modular. In its present form, the program can analyze five different transmission arrangements. Moreover, the program can be easily modified to include additional transmission arrangements.

PSHFT uses the properties of a common block two-dimensional array to separate the values that represent the properties of components and of the entire transmission from the analysis subroutines. The rows correspond to specific components, except that the first row contains the values for the entire transmission. Columns contain the values for specific properties. Inasmuch as the subroutines (which determine the life and dynamic capacity of the transmission) interact solely with this array of property values, they are separated from any specific transmission configuration. The system-analysis subroutines work in an identical manner for all transmission configurations considered. Thus, other configurations can be added to the program by simply adding

subroutines that determine properties of components.

PSHFT consists of a main program, a series of subroutines that apply to specific configurations, generic subroutines for the analysis of properties of components, subroutines for the analysis of the system, and a common block. The main program selects the routines to be used in the analysis and causes them to operate in the desired sequence. The series of configuration-specific subroutines put in the configuration data, perform the force and life analyses for the components (with the help of the generic component-property-analysis subroutines), fill the property array, call up the system-analysis routines, and finally print out the results of the analysis for the system and components.

PSHFT is written in FORTRAN 77(IV) and compiled on a MicroSoft FORTRAN compiler. The program will run on a computer that is compatible with an IBM AT personal computer and that has at least 104K bytes of memory. The program was developed in 1988.

This program was written by J. J. Coy of **Lewis Research Center**, *M. Savage of the University of Akron, and K. C. Radil and D. G. Lewicki of AVSCOM. For further information, Circle 24 on the TSP Request Card.*
LEW-14905

Computing Linear Mathematical Models of Aircraft

Nonlinear equations of motion, sensing, and control are linearized about specified points.

The Derivation and Definition of a Linear Aircraft Model (LINEAR) computer program provides the user with a powerful, and flexible, standard, documented, and verified software tool for the linearization of mathematical models of the aerodynamics of aircraft. LINEAR is intended for use in the software tool to derive linear analysis of stability and the design of control laws for aircraft.

Linear models of systems define the aircraft system in the neighborhood of an analysis point and are determined by the linearization of the nonlinear equations that described the dynamics and the sensors of the vehicle. A linear or nonlinear aerodynamical model is supplied by the user. The nonlinear equations of motion involve six degrees of freedom and assumptions of a stationary atmosphere and a flat, nonrotating Earth. LINEAR is capable of both extracting such linearized engine effects as net thrust, torque, and gyroscopic effects, and including these effects in the linear model of the system. The point at which this linear model is defined is determined either by completely specifying the state and control variables, or by specifying an analysis point on a trajectory and directing the program to determine the control variables and the remaining state variables.

The system model determined by LINEAR consists of matrices for both the state and observation equations. The program has been designed to provide easy selection of state, control, and observation variables to be used in a particular model. Thus, the order of the system model is completely under the user's control. Further, the program provides the flexibility of allowing alternate formulations of both the state and observation equations. Data that describe the aircraft and the test case are fed to the program through a terminal or formatted data files. All data can be modified interactively from case to case. The aerodynamical model can be defined in two ways: a set of nondimensional stability and control derivatives for the flight point of interest, or a full nonlinear aerodynamical model as used in simulations.

LINEAR is written in FORTRAN and has been implemented on a DEC VAX computer operating under VMS with a virtual-memory requirement of approximately

296K of 8-bit bytes. Both an interactive and batch versions are included. LINEAR was developed in 1988.

This program was written by Eugene L. Duke, Robert F. Antoniewicz and Keith D. Krambeer of **Ames Research Center**. *For further information, Circle 57 on the TSP Request Card.*
ARC-12422

Mathematics and Information Sciences

Source-Code-Analyzing Program

This program computes statistics that characterize a given FORTRAN program.

The FORTRAN Static Source Code Analyzer program, SAP, was developed to gather statistics automatically on the occurrences of statements and structures within a FORTRAN program and to provide for the reporting of those statistics. Provisions have been made to weight each statistic and to provide an overall figure of complexity. Statistics, as well as figures of complexity, are gathered on a module-by-module basis. Overall summed statistics are also accumulated for the complete input source file.

SAP accepts, as input, syntactically correct FORTRAN source code written in the FORTRAN 77 standard language. In addition, code written by use of features in the following languages is also accepted: VAX-11 FORTRAN; IBM S/360 FORTRAN IV Level H Extended; and Structured FORTRAN.

The SAP program uses two external files in its analysis procedure. A keyword file provides flexibility in classifying statements and in marking a statement as either executable or nonexecutable. A statistical-weight file enables the user to assign weights to all output statistics, thus allowing the user flexibility in defining the figure of complexity.

The SAP program is written in FORTRAN IV for batch execution and has been implemented on a DEC VAX-series computer under VMS, and on an IBM 370-series Computer under MVS. The SAP program was developed in 1978. The VAX and IBM versions were last updated in 1985.

This program was originally written by staff from **Goddard Space Flight Center** *with support from Computer Science Corporation. Point of contact is Linda Jun of* **Goddard Space Flight Center.** *For further information, Circle 102 on the TSP Request Card.*
GSC-13268

Computing Confidence Limits

Limits and the relationship between them and the maximum-likelihood value are plotted.

The Confidence Limits Program (CLP) calculates the upper and lower confidence limits associated with the observed outcome of N independent trials with M occurrences of the event of interest. CLP calculates the probability of the event of interest for confidence levels of 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, and 99 percent. The program provides a graphical presentation of all the limits and how they relate to the maximum-likelihood value.

CLP is written in IBM PC BASIC and has been implemented on an IBM personal computer operating under DOS 2.1 with a central-memory requirement of 67K bytes. The program was developed in 1987.

This program was written by Robert E. Biggs of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 14 on the TSP Request Card.*
MFS-29476

Mechanics

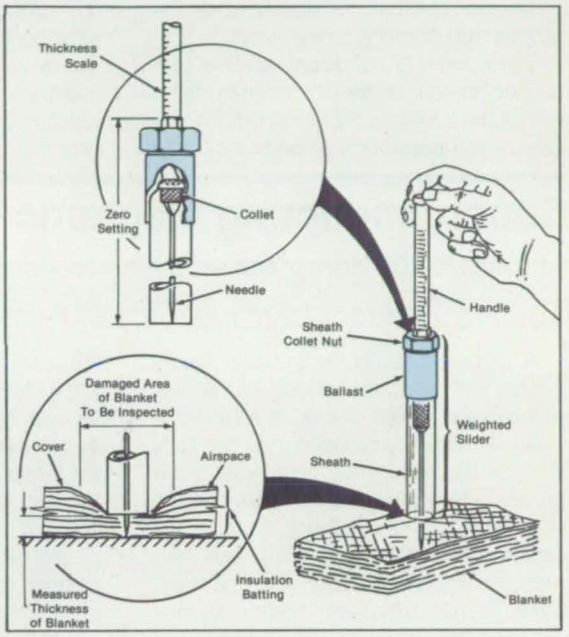
Hardware, Techniques, and Processes

Gauge Measures Thicknesses of Blankets

A simple tool is easy to use.

Lyndon B. Johnson Space Center, Houston, Texas

A tool makes highly repeatable measurements of the thickness of penetrable blanket insulation. It includes a commercial holder for replaceable knife blades, which holds a needle instead of a knife (see figure). The needle is inserted in a blanket until the point of the needle makes contact with the hard surface on which the blanket rests. The technician allows a weighted slider to move down along the holder until it makes contact with the blanket; the slider compresses the blanket slightly by applying its weight as a fixed preload. This ensures consistent measurements from place to place on a blanket and from blanket to blanket. The position of the top of the slider on an engraved scale on the handle of the tool indicates the thickness of the blanket.



The Needle Penetrates the Blanket to establish a reference plane. The ballasted slider applies a fixed preload to the blanket. The technician reads the thickness value on the scale.

The needle has a diameter of 0.041 in. (1.04 mm) and a length of 3 1/4 in. (83 mm). Its tip is ground to a three-sided pyramid with three cutting edges that easily penetrate the cover and inner layers of the multilayer insulating blanket. The weight and diameter of the slider are determined empirically by evaluation of its crushing and billowing effects and of the size of typical damaged areas of blanket to be inspected. For the particular blankets for which the tool was designed, the slider applies a preload of 23 g weight (about 0.23 N) over an area 5/8 in. (16 mm) in diameter.

This work was done by George R. Hagen and Stanley Y. Yoshino of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 51 on the TSP Request Card. MSC-21693*

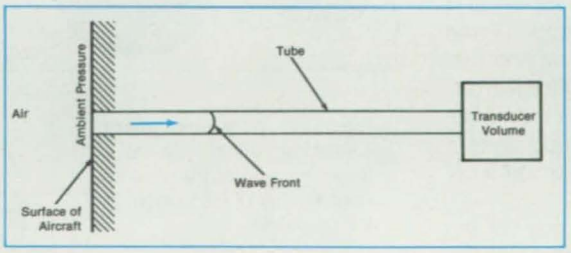
Calculation of Pneumatic Attenuation in Pressure Sensors

Errors are introduced by transmission along narrow tubes.

Ames Research Center, Moffett Field, California

Errors caused by attenuation of air-pressure waves in narrow tubes can be calculated by a method based on fundamental equations of flow. The method was developed because of the need to understand and compensate for frictional attenuation in the narrow tubes used to connect aircraft pressure sensors with pressure taps on the affected surfaces. This is an important problem because modern aircraft-control systems rely in part on accurate measurements of pressure, and frictional attenuation in the tubes is responsible for significant losses in the high-frequency components of pressure waves arriving at the sensors.

For the purposes of analysis, a round, cylindrical pressure sensor is considered to be connected to a surface pressure tap by a straight, narrow, round, cylindrical tube (see figure). The pressure P, density ρ, temperature T, and axial flow averaged across the diameter of the tube U are considered to depend only on time t and on the position along the axis of the tube x. The flow of air in the tube is represented by the Navier–Stokes equations of viscous, compressible flow. The polytropic equation of state is assumed to hold, the pressure behind a pressure wave propagating along the tube is assumed to be independent of position, the flow along the tube is assumed to be slow enough that the speed of sound can be treated as approximately constant, the changes in pressure are assumed to be small, and the tube and sensor are assumed to have lengths and diameters representative of those encountered in practice.



Changes in Ambient Pressure Are Transmitted along the narrow tube to the sensor. The attenuation of high-frequency components of the pressure wave is calculated from a wave equation derived from the Navier-Stokes equations of viscous flow in the tube.

The foregoing conditions allow the Navier-Stokes equations to be linearized, yielding

$$\frac{\partial^2 P(x,t)}{\partial t^2} + \left[\frac{R}{\rho(t)}\right]\frac{\partial P(x,t)}{\partial t} = \frac{\xi}{\gamma} c^2 \frac{\partial^2 P(x,t)}{\partial t^2}$$

where γ is the ratio of specific heats, ξ is the heat-transfer parameter ($1 \leq \xi \leq \gamma$), and c = the speed of sound. This is a classical wave equation with parameters that vary with time. Thus, the variation of pressure within the tube can be visualized as the propagation of a longitudinal wave.

The boundary conditions are the prescribed pressure at the upstream (surface) end of the tube plus those conditions that satisfy the equations of continuity and momentum at the downstream (sensor) end. The initial condition is constant pressure and zero flow at all locations.

The wave equation with the boundary conditions has been solved numerically by an implicit finite-difference technique. Comparisons of the solutions with experimental data from both laboratory and flight step-function and frequency-response tests indicate that the mathematical model can accurately predict the response of a simple measurement configuration for any sort of input. Thus, it is directly applicable to flight data.

In principle, by applying the boundary conditions in the reverse direction (letting the downstream pressure be directly measured and solving continuity and momentum at the upstream end), it should be possible to invert the mathematical model to obtain a computing routine that could correct for pneumatic attenuation. In practice, questions of numerical stability have arisen in connection with the inversion problem; this stability is still under study.

This work was done by Stephen A. Whitmore of **Ames Research Center**. *Further information may be found in NASA TM-100430 [N88-20302], "Formulation of a General Technique for Predicting Pneumatic Attenuation Errors in Airborne Pressure Sensing Devices."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12210

Superconducting Magnetic Projectile Launcher

Magnetic flux compressed by a superconducting plunger would expel a small projectile.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed projectile launcher would exploit the Meissner effect to transfer much of the kinetic energy of a relatively massive superconducting plunger to a smaller projectile, thus accelerating the projectile to high speed. Because it would operate with magnetic fields, the launcher would not be limited by gas-expansion thermodynamics. The plunger could be energized mechanically and/or chemically, thus avoiding the need for large electrical power supplies and energy-storage systems like those required by such electromagnetic launchers as rail guns or coaxial accelerators.

The speed of the projectile should exceed that achievable by direct chemical propulsion (e.g., artillery) and should be comparable to that achievable with the aforementioned electromagnetic launchers. Potential applications include the launching of projectiles for military purposes and for scientific and industrial tests of hypervelocity impacts.

The plunger and the projectile would fit into separate cylindrical clearance holes or barrels in a superconducting ring (see Figure 1). A slot would connect the two barrels. The operation of the launcher depends on the use of the trapped magnetic flux as a compressible medium to apply force to the projectile.

To trap magnetic flux in the ring, the ring must be cooled from the normal resistive state to the superconducting state while it is immersed in a magnetic field. Because magnetic flux cannot penetrate a superconductor (the Meissner effect), the flux passing through the hole in the ring when the ring became superconducting would be trapped there as long as the ring remained in the superconducting state. Typically, the initial strength of the magnetic field in the barrels would be in the range 0.01 to 0.10 tesla. In preparation for firing, the projectile would be placed in the smaller barrel at a point just beyond its equilibrium point. As the plunger entered the larger barrel from the opposite side of the ring, the magnetic flux would be compressed into the slot and the remaining clearance space around the projectile and plunger, reaching a flux density of about 5 to 10 teslas. In the process, part of the flux would pass from the larger barrel into the smaller barrel. The compressed flux would exert a large force on the projectile, expelling it from the barrel at high speed. Kinetic energy from the plunger would thus be transferred to the projectile via the magnetic field.

For greater overall acceleration of the projectile, several rings could be used in sequence, as shown in Figure 2. The positions of the small barrels must be progressively offset with respect to the large barrels to allow for the differing speeds of projectile and plunger.

For greater efficiency, a superconducting permanent magnet could be used as the plunger. The launcher could also accelerate permanent-magnet projectiles by ordinary magnetic repulsion.

This work was done by Darrell L. Jan and Daniel D. Lawson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 9 on the TSP Request Card. NPO-17746*

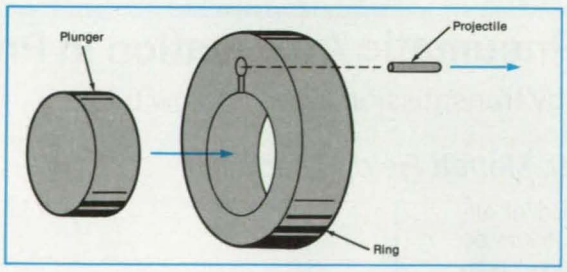


Figure 1. The **Magnetic Projectile Launcher** would use magnetic flux compressed by a superconducting plunger to accelerate a small superconducting projectile to a speed much higher than that of the plunger.

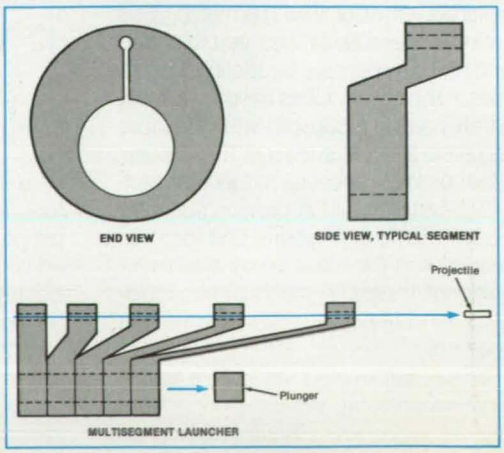


Figure 2. A **Multisegment Launcher** would transfer a larger fraction of the total kinetic energy of the plunger to the projectile

Rotary Coupling Extends Life of Hose

The coupling eliminates fatigue stress at the fixed end.

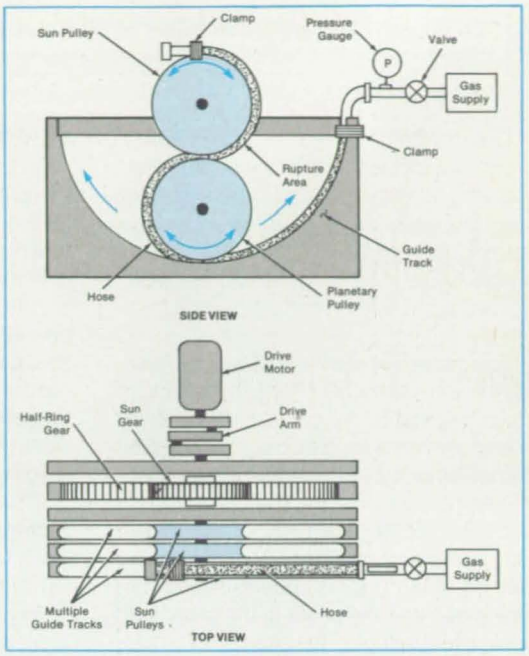
Goddard Space Flight Center, Greenbelt, Maryland

An oscillating rotary coupling enables a hose to withstand bending oscillations without leaking. The coupling is intended for use where a hose is connected to a stationary structure at one end and to an oscillating structure on the other end.

The coupling — a sun-and-planetary pulley system — eliminates torque at the fitting where the hose joins the fixed structure. This is the weakest point on the hose and the point where rupture usually occurs. The pulley coupling requires less hose than conventional helical-wrap couplings do, and its weight, pressure drop, heat loss or gain, and fluid contents are therefore also less.

The new coupling was conceived for use on the Space Station to transfer vapors across rotary joints to directional radiators for condensation or to transfer liquids to gimballed payloads for evaporation. On Earth, it could be used to carry working fluids to and from evaporative solar collectors that follow the path of the Sun. Although a single coupling can be turned through only a limited angle, it can be cascaded with another similar unit to give full 360° rotation.

An assembly that mimics the sun-and-planet pulley arrangement was used to test the endurances of hoses in the new couplings (see figure). Each test hose was wrapped around the 5-in. (12.7-cm) radius sun and planet pulleys, resting in the edge grooves of the pulleys. The mobile end of the hose was sealed, and a gas supply at the fixed end pressurized the hose. The sun pulley was rotated back and forth, repeatedly flexing the hose. If the hose ruptured, a pressure switch turned off the drive motor.



This **Machine Tests Hoses** for durability. As the sun pulley rotates, it moves the planet pulley in the guide track. The hose is flexed with each oscillation of the pulleys.

Corrugated stainless-steel hoses, each with one layer of braid and with inside diameters of 3/8 in. (9.5 mm) and 1/2 in. (13 mm), respectively, withstood between 30,000 and 40,000 flexures before rupturing. The same type of hose with a 1/4-in. (0.6-cm) inside diameter withstood twice as many cycles. Polytetrafluoroethylene hoses lasted even longer: after 400,000 cycles, convoluted polytetrafluoroethylene hoses of 1/2 in. (13 mm) inside diameter leaked only slightly, while smooth-bore polytetrafluoroethylene hoses of 3/8 in. (9.5 mm) inside diameter did not leak at all.

This work was done by Steve Benner, Frederick Costello, and Theodore Swanson of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13316

Two-Phase Bidirectional Heat Exchanger

A unit links two liquid-and-vapor loops such as heat pipes.

Goddard Space Flight Center, Greenbelt, Maryland

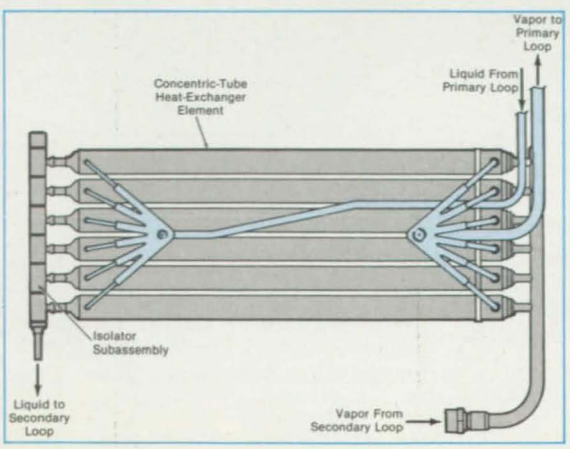
A heat exchanger transfers heat from one two-phase thermal loop to another. It condenses the vapor in one loop while evaporating the liquid in the other. It transfers heat with very small drops in temperature and pressure, and thus efficiently joins heat pipes thermally without mixing of their working fluids. Several such heat exchangers can be used to build long, complex multiloop heat-control systems.

The heat exchanger is bidirectional: it can transfer heat in reverse, condensing on the normally evaporating side, and vice versa. A heat-control loop that contains such a heat exchanger can thus warm equipment that it normally cools, when necessary, without using an auxiliary heater. In reverse transfer, wicks on the evaporating side supply liquid continuously by capillary action; a reverse-flow pump is not needed.

The heat exchanger is a tube-in-tube unit with many parallel legs (see figure). In the normal (forward) heat-transfer mode, the working fluid condenses in the inner tubes and evaporates in the outer tubes. In the reverse mode, the liquid in the inner tubes vaporizes while the vapor in the outer tubes condenses. Polyethylene wicks in the inner tube serve three purposes: they distribute flow uniformly to the heat-exchange surfaces, separate vapor from liquid during forward transfer, and act as the capillary pumps in the reverse mode.

A prototype unit uses anhydrous ammonia as the working fluid. It transfers up to 4,000 W of heat between two two-phase heat-control loops at a pressure drop of only 0.1 lb/in.^{2} (700 Pa) and a temperature drop of less than 5 °C. The design can be modified for other working fluids and larger heat-transfer rates.

This work was done by Edward Kroliczek and Jentung Ku of OAO Corp. for **Goddard Space Flight Center.** *For further information, Circle 134 on the TSP Request Card.*
GSC-13287.



This **Array of Concentric Tubes** transfers heat from condensing vapor (in outer tubes) to boiling liquid (in inner tubes). The parallel array transfers heat with less pressure drop than does a single tube of equal heat-transfer capacity.

Noncontact Measurements of Torques in Shafts

Additional information would be extracted from an eddy-current proximeter.

Marshall Space Flight Center, Alabama

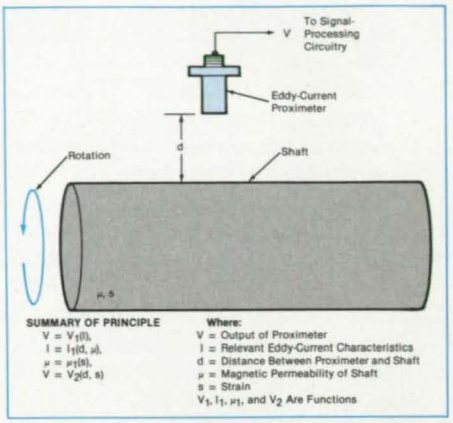
Commercially available eddy-current proximeters, already used to measure deflections of rotating shafts, might also be used to measure torques in the shafts, according to a proposal. The same instruments would thus serve a dual purpose. No contact with the shafts would be necessary.

The magnetic permeability of a metal varies with strain. Therefore, the torsional strain created by torque in a metal shaft should affect the magnetic fields and eddy currents induced by an eddy-current proximeter mounted near the shaft (see figure). The output of the proximeter should, therefore, contain information about torsion as well as about the distance between the proximeter and the shaft. In the proposed application, output of the proximeter would be fed to additional signal-processing circuitry, which would extract the torsion information. It may even be possible to extract torsion information from existing tape-recorded proximeter data.

It has already been demonstrated that the oscillation characteristics of an oscillator circuit that includes an inductor adjacent to a magnetostrictive material vary with the strain in that material. Depending on the shaft material, it may or may not be necessary to deposit a magnetostrictive material on the shaft to obtain usable readings from the proximeter. It may also be possible to extract torques from previously recorded eddy-current-proximeter readings.

This work was done by Aaron Schwartzbart of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16].Refer to MFS-29717.



An **Eddy-Current Proximeter** positioned over a rotating shaft would measure both displacement of and torsion in the shaft. The torque applied to the shaft should be calculable from the output of the proximenter.

Laminar-Separation Sensor

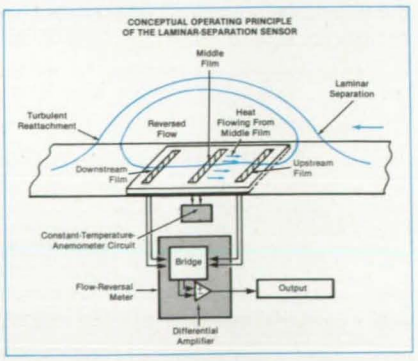
An advanced method for measuring transitions resolves reversals of flow with high spatial resolution.

Langley Research Center, Hampton, Virginia

Current research in the reduction of viscous drag on airplanes explores the limits of practical applications of natural laminar flow. To understand these limits better, advanced measurement techniques are required to study the characteristics of laminar-to-turbulent boundary-layer transitions. Wind-tunnel and flight tests have recently been conducted by the NASA Langley Research Center to explore the abilities of hot-film sensors to identify the separation of laminar flow as the principal mode of amplification of instability leading to the transition from laminar to turbulent flow. Two different laminar-separation-sensor configurations have been developed and used to detect boundary-layer transitions.

The laminar-separation sensors are based on the fact that the airflow recirculates, with reversal, in the laminar bubble. One sensor of this type consists of a flush array of three parallel films oriented perpendicularly to the freestream airflow ($\mathbf{U}_\infty$) as shown in the figure. The middle film is electronically heated by a constant-temperature anemometer (CTA) circuit, so that it acts as a typical hot-film transition sensor. The upstream and downstream films are incorporated into two legs of a differential bridge amplifier circuit for use as resistance thermometers.

During a test, when the laminar-separation sensor is exposed to the flow of air, heat is transferred from the middle film to either the upstream or downstream film, depending on the direction of the flow over the middle sensor surface. The difference between the temperatures of the upstream and downstream films results in changes in the electrical resistances of the films, which changes are measured by the bridge and a high-gain differential amplifier. The direction of the flow is then determined by the polarity of the output of the amplifier, which is monitored by use of a flow-reversal meter (FRM).



Reversed Flow in a Laminar-Separation Bubble is indicated by the polarity of the output of the amplifier.

A prototype 3-element laminar-separation sensor was developed, followed by the development of a sensor array of 48 elements operated such that any 3 elements could be switched into the CTA/FRM circuitry for detection of separation of laminar flow. The results of flight and wind-tunnel tests have shown the hot-film laminar-separation-sensor technique to be a viable means for detecting the existence of transition as well as for indicating reversed flow in a laminar-separation bubble.

This hot-film method has overcome the limitations of other intrusive techniques that disturb the boundary layer near the point of interest. The advanced array provides the ability to acquire detailed information about the physics of laminar-separation bubbles. Refinement of the sensor configurations will continue to provide the tools necessary to explore, in all speed regimes, the practical limits of laminar-flow applications and viscous-drag-reduction technology.

This work was done by G. S. Manuel, D. L. Carraway, and C. C. Lee of **Langley Research Center**. *For further information, Circle 109 on the TSP Request Card.*
LAR-14314

Machinery

Hardware, Techniques, and Processes

Computer Programs

Nonazeotropic Heat Pump

Waste heat from the motor is also recovered.

Marshall Space Flight Center, Alabama

A heat pump collects heat from water that circulates in a heat-rejection loop, raises the temperature of the collected heat, and transfers the collected heat to water in a separate pipe. The pump is intended to recover relatively-low-temperature waste heat and use it to make hot water for washing, for example.

The heat pump includes a motor/compressor that forces a working fluid through a condenser and an evaporator, both of which are tube-in-tube heat exchangers wrapped in coils (see Figure 1). The heat-rejection loop is connected to the evaporator, while the water to be heated flows along one of the tubes in the condenser. The design is based on a standard vapor-compression cycle, except that the fluid is a nonazeotropic mixture, which can produce a substantial gradient of temperature in the evaporator and condenser (see Figure 2). Such a mixture (for example, 70 percent CCl_3F and 30 percent $CHClF_2$) can increase the coefficient of performance (a measure of the heat-transfer efficiency of the cycle).

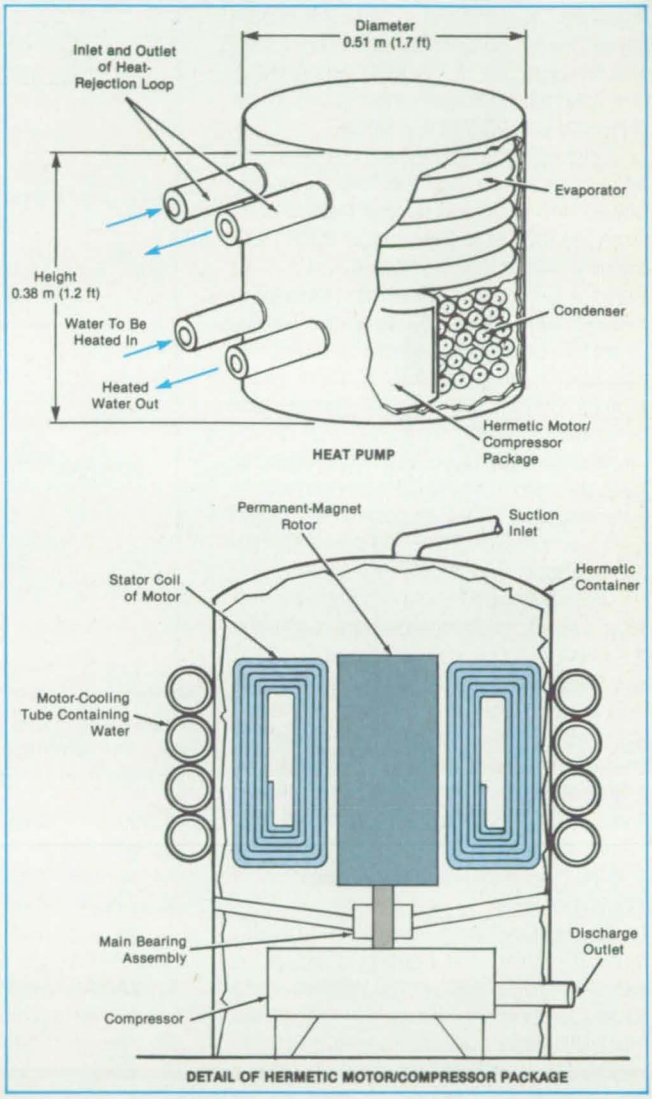
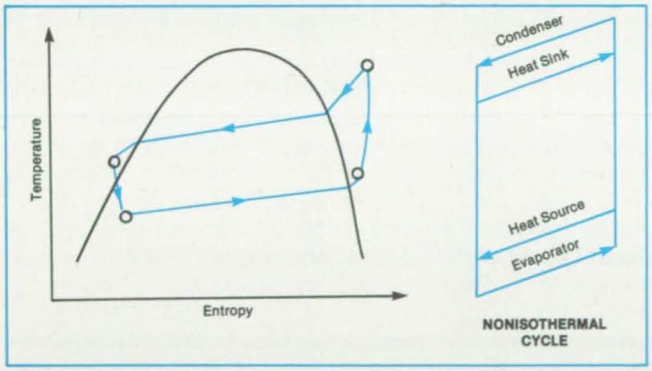


Figure 1. The **Heat Pump** includes a sealed motor/compressor with cooling coils, an evaporator, and a condenser, all mounted in an outer housing.

Figure 2. The **Gradients of Temperature** in the evaporator and a condenser increase the heat-transfer efficiency of the vapor-compression cycle.



The compressor is driven by a permanent-magnet brushless dc motor. The compressor and motor are mounted in a hermetic container. Part of the path of the water to be heated lies along a tube wrapped around this container to remove waste heat from the motor. Thus, the waste heat from the motor is added directly to the output stream of water, increasing the overall efficiency and the amount of heat recovered.

The hermetic motor/compressor container is mounted in an outer housing with the evaporator and condenser coils. The only external connections are the inlets and outlets for water and electric power.

This work was done by David H. Ealker and Glenn Deming of Foster-Miller, Inc., for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-26099

Regenerative Sorption Refrigerator

The combination of two types of sorption compressor increases efficiency.

NASA's Jet Propulsion Laboratory, Pasadena, California

A two-stage sorption refrigerator achieves increased efficiency via a regenerative-heating concept in which waste heat from a praseodymium/cerium oxide (PCO) chemisorption compressor runs a charcoal/krypton (C/Kr) sorption compressor. The new refrigerator has no wearing moving parts other than extremely long life,

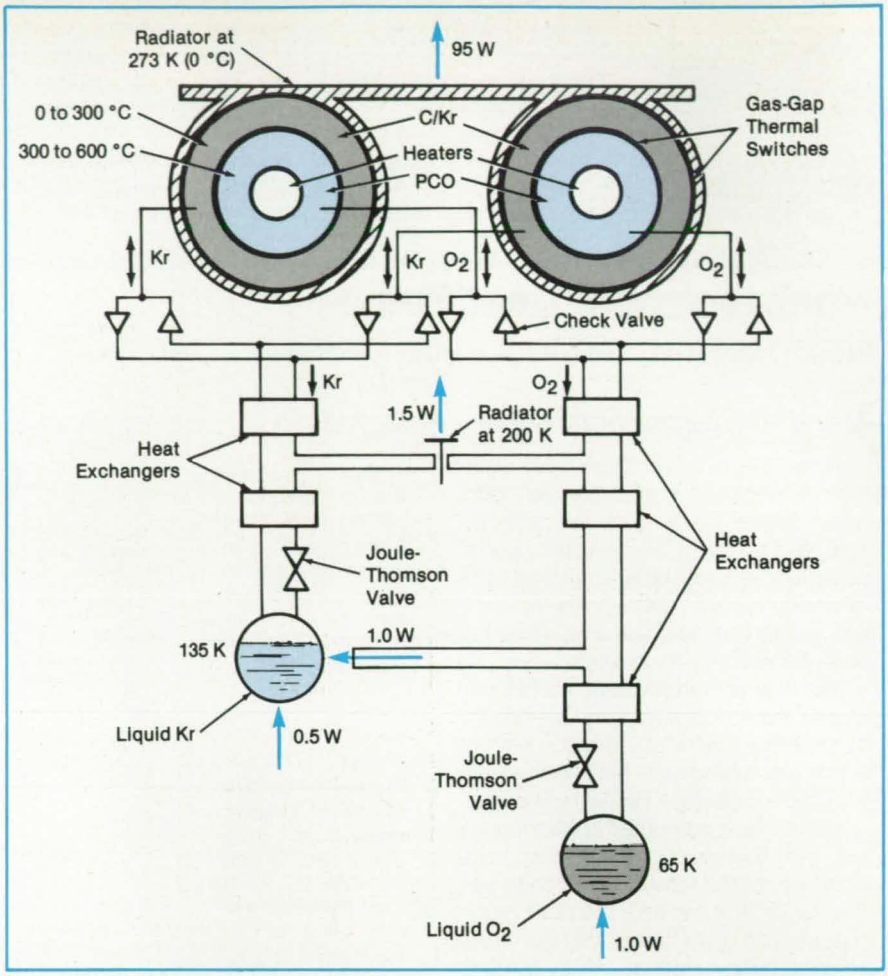
room-temperature check valves that operate about twice per hour. Thus, there is virtually no measurable vibration, and the refrigerator has a potential operating life of at least ten years.

The refrigerator (see figure) includes two compressor modules, which operate at opposite phases of their heating-and-cooling cycles and are coupled through check valves to provide continuous cooling. At the beginning of a cycle, the heater in, say, the left compressor assembly raises the temperature of the PCO compressor from 300 to 600 °C, causing it to vent O_2 at a pressure of 22 atm (2.2 MPa).

A gas-gap thermal switch between the PCO compressor and the C/Kr compressor is then activated so that heat passes from the former to the latter, and the PCO compressor is cooled from about 600 to about 300 °C while the C/Kr compressor is heated from about 0 °C to about 300 °C. The PCO compressor then chemically reabsorbs O_2 at a pressure of about 0.023 atm (2.3 kPa), while the C/Kr compressor liberates krypton at 40 atm (4 MPa). Another gas-gap switch is then activated to pass the heat from the C/Kr compressor to a radiator at 0 °C. When cooled to 0 °C, the C/Kr compressor physically adsorbs krypton at about 3 atm (0.3 MPa).

The high-pressure krypton gas (whether from the left or right compressor module) is liquefied at 200 K and expanded to 135 K, providing 1 W of precooling as a refrigeration upper stage for expansion of the oxygen gas, plus an extra 0.5 W of cooling that can be used for other purposes. The high-pressure oxygen (from the module that is not supplying krypton at the moment) is cooled to 200 K, preliquefied at 135 K, then expanded to provide 1 W of cooling at 65 K.

A typical two-stage sorption refrigerator without regenerative heating could be expected to require about 160 W of power to produce cooling equivalent to that of the new refrigerator, which requires only 95 W of power. The performance of the new refrigerator thus approaches that of a mechanical refrigerator, which requires about 60 W to produce equivalent cooling.



Waste Heat From Each PCO Sorption Compressor is used to power its surrounding C/Kr sorption compressor. The flows of heat in the two compressor modules are controlled by gas-gap thermal switches.

This work was done by Jack A. Jones, Liang-Chi Wen, and Steven Bard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 15 on the TSP Request Card.*

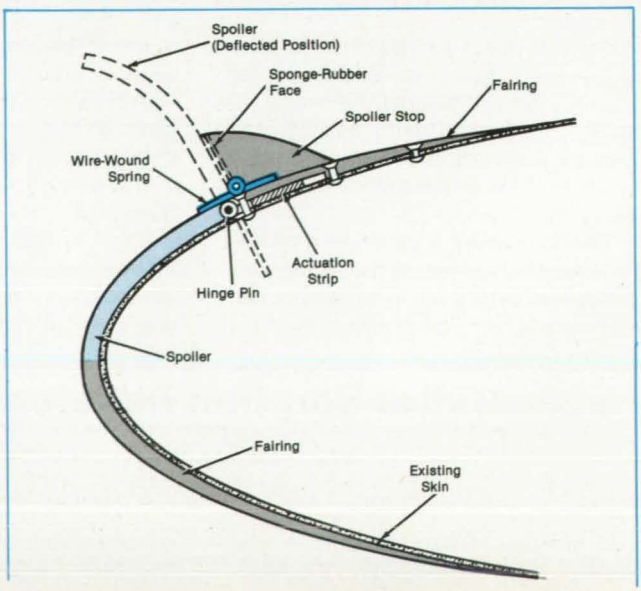
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 16]. Refer to NPO-17630

Leading-Edge "Pop-Up" Spoiler for Airfoil

This device can be retrofitted to an existing airfoil without major rework.

Langley Research Center, Hampton, Virginia

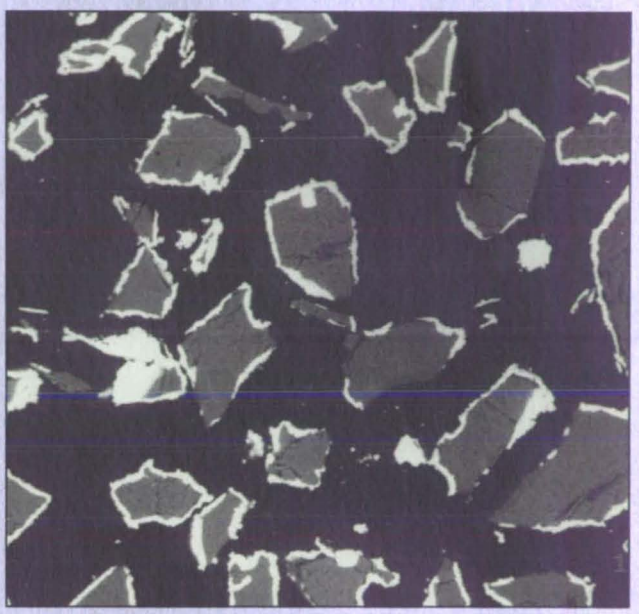
Spoilers are devices designed to spoil the airflows around lifting airfoils. A traditional spoiler, which is built into a wing structure, is located well aft of the leading edge and deflects with its trailing edge in the airflow and its leading edge attached to the wing surface. The airflow works against the deployment of such a spoiler. A new concept places the spoiler in the leading edge of the airfoil, hinged along its trailing edge, so that the airflow helps to deploy it and force it against a mechanical stop.



Airflow Helps To Deploy the Spoiler, which is located in the leading edge of the airfoil.

CHOOSE INCO COATED PRODUCTS FOR HIGH PURITY AND PREDICTABLE PROPERTIES.

Nickel Coated Graphite Powders



Nickel Coated Alumina

INCO Specialty Powder Products' development of the use of carbonyl gas coating allows deposition of nickel with very high purity and predictable properties and is uniquely suited for a variety of coated products and applications.

INCO SPP COATED PRODUCTS

Nickel combines a unique mixture of special physical, conducting and magnetic properties. The ability to deposit nickel on various substrates greatly extends the potential for the use of these properties. Coatings are being made, for example, on silica, graphite, alumina, tungsten carbide, clays and ceramics. INCO SPP has the capability to coat special substrates on a custom basis for individual users.

APPLICATIONS

New uses for INCO SPP Coated Products include conducting film technology, electronics packaging, EMI shielding, electronic detection devices, controlled heating systems, hard metals and powder metallurgy parts.

RESEARCH

INCO SPP research activities for this line of products include nickel carbonyl coated powders and other substrates. Applications include advanced products for EMI shielding, ESD, arc welding, powder metallurgy additives, and in battery technologies.

One highly interesting area of research is in the area of electronic detection. Coated products are being combined with paint for highway divider strips and as ink in bar codes for vehicle identification. This could provide an accurate measure of automobile speed on those highways. Another futuristic consideration is "computer trips for cars" using those strips and bar codes to program automotive travel and identification.

INCO SPP

INCO Specialty Powder Products is your unique resource for coated products. Our customer focused worldwide marketing service group is ready to help you with your current and future needs for coated products.

For more information write INCO Specialty Powder Products, Dept. 2-90, Park 80 West-Plaza Two, Saddle Brook, NJ 07662

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Shin-Muromachi Building, 4-3 Nihonbashi-Muromachi 2-Chome, Chuo-ku, Tokyo 103 Japan
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Circle Reader Action No. 452

The stabilator, or variable-incidence horizontal tail component of a helicopter, can inadvertently sustain a lift force beyond the pilot's capability to counteract when the helicopter is operated in forward flight. In this situation, the lift must be quickly eliminated. The actuation of the "pop-up" spoiler at or very near the upper leading edge (less than 6 percent chord) of the stabilator enables the pilot to regain control of the helicopter. The deployed "pop-up" spoiler very quickly eliminates almost all the aerodynamic lift of the stabilator. This spoiler is designed to be added to the leading edge of the existing stabilator, without major rework.

As shown in the figure, the spoiler locked in the retracted position fairs into the airfoil with minimum alteration of the contour. Wire-wound springs at several locations across the span of the stabilator effect only modest local disruption of the airflow over the surface. In an emergency, when the lift generated by the stabilator exceeds a limit, the pilot would move the actuation strip (via a control cable for example) so that the spoiler "pops up" by rotating about its hinge assembly. The wire-wound spring provides the force to initiate the deployment of the spoiler, but the pressure of the airflow completes the deployment, and the spoiler comes to rest against a mechanical stop.

Though the initial application of this device is considered to be on helicopter stabilators, it is equally applicable to wings or winglike components, inasmuch as the stabilator is essentially a variable-incidence wing. The placement of the spoiler so close to the leading edge results in almost complete negation of aerodynamic lift force upon deployment. The "pop-up" spoiler retains its effectiveness up to angles of attack of approximately 30°, whereas traditional spoilers are effective to less than 15°

This work was done by John C. Wilson of USAARTA-AVSCOM, **Langley Research Center** *and Michael B. Lance of PRC Kentron, Inc. For further information, Circle 5 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13781

Quick-Actuating Closure and Handling System

A device facilitates entry into containers and high-pressure vessels.

Langley Research Center, Hampton, Virginia

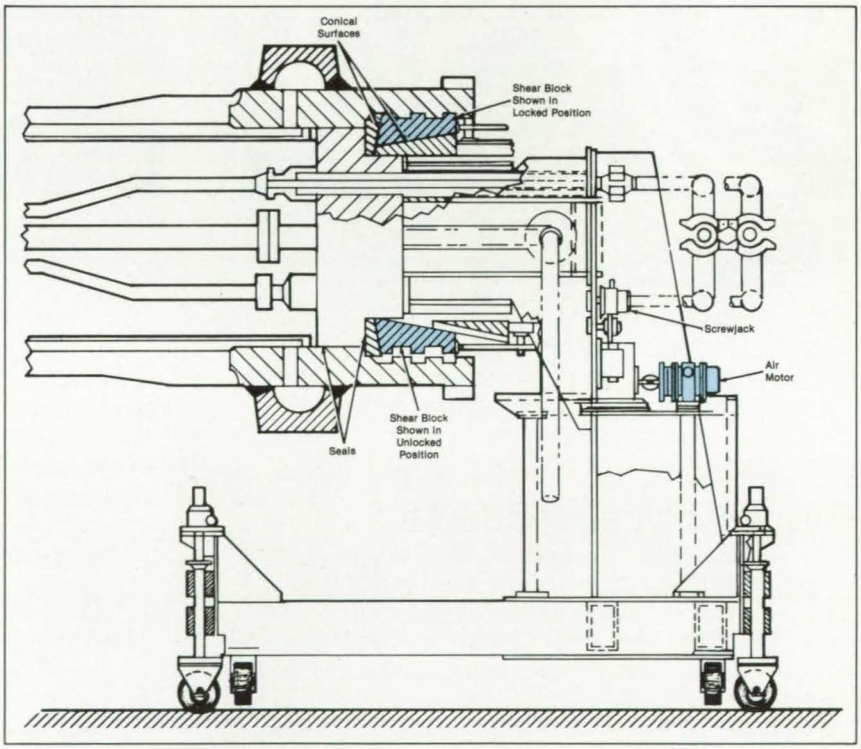
A quick-actuating closure and handling system has been developed for containers, particularly for high-pressure vessels or shells that must be entered frequently. Prior methods for entry into high-pressure vessels have been very time-consuming, involving considerable use of equipment, such as overhead cranes, and labor. The new system greatly facilitates access to the insides of such vessels.

All components, as shown in the figure, stay in contact with the handling system, which is operated by readily available low-pressure air. The air motor operates several screwjacks and conical surfaces to force the shear blocks into position. Seals are also provided to prevent leakage from the internal gas or liquids. The engagement of the shear blocks and sealing of the fluid can be accomplished in minutes without the use of large bolts.

A significant feature is the use of the conical surfaces to engage effectively the shear blocks in the locked position to provide the necessary preload and to transmit the internal-pressure load directly to the pressure vessel. The conical surfaces are designed to impart the proper radial movement to the shear blocks, based on the space available for longitudinal travel of the screwjacks.

The entire assembly shown in the figure (shear blocks, seal ring, end closure plug, wedge ring, jacks, air motor, and cart) is rolled out of the way to gain access to the inside of the container or vessel. The assembly can be moved aside if long inspections or modifications are to be made to the container or vessel.

The quick-actuating closure and handling system concept is adaptable to many applications. For example, it can be used for such containers as autoclaves, vacuum chambers, and a wide variety of specialized vessels requiring frequent entry and closure.



The **Quick-Actuating Closure and Handling System** features simplicity in design and operation, saving of time, monitoring of leakage, and safety.

This work was done by Dorsey E. White, Benjamin T. Updike, and Johnny W. Allred of **Langley Research Center**. *For further information, Circle 4 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,823,976). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16].Refer to LAR-13774

Computer Simulation of a Small Turboshaft Engine

A mathematical model represents performance accurately, in real time.

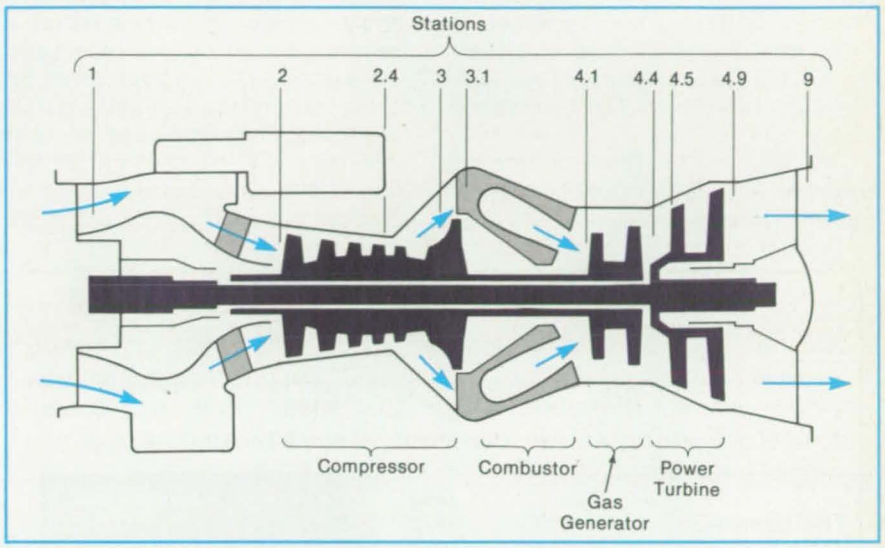
Ames Research Center, Moffett Field, California

A component-type mathematical model of a small turboshaft engine has been developed for use in real-time computer simulations of the dynamics of helicopter flight. The model yields shaft speeds, torques, fuel-consumption rates, and other operating parameters with sufficient accuracy for use in the real-time simulation of maneuvers that involve large transients in power and/or severe accelerations.

The model represents the engine (including its control system) used in the UH-60A Black Hawk helicopter. This is a free-turbine (two-shaft) engine that includes a compressor (on the outer shaft), a combustor, a gas-generator turbine (also on the outer shaft), and a power turbine (on the inner shaft). These four major components are separated by fluid-mixing volumes, each of which is associated with flow passages wherein the thermodynamic states are quantifiable.

The figure illustrates the major components and locations, or stations, where thermodynamic states of the gas must be modeled. The six compressor stages and variable-geometry flow vanes are represented with the compressor component, between stations 2 and 3. Bleed flow, which is used to pressurize seals and balance the power turbine, is extracted from the fourth stage of the compressor, which is represented by station 2.4. Station 3 is the diffuser, or outlet of the compressor. Flow is bled at this point to cool the combustor and gas-generator turbine. Station 3.1 is the combustor, and station 4.1 is the mixing volume representing the combustor outlet and gas-generator-turbine inlet. The two stages of the gas-generator turbine are modeled by the generator-turbine component. Station 4.4 represents the thermodynamic state of output gases passing through this turbine, not including the effects of the cooling bleed flow. These effects are added at station 4.5, which represents the inlet of the power turbine. The two-stage power turbine is represented by the power-turbine component. Station 4.9 is the outlet of the power turbine, and station 9 is the exhaust.

The state of the gas in each control volume is expressed in terms of pressure, temperature, and flow of mass. The states are determined as functions of transfer of energy across each component. Equations describe each component in terms of the state of the component, thermodynamic states upstream and downstream of the component, energy applied to or taken from the component, and efficiencies of transfer of energy. Conservation of mass is used to determine the mass flows into and out of each control volume. Dynamics of the rotating components are modeled by relating changes of angular rotation on a



The **Mathematical Model of the Turboshaft Engine** represents the behavior of the four major components labeled at the bottom and the thermodynamic conditions in the gases in the control volumes at stations designated by numbers at the top.

given component to its moment of inertia and the applied torque. A load from an external source is required to determine the speed of the power turbine and output shaft. Losses associated with fluid-dynamic or mechanical processes are represented by single-variable or multivariable functions based on previously derived or empirical data. Inputs consist of ambient temperature and pressure at the inlet, pressure at the exhaust, fuel flow, and load torque.

The accurate simulation of transient response requires the modeling of nonadiabatic processes in regions where large gradients of temperature give rise to transfers of heat between the hot gases and the metal components, especially downstream of the combustor. This heat-sink effect is modeled by lumped-parameter heat-transfer equations.

To model the high-frequency dynamics of the helicopter in real time without excessive computation, it is necessary to make some simplifying assumptions. One of the most important is that the pressure and flow of mass within each mixing volume remains at equilibrium at all times; that is, the dynamics associated with changes in the state of the gas in each such volume are characterized by frequencies far above those of interest in the simulation.

The validity of the model has been demonstrated by comparison with data supplied by the manufacturer of the engine and by data from independent tests, including flight tests. The model was found to simulate performance adequately over the complete range of operating conditions. The modeling of the fast dynamics that represents the changes of flow between control volumes was found to be unnecessary. However, it was found necessary to add elements to the model that represent the transfer of heat, the losses between the outlet of the power turbine and the exhaust, damping of the speed of the power turbine, and the dynamics and nonlinearities of sensors and actuators.

This work was done by Mark G. Ballin of **Ames Research Center**. *Further information may be found in NASA TM-100991 [N88-26378], "A High Fidelity Real-Time Simulation of a Small Turboshaft Engine."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12299

Fabrication Technology

Hardware, Techniques, and Processes

Laser Welding of Contoured Thin-Wall Housings

Superalloy parts are joined with less distortion.

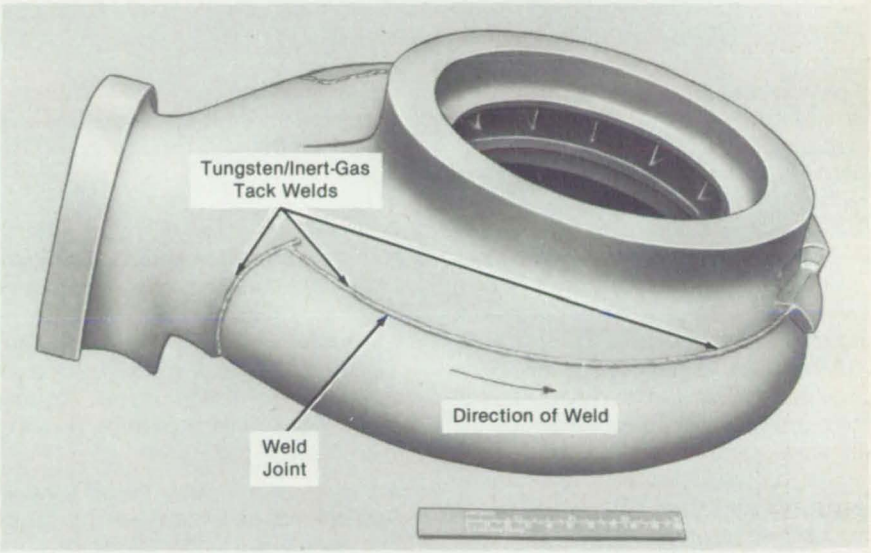
Marshall Space Flight Center, Alabama

A carbon dioxide laser beam directed by optics in a numerically controlled robot arm welds shell-type turbopump housings that have complicated shapes. The 5-kW laser, following a single programmed three-dimensional pass, produces a high-quality, full-penetration weld pass in an age-hardenable nickel superalloy.

Laser welding succeeds in this task where other welding techniques fail. Electron-beam welding, for example, cannot be used because it requires a backup bar inside the housing, and the bar cannot be retrieved when the weld is complete. Gas/tungsten-arc welding and plasma welding cannot be used because the large amount of heat they introduce distorts the housing to an unacceptable degree.

The two components of a shell are first tacked together by a few tungsten/inert-gas spot welds. The laser then butt-welds the ¼-in. (6.4-mm)-thick components (see figure).

An operator can easily program the robot by using a teaching pendant to track the weld joint and keep the laser focused on the workpiece while following the contour of the shell. Shells can be welded in rapid succession, with minimal change in the setup for each.



The **Laser Weld Follows the Complex Contour** on a turbopump shell.

This work was done by Lyle B. Spiegel and Carl E. Oleksiak of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 11 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-29653.

Multipiece Mandrel for Spray-Forming Complex Parts

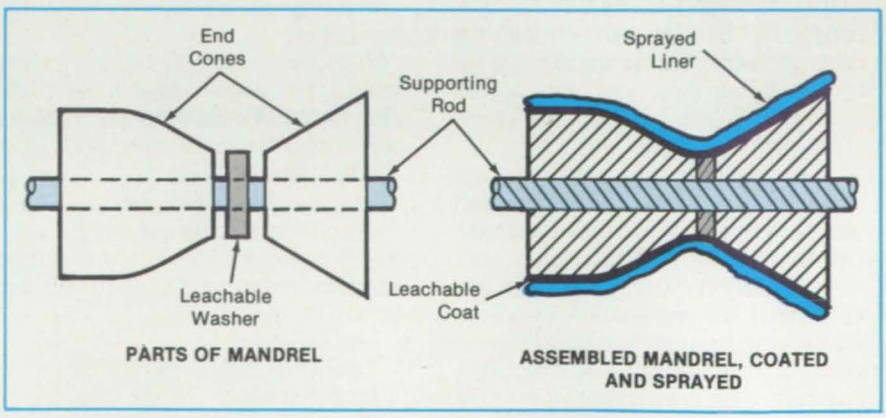
The segmented mandrel is removable and reusable.

Marshall Space Flight Center, Alabama

With the help of a multipiece mandrel, parts of complicated shapes can be fabricated by spray forming. The spray-forming process is faster and less costly than machining is. After the part has been fabricated, the mandrel can be easily removed and reused.

The part for which the multipiece mandrel was developed is a combustion-chamber liner that has an hourglass shape. The mandrel, which defines the inner surface of the liner, consists of two end cones and a middle washer (see figure). The washer material is soluble in an acid etchant; the end-cone material is resistant to the acid.

The mandrel is assembled on a central supporting rod and is coated with a thin layer



The **Mandrel** consists of etch-resistant end cones and an etchable washer between them. An etchable layer applied over the mandrel and under the spray-formed part helps to ensure easy removal of the mandrel.

of filler material — the same etchable material as that of the washer. The liner is then formed by spraying the liner material (in this case, copper-base alloy NARloy-Z) onto the mandrel.

The supporting rod is removed, and the liner-and-mandrel unit is immersed in the acid etchant. After several hours, the filler layer and the washer are dissolved. When this happens, the end cones of the mandrel simply fall out, leaving the finished liner.

The end cones are cleaned in acetone and are ready for reuse. Only the inexpensive washer and filler layer have to be replaced. The shape, size, and number of segments in the mandrel can readily be adapted to the spray forming of other complicated parts. In any case, the process eliminates the need for difficult internal and external machining.

This work was done by Timothy N. Mc Kechnie, George P. Beason, Jr., and Richard R. Holmes of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 106 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-29680.

Bar-Code-Scribing Tool

A hand-held tool would mark indelible bar codes.

Marshall Space Flight Center, Alabama

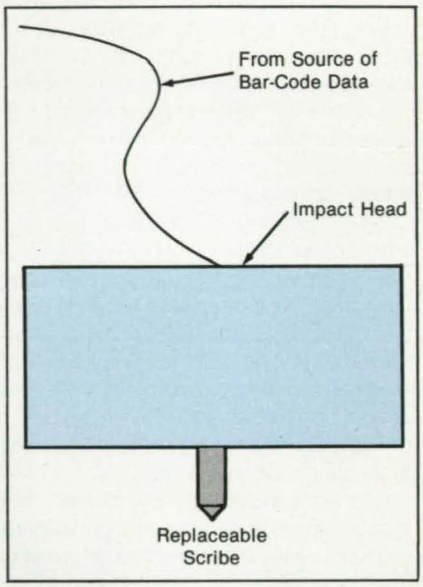
A proposed hand-held tool would apply an indelible bar code to small parts. The indelible marks would make it possible to identify parts for the management of inventory without tags or labels, which can easily be lost or damaged beyond legibility.

The tool would include a hard metal scribe with a tungsten carbide point on a small mechanism that would resemble a dot-matrix-printer head (see figure). A microprocessor would send commands to the mechanism to move it in the appropriate bar-code pattern. The scribe would thus cut the bar code into the part.

The tool would be used to mark serially controlled parts for military and aerospace equipment. It could also be adapted for discrete marking of such bulk items as those used in food and pharmaceutical processing. Although large bar-code marking machines have been available, the proposed unit would be the first hand-held tool of this type.

This work was done by Michael A. Badinger and George J. Drouant of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-28441.



A **Microprocessor Would Supply Bar-Code Data** to an impact-printer-like device. The device would drive a replaceable scribe, which would cut the bar code on the surface of a part.

Formation of Ohmic Gold Contacts on Epitaxial GaAs

Keeping the wafer in vacuum until metallization prevents the formation of rectifying contacts.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new low-temperature procedure can be used to deposit ohmic gold contacts on gallium arsenide epitaxial films, forming ohmic electrical contacts. Previously, annealing at a temperature of at least 350 °C was necessary to initiate diffusion of gold into gallium arsenide film to form ohmic (as opposed to Schottky-barrier rectifying) contacts. Such a high temperature can alter or damage other structures already formed in multilevel gallium arsenide semiconductor devices.

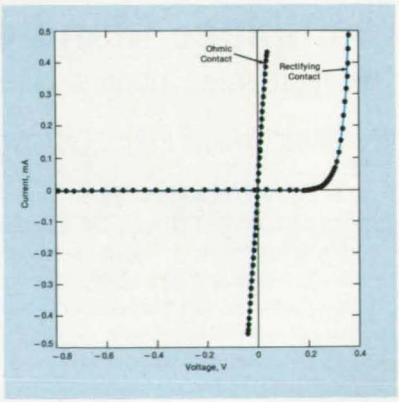
In an experiment to demonstrate the new procedure, the gallium arsenide film was deposited on a wafer by molecular-beam epitaxy; the resulting film has a lower defect density than that of material grown from a melt. After deposition of the gallium arsenide film, the wafer was transferred — while still under vacuum — to a metallization chamber, where a gold dot 10 nm thick was deposited on it from a gold filament.

The contact thus formed was ohmic — its current was linearly proportional to the voltage and symmetrical about zero voltage (see figure). If the wafer had undergone conventional processing before metallization, however, its current-versus-voltage characteristic would have been typical of a diode. Apparently, conventional processing results in a barrier to the diffusion of gold.

This work was done by Michael H. Hecht, L. Doug Bell, and William J. Kaiser of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 81 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125



The **Current- vs- Voltage Characteristic** of on ohmic gold contact on gallium arsenide is a straight line passing through zero. However, if the gallium arsenide is processed by conventional methods prior to the deposition of the gold, the characteristic is that of a diode.

Refer to NPO-17795, volume and number of this NASA Tech Briefs *issue, and the page number.*

Alignment Tool for Inertia Welding

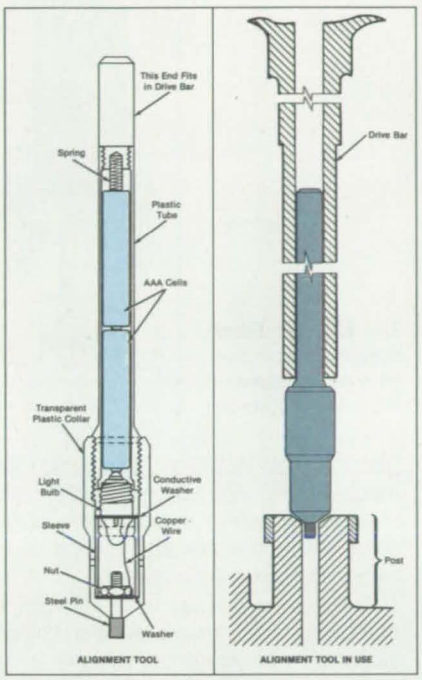
A drive bar is aligned faster and more accurately.

Marshall Space Flight Center, Alabama

A compact, easy-to-use tool aligns the drive bar of an inertia welder over a hole in a stub. The tool ensures that the drive bar is concentric to the hole within 0.002 in. (0.051 mm). The tool was built for use in making repair welds on the liquid-oxygen-injector posts in the Space Shuttle main engine. A version that has suitably modified dimensions could be used to facilitate alignment in other forests of posts. Previously, a welder had to align a sliding steel pin in the drive bar with the hole and ensure that the tip of the pin was seated in the hole. This was a difficult procedure because a post was surrounded by other posts in the dark recesses of a nearly completed injector.

The new tool includes a battery-powered lamp that lights when the drive bar is not centered. When the lamp turns off, the welder knows, even without seeing the end of the drive bar and the hole, that the drive bar is aligned. The welder can then proceed with the inertia-welding operation.

Like its predecessor, the new tool slides in the hollow core of the drive bar. A metal probe at the end of tool maintains electrical continuity when it rests on the side of the hole in the post, thus keeping the light on (see figure). When the tool and drive bar are centered in the post, the pin does not touch the post, and so electrical contact is broken. The alignment tool does not interfere with adjacent posts.



This work was done by Gary L. Snyder of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 108 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-29667.

The **Simple Alignment Tool** holds two batteries and a light bulb. The electrical circuit is completed, providing current to the bulb when the pin is in contact with the post. When the pin is centered in the post hole, it does not touch the post, and so the lamp is turned off.

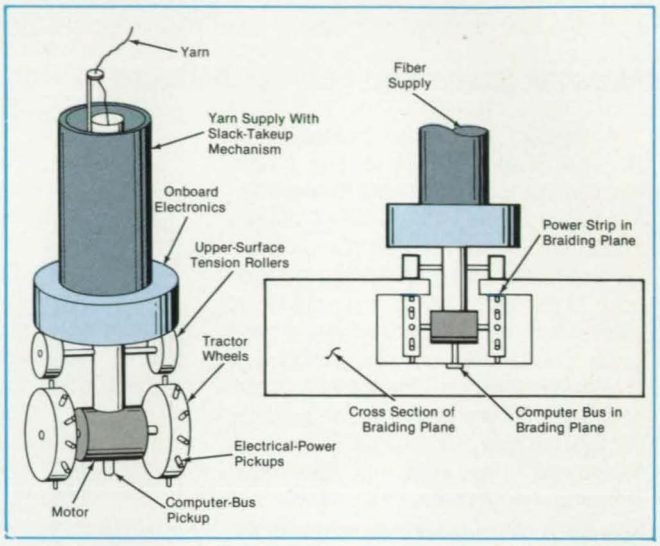
Farley Three-Dimensional-Braiding Machine

Fiber-reinforced preforms of complicated shapes can be made.

Langley Research Center, Hampton, Virginia

A process and a device known as the Farley three-dimensional-braiding machine have been conceived to fabricate dry continuous fiber-reinforced preforms of complex three-dimensional shapes for subsequent processing into composite structures. There are numerous textile processes for fabricating dry continuous fiber-reinforced preforms. Some of these techniques are restricted to planar material forms while others can make limited structural shapes. The textile processes can generally be categorized as forms of weaving, knitting, or braiding. All such current processes have significant limitations with regard to fabrication of fiber-reinforced preforms of suitable mechanical properties. The new process is a hybrid, one that combines many of the attributes of the weaving and braiding processes with other attributes and capabilities.

With the Farley three-dimensional-braiding machine, the fiber supplies are moved across the fiber-supply surface to produce a braiding motion. However, the shape and movement of the backplane and the freedom of movement of the fiber supplies provides for the development of unique fiber patterns. Also included in this design is a mechanism to insert fill yarns into any element of the preform independently of any other element. A pneumatic comb is included to compact the preform.



The **Robotic Fiber Supply** dispenses yarn as it traverses the braiding surface.

The fiber-supply surface consists of multiple surfaces, some moving and others stationary. The innermost surface is the braiding surface. The fiber supplies located on the braiding surface are used to perform the braiding motion. The braiding surface consists of segments that are moved in the braiding process.

Fiber supplies move along and between the segments in a prescribed pattern. Periodically, the segments are moved relative to one another to allow the insertion of fill yarns. The fiber-supply path on the braiding surface can be oriented in either a Cartesian or a polar grid. The fiber supplies on the Cartesian and polar braiding surfaces can move in circumferential and radial directions, respectively. Fill-yarn dispensers have been designed for both Cartesian and polar braiding procedures.

The fiber supply (see figure) is a self-propelled robotic device that dispenses yarn as it traverses the braiding surface. The fiber supply includes a motor for propulsion, power- and information-bus pickups, wheels or tractors to move along the track, and a yarn bobbin. The computer that controls the braiding process commands the fiber supply, via the bus, to move to a new position. The appropriate fiber supply recognizes the command and moves to the new position. Each segment of the braiding surface includes a device for combing the braiding yarns. The combing device telescopes out of the braiding segment and pushes the braided yarns against the braided preform.

The Farley three-dimensional braiding machine can be employed to produce fiber preforms for applications other than composite materials and structures. Other applications include decorative cloths, rugs, and other domestic textiles. This concept could lead to a large variety of fiber layups and to entirely new products as well as new fiber-reinforcing applications.

This work was done by Gary L. Farley of **Langley Research Center**. *For further information, Circle 40 on the TSP Request Card. LAR-13911*

Mathematics and Information Sciences

Planning the Route of a Robotic Land Vehicle

The distance traveled is minimized to the extent possible consistent with avoidance of obstacles.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm enables an experimental robotic land vehicle to follow automatically a route that is computed on the basis of terrain-height-map data (see figure). A computer executing the algorithm merges coarser global topographical data with finer local topographical data that it obtains through a stereoscopic video system as the vehicle moves along, then smoothes the merged elevation map, interpolates the map to evenly-horizontally-spaced grid points, and differentiates the map to produce data on slopes and roughness for use in calculations of traversability and the optimum route(s).

In processing the merged terrain-height data, the algorithm takes a probabilistic approach in which the statistical weight of each datum increases with the accuracy with which it is known and its nearness to the interpolated output point. Then the interpolation, smoothing, and calculation of slopes involve a weighted-least-squares fit of planes to small areas around the output points, using the residuals of the fit to estimate roughnesses.

The next task is to compute a cost function that takes account of both the distance traveled and the probability that each region to be crossed is traversable. In general, this function could take into account such factors as the energy expended in going uphill, the need to move more slowly over rough ground, and the effects of going in different directions. It could even include a negative cost to account for the desirability of gaining a closer look at a terrain feature of interest. However, in the experimental version, the cost function is computed from only two components: the distance traveled and the probability that the slope or roughness may be too large to allow the vehicle to pass safely.

If the video system, inclinometers, or mechanical feelers detect an excessive slope or other previously unidentified obstacle after the vehicle travels part of a tentatively planned route, the vehicle can backtrack. Therefore, the cost function accounts for the probability and cost of backtracking.

The main route-planning computation is iterative. It involves the use of one array of data that represent a forward growth from the starting position and another array of data that represent backward growth from the goal position, to integrate the cost of going from the starting point to each point in the grid and the cost of going from each point in the grid to the goal point. At each iteration, each point in the forward or backward array is replaced by the minimum of its previous value and the eight values obtained by adding, to the previous values of its eight nearest neighbors, the cost of moving from each such neighbor to the point (in the forward array) or from the point to each such neighbor (in the backward array).

At the end of the iterations, each point in the forward array contains the total cost of moving from the starting point to this point by the cheapest route, and each point in the backward array contains the cost of moving from this point to the goal by the cheapest route. The sum of the two arrays is an array in which each point contains the total cost of moving from the start to the goal through this point. The optimum path is the one along which the values at the points in the same array have the minimum value. This value equals the value in the forward array at the goal point and the value in the backward array at the starting point.

This work was done by Donald B. Gennery of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 139 on the TSP Request Card.*
NPO-17857

An **Experimental Robotic Vehicle** (a developmental model of the proposed Mars rover) avoids obstacles as it plans and follows the shortest route to a goal position.

Parallel Inferencing for Rule-Based Expert Systems

Hidden parallelism is detected and exploited to speed execution.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved approach to the development of expert-system computer programs is expected to increase the speed of execution on parallel processors; that is, on multiple coordinated computers operating simultaneously, each on a different part of a problem. Heretofore, expert-system programs for parallel processors have contained production systems (software systems based on "if...then..." rules) that have not exploited the full potential for speedup over a single sequential processor because they have been written in serial languages and designed to exploit only obvious sources of parallelism. The new approach is based on the detection and analysis of hidden parallelism in knowledge bases (collections of "if...then..." rules) and the exploitation of this parallelism to maximize the speed of execution on parallel processors connected to each other in a hypercube configuration.

A typical expert-system program following the previous approach provides for a knowledge base, a working memory, and an inference engine. Such a system operates in a three-phase inference-engine cycle: (1) match production rules; (2) resolve conflicts and select a rule; (3) fire a rule. An expert-system program following the new approach includes a parallelism matrix and a communication matrix in addition to the other features, and it operates in a four-phase inference-engine cycle: (1) match production rules; (2) resolve conflicts and select multiple rules; (3) broadcast selections; (4) fire selected rules.

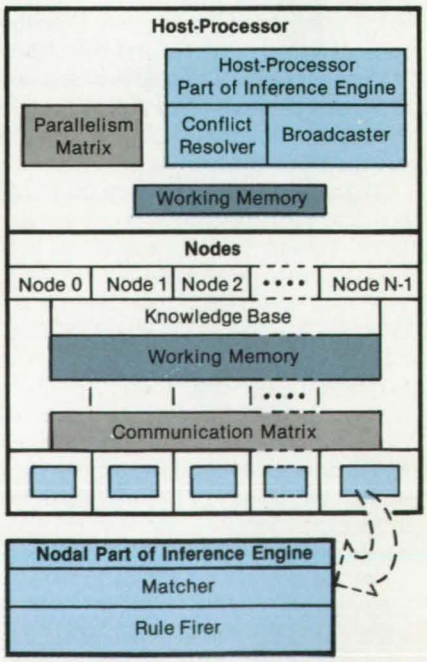
The parallelism and communication matrices indicate inherent (and sometimes hidden) parallelism and requirements for communication, respectively, and are obtained by analyzing dependencies among rules. Relevant dependencies include dependence on input, dependence on output, and dependence on communication. An element p_{ij} of the parallelism matrix is 0 if rules i and j can be fired in parallel and 1 if they cannot. An element c_{ij} of the communication matrix is 0 if rules i and j can be allocated to different processors and fired without passing messages to report changes to the working memory; that is, if rules i and j do not depend on input or communication. Otherwise, $c_{ij} = 1$.

The knowledge base, the working memory, and the communication matrix are distributed among the N nodes of a hypercube computer. The parallelism matrix is located in a host processor that controls the processors at the nodes (see figure). The inference engine is partially located in the host and partially distributed among the nodes. The production rules are distributed among the nodes to obtain maximum parallelism.

Conflicts are resolved in the host processor. Several strategies for the resolution of conflicts are undergoing investigation. One is to perform a sequential-type resolution by selecting the "best" one of the conflicting rules, then use this "best" rule in conjunction with the parallelism matrix to determine the maximum number of remaining rules that can be fired in parallel with the "best" rule.

This work was done by Ursula M. Schwuttke of Caltech and Dan Moldovan and Steve Kuo of USC for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 146 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-18004.



Parts of the Expert-System Software are allocated to the various processors in a hypercube computer in such a way as to exploit the potential for speedup in parallel processing.

Estimating Confidence in Data Via Trend Analysis

A probability-density function stores trends in data.

Marshall Space Flight Center, Alabama

A recursive equation defines a probability-density function that stores trends in noisy or potentially erroneous data. The recursive equation is part of an algorithm for analysis of trends in the data. The algorithm was developed to determine the reliability of data from a sensor used to guide a robot, and the mathematical approach that it represents may prove valuable in other applications.

The algorithm enables the computation of a statistic (called the "confidence statistic") that indicates the level of confidence in a new datum. The algorithm generates a confidence statistic that is high or low, depending on whether a new datum is consistent or inconsistent, respectively, with previous trends. This method for the generation of confidence statistics stands in contrast to prior methods based on heuristics, which proved unreliable.

Each time a new datum is encountered, its confidence statistic is calculated and it is then used to update the probability-density functions by use of an exponential decay function. The recursive equation expresses the relationship between the probability-density functions at the $n+1$st and nth increment of time, including the effect of the decay:

$$P(x,n+1) = (1-a)P(x,n) + aG(x-d),$$

where

- x = position in the probability-density function,
- $P(x,n)$ = the probability-density function at the nth increment of time,
- a = the factor of exponential decay at each increment of time ($0<a<1$),
- d = the value of the datum encountered at the nth increment of time, and
- G = a Gaussian function, the standard deviation of which is specified by the user.

The exponential decay causes the probability-density function to discount data more heavily as they recede into the past, thereby emphasizing recent trends in the data.

The confidence statistic is calculated from trends stored in the array of probability-density functions, which trends are indicated by peaks in the array. Because spurious data may be correlated, a probability-density function may contain multiple peaks. Therefore, the confidence statistic is based on both the local and the global characteristics of the data.

To calculate the local characteristics of the data, the peak nearest the new datum is located, and the mean and variance of this peak are calculated. Then assuming a Gaussian (normal) error distribution, the probability that a datum could be a given distance away from this peak is calculated.

Next, a global characteristic of this peak is calculated in the form of the ratio between the height of this peak and the height that it would have if all previous data had fallen exactly at this peak. The inclusion of this ratio ensures that a low confidence statistic will be reported for a datum that falls close to a peak that is low or that is just beginning to grow or decay. The probability described in the preceding paragraph is multiplied by this ratio to obtain the final confidence statistic for the new datum.

When the array of probability densities is used, trends in the data shift as new data shift. In the robot-control application for which the algorithm was originally developed, it was desired that the trends be allowed to vary more slowly than the robot could move. However, this meant that the robot could respond more quickly to an error command than the probability-density function could adapt to the data. To prevent this undesired response, the data in the probability-density function are shifted in anticipation of the movement of the robot. Whenever a command is sent to the robot, it is delayed for a short time and then used to translate the trend data in the array of probability-density functions. The delay interval is the measured response time of the robot. Because the data are shifted, the trends built up previously do not have to be rebuilt every time a correction is sent to the robot.

This work was done by David A. Gutow and Gregory A. Arnold of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

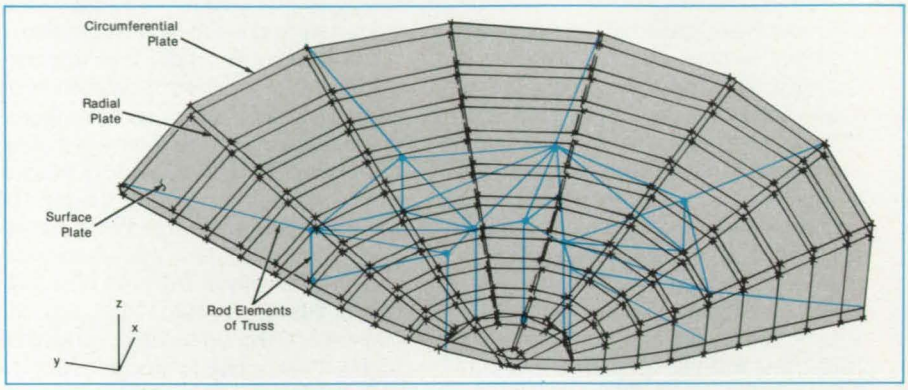
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-29710.

Fast Approximate Analysis of Modified Antenna Structure

Effects of modifications on path-length errors can be computed via "short-cut" algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

Abbreviated algorithms have been developed for the fast approximate analysis of the effects of modifications in supporting structures upon the root-mean-square (rms) path-length errors of paraboloidal-dish antennas. (The rms path-length error is a measure of the accuracy of the antenna reflector surface.) The rapid determination of the effects of modifications is useful in design, design-sensitivity analysis, and parametric studies. Without a fast, approximate method, it is necessary to compute the effect of each change via a complete finite-element or other structural analysis — a procedure that requires considerable computational resources and long computing times because it typically involves the solution of thousands of simultaneous load-vs.-displacement equations (see figure).



The **Finite-Element Model** of a microwave antenna, or subreflector, includes many surface, radial, and circumferential plate elements as well as rod elements that represent the supporting truss structure. The solution of the complete finite-element problem requires the solution of many simultaneous equations. The shortcut method makes it possible to calculate, in a few steps, the effects of changes in the cross sections of structural members.

The shortcut approach involves the combination of methods of structral-modification reanalysis with new extensions of correlation analysis to obtain the revised rms path-length error. The full finite-element analysis, which usually requires a computer of substantial capacity, is necessary only to obtain the responses of the unmodified structure to known external loads and to selected self-equilibrating "indicator" loads. These responses are used in the shortcut calculations, which, although theoretically "exact," are simple enough to be performed on a hand-held calculator.

The shortcut approach depends on the linearity of the load-vs.-displacement formulation. Linearity implies that the superposition of displacements is also valid when loads are superimposed. For each member in the structure to be changed, there is considered to be a parallel member attached to the structure in the same way. The cross-sectional area of the parallel member can be positive or negative and is equal to the change in cross-sectional area that corresponds to the modification of the structure. An independent pair of unit indicator loads directed toward each other are applied at the ends of each member in the unmodified structure. The response (displacements and loads in members) to the modification is obtained as the sum of the response of the unmodified structure to the known external loads plus the responses to particular vectors of unit indicator loads that are scaled for compatibility in the unmodified structure.

The computation of the approximate rms path-length error does not require the recomputation of the displacements of all the nodes of the finite-element model of the antenna surface followed by the recomputation of the least-squares best-fit surface for the new set of displacements. Instead, one uses the mean-square path-length errors already computed for the several loading cases, along with the coefficients of correlation among them. As a result, one can compute the rms path-length error of the modified structure in a few steps.

This work was done by Roy Levy of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 90 on the TSP Request Card.*
NPO-17901

Life Sciences

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Processing of Visual Information in Primate Brains

Processing strategies and pathways of the macaque are analyzed.

A report reviews and analyzes the information-processing strategies and pathways in the primate retina and visual cortex. It would be of interest both in biological fields and in such related computational fields as artificial neural networks. The report focuses on data from the macaque, which has a superb visual system similar to that of humans. The authors stress the concept of "good engineering" in understanding the visual system. For example, distances between adjacent photoreceptors in the fovea (the region of highest acuity in the middle of the retina) closely match the resolution limit of the lens. To the extent to which evolutionary pressures have produced a system of some nearly optimal configuration, the properties of individual components should all be related to the performance of the whole visual system.

The retino-geniculate pathway leads from the retina to the lateral geniculate nucleus in the brain. Intermediate layers within the retina perform a highly selective pruning of the information that enters the eye. In the "good engineering" approach to constructing a conceptual model of the visual system, the representations that emerge from this preliminary image processing severely constrain the components of subsequent stages of analysis of visual information in the visual cortex.

The spatial sampling of the retina exhibits a linear decrease in resolution with angular displacement from the fovea. Luminance information at each sampling locus is compressed by use of spatial and temporal differencing. This information is distributed into the parvocellular (P) and magnocellular (M) systems, each of which includes its own "on" and "off" subsystems. The P system responds to patterns, the luminances of which vary at frequencies of $\lesssim$ 20 Hz (peaking at $\sim$ 10 Hz), and carries luminance information from the lowest resolution up to the highest allowed at a given angular displacement from the fovea. The M system emphasizes luminance at lower spatial resolution, but higher temporal rates (up to about 80 Hz).

Chromatic information is multiplexed into the P system, but constitutes only a few percent of the total information that it normally carries. Multiplexed into the M system is a nonlinear measure of spatial and/or chromatic information, which may be useful for the analysis of texture, segmentation of images, and preattentive visual processing. The differences between P and M cells suggest a systematic division of labor in transmitting spatial, temporal, and chromatic information to the cortex; the authors view this as a strategy for packing the maximum amount of useful information into the optic nerve.

The report describes the functions of the visual cortex, including both the static ("hard-wired") and the dynamic aspects of the processing of visual information. The cerebral cortex, the dominant structure of the mammalian brain, is the principal site of higher levels of visual processing. More than half of the cortex is related to vision, the striate cortex, or primary visual cortex occupying about 15 percent of the total. Visual information that enters the striate cortex is processed in a highly localized fashion to generate a multitude of representations of data for distribution to other areas that subserve more specialized analyses. The discussion of the flow of information through the visual cortex reviews the evidence that the processing of information in the cortex is fundamentally hierarchical in nature, with extensive feedback as well as parallel processing.

In their discussion of the functionalities of different cortical layers, the authors hypothesize that the laminar organization of the cortex reflects a tripartite division of labor, in which the data-analysis stage is handled mainly within the superficial cortical layers, that the middle layer is involved primarily in the switching of inputs for distribution to the superficial layers, and that the deeper layers mediate the control of this selection-and-routing process. Finally, the report discusses the application of modeling approaches (such as connectivity matrices), which have been used with artificial neural networks to the analysis of cortical microcircuitry and cascaded-network architecture of the cortex.

This work was done by Charles H.

Anderson and David C. Van Essen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Information Processing Strategies and Pathways in the Primate Retina and Visual Cortex," Circle 1 on the TSP Request Card. NPO-17900*

Physiology of Prolonged Bed Rest

Deconditioning proceeds concurrently with healing.

A report describes the physiological effects of prolonged bed rest. Rest in bed, the report notes, has been prescribed for centuries in treatment of injury and disease. However, rest for periods of 24 hours or longer deconditions the body to some extent; thus, healing proceeds simultaneously with deconditioning.

Deconditioning results from decreased hydrostatic pressure in the cardiovascular system, elimination of longitudinal pressure on long bones, some decrease in total-body metabolism, changes in diet, and perhaps the psychological impact of forced inactivity. Every system in the body is affected.

Fluid electrolytes are disturbed almost immediately in bed rest. Muscles begin to atrophy noticeably within the first week, with increased nitrogen in the urine and reduced lean body mass. After 14 days, significant calcium is lost through the urine, and bone density decreases.

The report provides details on shifts in fluid electrolytes and the loss of lean body mass, which comprises everything in the body besides fat — that is, water, muscle, and bone. The discussion is based on published research.

This work was done by John E. Greenleaf of **Ames Research Center**. *To obtain a copy of the report, "Physiology of Prolonged Bed Rest," Circle 6 on the TSP Request Card.*
ARC-12241

Flight Checklists and Interruptions

How a crew handles interruptions affects safety.

A report examines the relation between performances of flight checklists and interruptions. The report is based on a study of simulated flights of a Boeing 707 Airplane. Each flight was conducted with 1 of 14 different crews, and during each flight a series of overlapping problems was introduced. The study investigated patterns of communication that in carrying out checklists, may contribute to accidents.

A checklist is a list of actions to be performed in a challenge-and-response manner. Ordinarily, the actions are verifications that activities have already been performed, rather than immediate performances of the activities. They are performed routinely during commercial flights and include sequences done at various times from before starting engines, throughout the flight, and until after arrival at the destination air terminal.

Ideally, a checklist should be followed without interruption. However, a crew may decide to interrupt a checklist to deal with other cockpit concerns, to listen to the radio and discuss the information received, or to discuss checklist items informally. In any case, the correct procedure at the outset of an interruption is for the pilot to place an explicit hold by saying, "Hold it at (name of checklist item)." When the interruption is concluded, the pilot is supposed to say, "Continue the checklist," and the reading should continue just as if there had been no interruption.

Each simulation was a mock flight from Tucson to Los Angeles via Phoenix. The problems en route included a hold to burn excess fuel, a missed approach because of a false indication that the nose gear was not down, deteriorating ceilings because of incoming coastal fog, and the forced choice of an alternative airport. The safety performance of each crew was rated by retired captains according to assessments of the risks in solutions of the problems.

The study showed that good crews had high continuity in following their checklists and that it is not the number of interruptions but rather the duration of interruptions that is associated with the quality of the performance. This suggests that a greater burden may be placed on the memory by one long interruption than by several short ones. The study also showed that only the best crews used explicit holds to suspend checklists.

This work was done by C. Linde and J. Goguen of Structural Semantics for **Ames Research Center**. *Further information may be found in NASA CR-177460 [N88-26348], "Checklist Interruption and Resumption: A Linguistic Study."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12324

Effect of Bed Rest on Tolerance to Acceleration

Paradoxically, physically fit people lose tolerance to acceleration after bed rest more than sedentary people do.

A report describes an experimental comparative study of the tolerance of aerobically fit men and of sedentary men to $+G_z$ acceleration. The study was designed to confirm or deny previous observations that long-term aerobic training reduced tolerance to acceleration. The study is the first to examine the responses of subjects who, like astronauts, participate regularly in aerobic activities to high accelerations after prolonged exposure to a regimen of bed rest designed to simulate the effects of microgravity.

Twenty men between the ages of 35 and 50 served as subjects. Thirteen subjects were aerobically fit; they ran or bicycled regularly and had a maximal treadmill oxygen uptake (VO_2 max) greater than 41 mL/(kg•min). The other seven were sedentary; they had significantly lower VO_2 max and higher weight and body fat.

The subjects were confined to bed, resting in a $-6°$ head-down orientation, for 10 days to simulate exposure to microgravity. Each subject was accelerated in a human centrifuge before bed rest and again on the sixth or seventh day of bed rest. The subjects were exposed to accelerations equivalent to three times the normal terrestrial gravitation until they approached grayout, which was signaled by a reversal or loss of flow in the temporal artery. Heart rates and blood pressures were monitored during acceleration. In addition, plasma volumes were measured before, and echocardiograms were taken after, the acceleration tests.

The data accumulated in the study showed that the decrease in tolerance to acceleration caused by the deconditioning effect of bed rest was more pronounced in the fit men than in the sedentary men. Before bed rest, both fit and sedentary men could tolerate acceleration for about 370 s, on the average. After bed rest, the average time during which the sedentary subjects could tolerate acceleration was 167 s shorter, while for the fit subjects it was 259 s shorter. Two of the fit subjects were barely able to complete the initial rise to the peak acceleration. The loss of $+G_z$ tolerance in the fit subjects was strongly correlated with their greater increase in resting heart rate and larger loss of plasma volume after bed-rest deconditioning.

The report suggests that physically fit people may need additional measures to reduce the loss of tolerance to acceleration during microgravity exposure. For example, fluid loading and antigravity suits may be needed to increase central blood volumes during reentry acceleration.

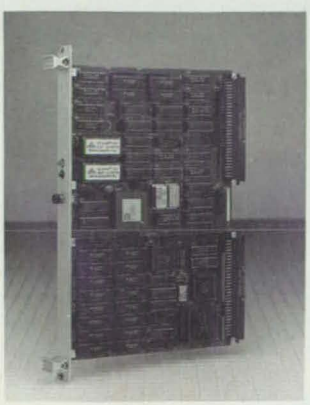
This work was done by Danielle J. Goldwater of **Ames Research Center**. *To obtain a copy of the report, "Factors Related to +Gz Acceleration Performance in Aerobically Trained and Sedentary Men After Shuttle Microgravity Simulation," Circle 41 on the TSP Request Card.*
ARC-12400

New on the Market

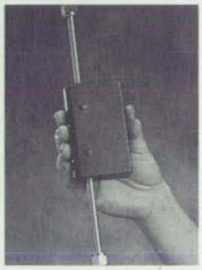
A new **battery backup IC** using bipolar linear technology is offered by Fujitsu Microelectronics Inc., San Jose, CA. Designed for SRAMs, ROMs, and logic IC devices, the model MB3780A automatically switches to either a nonrechargeable primary battery or a rechargeable secondary battery during DC power losses. It features a standby current of 1.0 mA and an output drive current of 200 mA.
Circle Reader Action Number 782.

The Thermalert 5 Plus **infrared thermometer** from Raytek Inc., Santa Cruz, CA, allows the user to save, recall, and print graphics. It can display temperature alone or several process temperature parameters, such as trending data, setpoint, external thermocouple or RTD temperature input, background temperature, emissivity, and peak, valley, and sample hold. The T-5 Plus provides programmable temperature ranges from -20° to +3000° C.
Circle Reader Action Number 786.

Silicon Composers Inc., Palo Alto, CA, has introduced the SC/FOX™ VME **single-board computer**, a system controller board for real-time embedded system applications. Using the Harris 16-bit RTX 2000™ real-time processor, the SC/FOX VME board hits 18 MIPS at 12 MHz with burst speeds up to 60 MIPS by executing multiple instructions per clock cycle. The board supports all VME bus master/slave system controller functions.
Circle Reader Action Number 788.



RGB Spectrum, Berkeley, CA, has released X.TV, a **software program for multimedia capability** on workstations running X Windows. The video image is contained in a standard window which can be repositioned anywhere on the screen, scaled to full screen size, or reduced to icon size. X.TV communicates with the RGB/View hardware via VME bus, SCSI, or RS-232 port.
Circle Reader Action Number 776.



M-Tek, Pittsburgh, PA, has introduced a compact **liquid flow sensor** which measures flow rates from 0.05 to 250 ml/minute with better than 0.1 percent precision. Made from teflon and glass or stainless steel and glass, the sensor has no moving parts and needs no lubrication or maintenance. Output signals include 4 to 20 mA, 0 to 5 volts, and RS-232.
Circle Reader Action Number 780.

Version 2.3 of S-PLUS UNIX-based **statistical analysis software** is now available from Statistical Sciences Inc., Seattle, WA. S-PLUS provides an interactive computing environment which features both a graphical and data analysis system and a statistical programming language. An enhanced version of AT&T's *New S* programming language, S-PLUS offers more than 500 functions including time series analysis, modern regression, and multivariate analysis. It graphically displays results to legends, tables, text, pie charts, histograms, time series plots, and color or grey scale images.
Circle Reader Action Number 778.

A **portable video frame grabber** that can digitize and store a video frame in 1/60 second is available from Portable Technologies, Castro Valley, CA. The resultant image has a resolution of 320 x 200 pixels with 64 levels of gray. Square pixels are obtained with standard NTSC or RS-170 video signals from video cameras, camcorders, VCRs, or TV monitors. Using one 9-volt lithium battery, the frame grabber can perform up to ten years or more than 100,000 frame grabs and readouts.
Circle Reader Action Number 784.

New on the Market

Centera Technologies Inc., Louisville, CO, has introduced GRAFkit **scientific visualization software**, based on GKS and X Window, for the IBM RISC System/6000. GRAFkit is used for data reduction, trend analysis, and modelling in such fields as aerospace, manufacturing, medicine, and environmental and geophysical sciences. It automatically creates X-Y plots, contours, 3D solids and surfaces, maps, and map data overlays.
Circle Reader Action Number 794.

The VCS-20A **fiber optic talk set** from EXFO EO Engineering, Quebec, Canada, allows full-duplex voice communication over one fiber, at distances up to 120 km. It features a stable light source for attenuation testing, a 2 kHz tone generator for active fiber detection, and a 2 kHz tone detector.
Circle Reader Action Number 792.

New **turbo-drag pumps** that produce oil-free vacuum from UHV to atmosphere are available from Balzers High Vacuum Products, Hudson, NH. The devices include a turbopump and a two-stage drag pump to achieve increased volume flow rates and an N_2 compression ratio of 10^{12} for an operating range of 10^{-12} Torr to 0.75 Torr continuous inlet pressure. In most applications, the turbo-drag pump can be backed with a dry diaphragm pump, eliminating oil backstreaming and process contamination.
Circle Reader Action Number 800.

The model CMS 52 **radio test set** from Rohde & Schwarz, Lanham, MD, is suited for mobile or stationary use and can measure all parameters of AM, FM, and ϕM radio equipment, including selective call and DTMF. The lightweight system features a spectrum monitor, storage oscilloscope, continuously-tunable distortion meter, and programmable AF filters. It employs a high-resolution LCD display with backlighting and graphics capability.
Circle Reader Action Number 796.

The PowerPointer, a **pocket-size laser pointer** for audio-visual presentations, has been introduced by Power Technology Inc., Little Rock, AR. Using four-element glass optics and a single-mode laser diode, the device projects a bright red spot onto graphs and other presentation materials. Made of anodized aluminum, the PowerPointer weighs 1.9 ounces and is 6 inches long.
Circle Reader Action Number 798.

The Furon Company's Dixon Facility, Bristol, RI, has developed the MELDIN® 2000 series of self-lubricating **polyimides** for aerospace, automotive, electronics, and industrial applications. The polyimides operate from -240° to +316° C in continuous use, with intermittent use up to 482° C. Furon offers three polyimide formulations: an unfilled polyimide, a 15 percent (by weight) graphite-filled polyimide, and a PTFE-filled polyimide.
Circle Reader Action Number 790.

New Literature

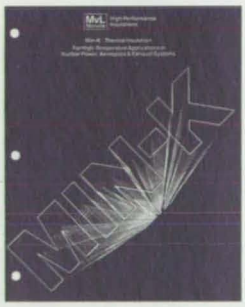
More than sixty **test instruments** are featured in a new catalog from Protek, Norwood, NJ. Included are digital and analog oscilloscopes in the 20 to 100 MHz range, handheld multimeters, DC and AC voltage and current measurement panel meters, function generators, frequency counters, and insulation testers.
Circle Reader Action Number 728.

The World Directory of Aerospace Vehicle Research and Development, from DIANE Publishing Co., Upland, PA, describes the principal **aerospace test facilities** in eight countries: Australia, Belgium, France, Italy, Japan, the Netherlands, the United Kingdom, and Germany. The first in a series of reports on aerospace investment outside the US, the directory provides data on wind tunnels and air-breathing propulsion test cells, listing the location, owner, operator, and performance characteristics. It features photos and/or schematic drawings of each facility.
Circle Reader Action Number 724.

A short-form catalog from Quatech Inc., Akron, OH, highlights the company's line of **communication, data acquisition, signal conditioning, and industrial control products** for IBM PC/AT and PS2 systems. It features Quatech's new 16-bit data acquisition system for AT compatibles and multi-port RS-422 communication card for Microchannel systems.
Circle Reader Action Number 726.

Chemical Resistance of Plastics Materials, from Information Retrieval Systems Inc., New York City, details **how more than 1600 chemicals affect 60 generic plastics**. Offered in computer program and printed formats, the guide provides data on exposure conditions of chemical concentration, test temperature, length of exposure, and stress/strain on the sample. The test material is identified by supplier, trade name, grade number, and characteristics.
Circle Reader Action Number 718.

A 12-page **noise control products** catalog from Azonic Inc., Burnsville, MN, features application ideas, an ordering guide, and information on the company's acoustical modeling service. Azonic acoustical foam has a patented pyramid surface pattern that scatters, dissipates, and deflects noise.
Circle Reader Action Number 720.

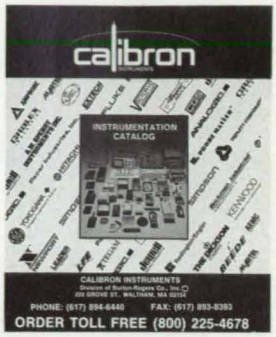


Manville Engineered Products, Denver, CO, has published a 12-page brochure on its Min-K® **high-temperature insulations** for OEM applications such as nuclear power, aerospace, and exhaust systems. The free brochure explores the benefits of Min-K, such as its low thermal conductivity, high purity, strength, and light weight. Included are product descriptions and photos of both flexible and molded Min-K, with new thermal conductivity data in air, hydrogen, helium, and argon, at varying pressures.
Circle Reader Action Number 722.

L'Garde Inc., Tustin, CA, has released a full-color brochure describing its **inflatable elastomers** and electronic technologies for space and terrestrial applications. Through pictures and diagrams, the booklet illustrates L'Garde's current development programs, including inflatable solar concentrators and improved elastomers for the Department of Energy, and breakthroughs in military electronics.
Circle Reader Action Number 716.

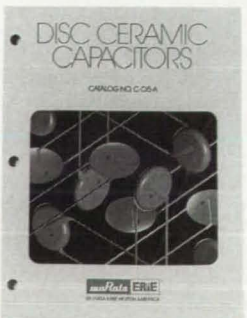
New Literature

A new catalog offered by Calibron Instruments, Waltham, MA, presents thousands of **meters and instruments** from more than 35 manufacturers. The main sections include digital and analog panel meters, meter relays, switchboard meters, controllers, recorders, test and measurement equipment, and temperature and process controllers. Accessories such as thermocouples, transformers, and scope probes are also featured.
Circle Reader Action Number 706.



Copley Controls Corp., Newton, MA, has published a 36-page catalog which provides specifications, diagrams, and application guidance for a variety of **electric power sources**, including 20 modular PCB-mounting servoamplifiers and 15 high-power, wide-bandwidth PWM amplifiers. The free catalog also features DC power supplies, transformers for custom power supplies, electronic loads for absorbing servomotor regenerative energy, filters, and digital controllers.
Circle Reader Action Number 712.

A free catalog from Murata Erie North America, Smyrna, GA, provides technical specifications for **disc ceramic capacitors** in a variety of voltage ratings. The 36-page catalog covers Class I,II, III, and IV devices rated from 12v DC to the kv range, and safety capacitors listed by UL, CSA, and VDE. Also detailed are capacitor design engineering kits for prototype and breadboard-ing requirements.
Circle Reader Action Number 702.



A four-color product guide from Shin-Etsu Silicones of America Inc., Torrance, CA, illustrates applications of its **silicone products**. The publication shows how silicone rubber is used in the automotive, aviation, computer, printing, and sporting goods industries.
Circle Reader Action Number 714.

Siemens Optoelectronics Division, Cupertino, CA, is offering a 48-page catalog spotlighting its **Intelligent Display® devices**, military high-rel displays, numeric displays, optocouplers, LED lamps, IR emitters, photodetectors, and plastic fiber optic emitter/detector components.
Circle Reader Action Number 710.

A four-color brochure from Bally Engineered Structures Inc., Bally, PA, describes **modular chambers** for aerospace and electronics research. Suited for installations with internal temperatures ranging from -67.8° C to +121° C, the chambers feature interchangeable panels composed of four-, five-, or six-inch poured-foam-urethane between metal skins.
Circle Reader Action Number 708.

Valnet Industrial Systems, Milwaukee, WI, has released a brochure on its **industrial laptop, portable, desktop, and rack-mount computers and accessories**. New products include the VGA-AMTFT color laptop and the VGA II-486 EISA portable. The computers all feature expansion slots and can interface to most popular PLCs.
Circle Reader Action Number 704.

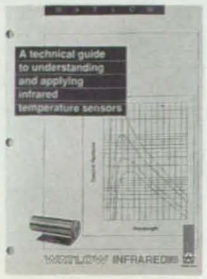
New Literature

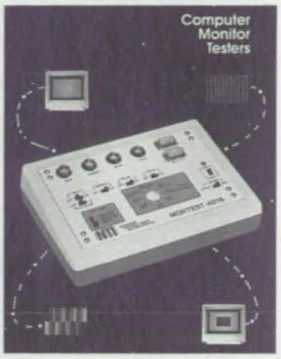
A six-page brochure on **single point automatic lubricators** is available from Perma Distributors International, Cerritos, CA. Perma's automatic lubrication system consists of a cylinder containing a pressure generator and a piston, which, in response to regulated pressure, pushes the lubricant into the bearing. Pumps or electric motors are not required.
Circle Reader Action Number 740.

Master Circuits Inc., Kokomo, IN, has published a full-color brochure detailing its **printed circuit board services**. The literature features single-sided circuit boards and complex multilayer boards with up to 12 layers. High-temperature multilayers, flexible circuits, surface mount boards, and Gerber photoplotting are also described.
Circle Reader Action Number 742.

Spectrum Signal Processing Inc., Vancouver, BC, has issued a catalog of digital signal processing **(DSP) development tools** and OEM systems for the IBM PC/XT/AT, PC compatibles, and VMEbus. The 72-page catalog lists several new software and hardware modules, and includes an article on how to select the appropriate DSP chip for a given application.
Circle Reader Action Number 732.

Applications of **infrared sensors** are explored in a 14-page guide from Watlow Electric, St. Louis, MO. Using charts and graphs, the booklet illustrates the advantages and disadvantages of both contact and noncontact temperature sensing, and explains how infrared sensors work. It includes a glossary and information on system installation.
Circle Reader Action Number 730.





A four-page brochure describing handheld **computer monitor testers** is available from Network Technologies Inc., Chagrin Falls, OH. It focuses on the MONTEST line of monitor testers, which generate video, intensity, RGB, horizontal and vertical sync, TTL, and analog signals in four patterns. The handheld units can align projectors and monitors on site, reducing equipment downtime.
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A free brochure describes **digital signal processing** solutions for high-end signal analysis applications in military/SIGINT, research physics, and satellite communications. Published by Tektronix Federal Systems Inc., Beaverton, OR, the brochure highlights a VMEbus-based analysis system with amplitude versus frequency, spectrogram, phase and view limit color displays. It includes application notes and material on pulsed radar, FSK, and other difficult measurements.
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Mupac Corp., Brockton, MA, has published a catalog of **system packaging products** for VME, VXI, Sun, Futurebus+, Multibus I, Multibus II, and PC/AT systems. The 250-page publication details enclosures, subracks, backplanes, wire wrap boards, bus analyzers, extender boards, 19-inch cabinets, and accessories. Also included are backplane pinouts for each bus structure, backplane design concepts, and emission standards and enclosure cooling information.
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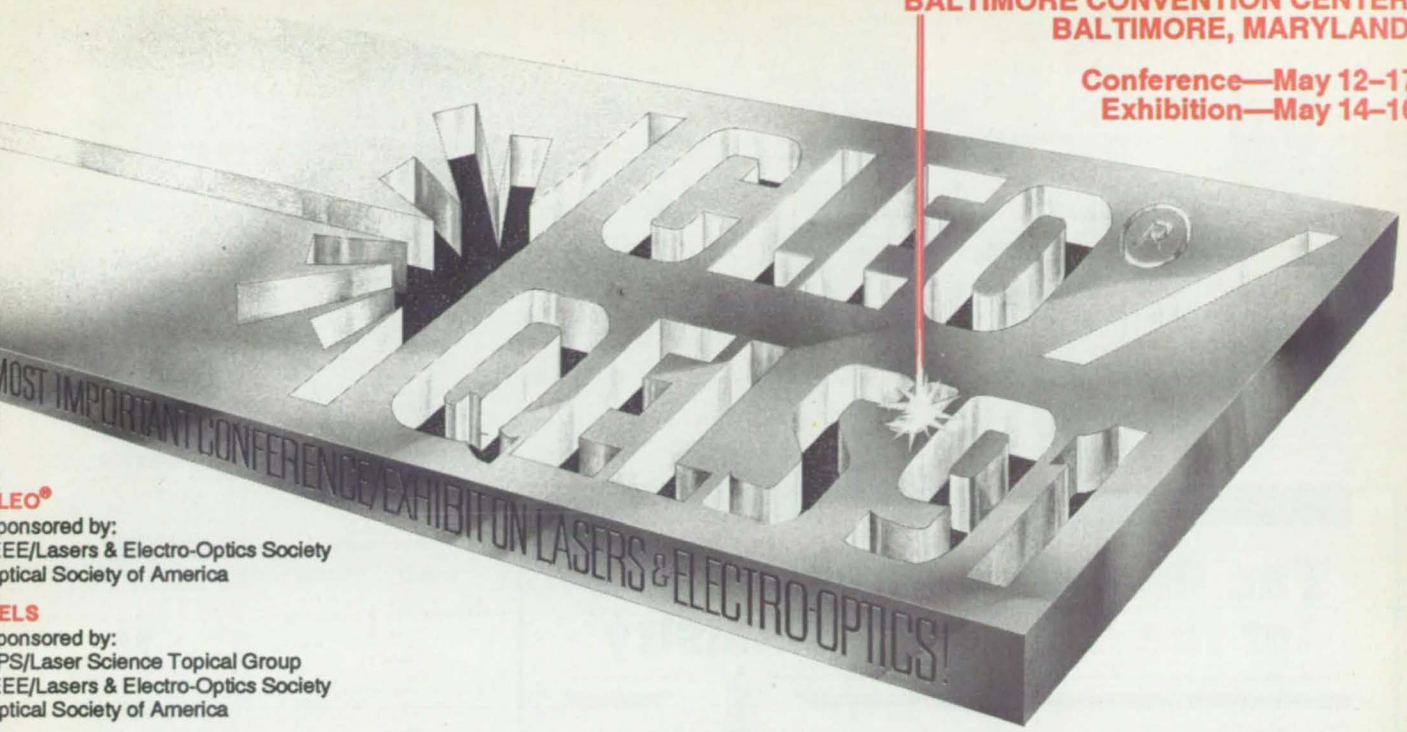

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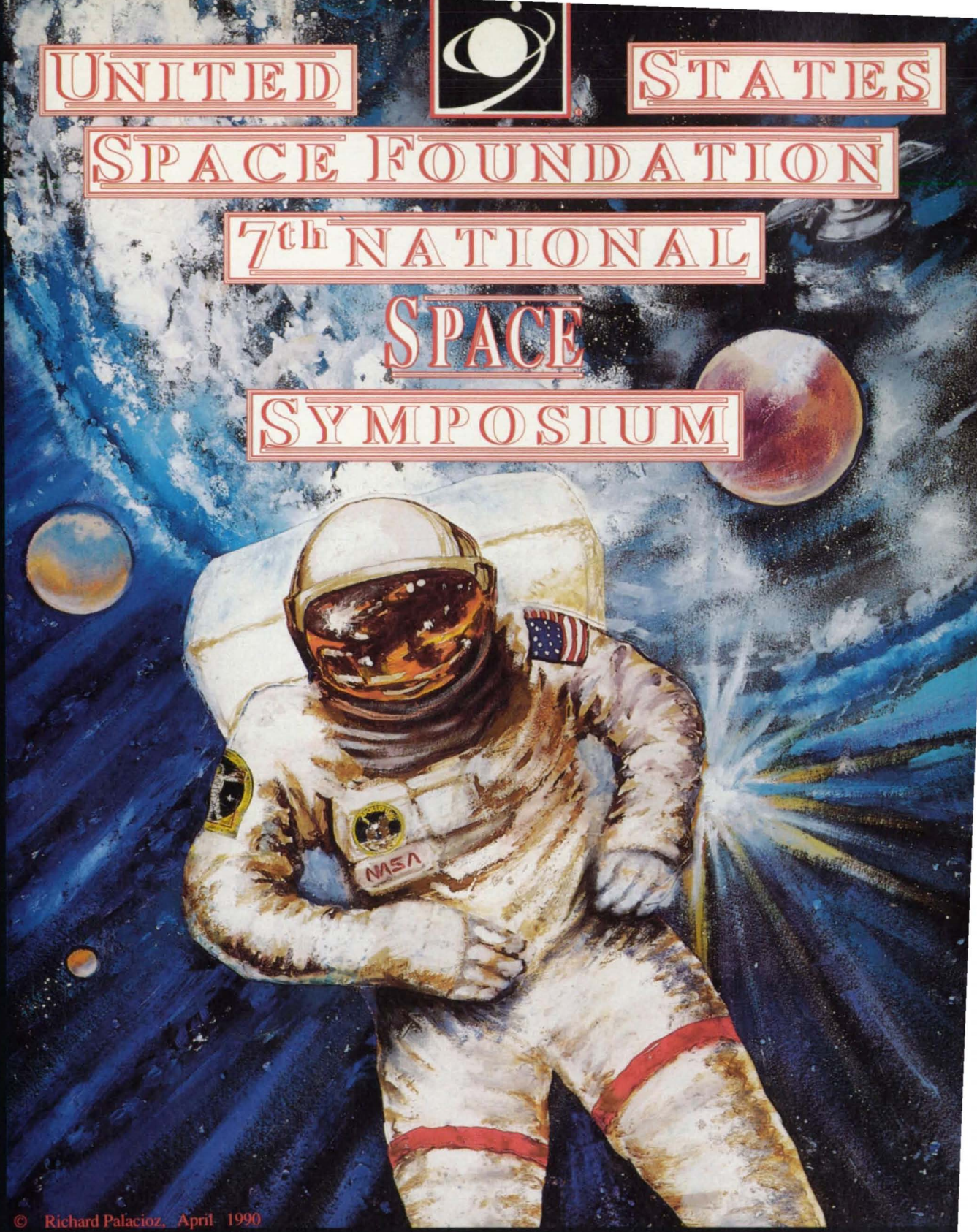

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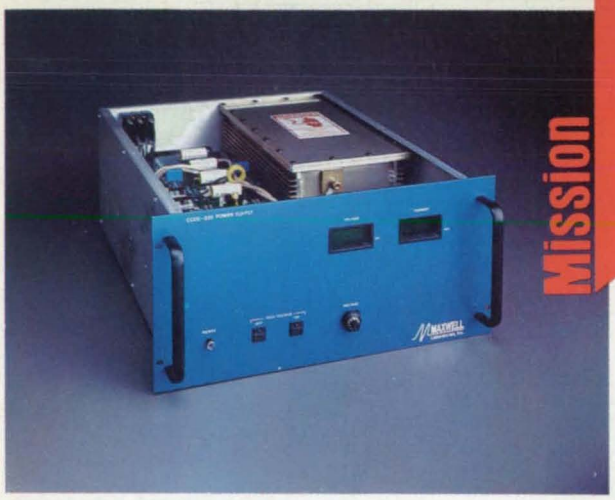

Photo courtesy Maxwell Laboratories Inc.

Through the technology transfer process, many of the systems, methods, and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

A stronger, more efficient power supply for industrial and medical equipment represents the first technology spinoff from NASA's 16 nationwide Centers for the Commercial Development of Space. Targeted initially for the laser industry, the new product is a result of a joint effort by the NASA-sponsored Center for Commercial Development of Space Power at Auburn University and Maxwell Laboratories of San Diego to develop an electrical power converter for future spacecraft. Maxwell, one of the center's four industrial partners, is marketing the invention under a revenue-sharing arrangement with Auburn.

"The commercial application of this technology is a major breakthrough in system efficiency, compactness, and reliability," said Ray Askew, director of the Auburn center. "These features are critical to industrial, medical, and space applications."

A rectangular device the size of a stereo receiver, the power supply transforms and conditions large voltages to charge capacitors used in x-ray systems, lasers, radar, and microwave communications equipment. It features high-frequency MOSFET switching and a unique circuit architecture that simplifies the overall electronic design and reduces the number of required parts. In addition, the system is designed to protect against failures due to electrical short circuits. It employs an innovative pulsewidth modulation control technique to provide open circuit overvoltage protection and achieve output voltage regulation of better than 0.1 percent for load repetition rates up to 2 kHz. The delivered power quality is double that of the best current technology, according to project engineers.

Collaborative research on the power supply concept began in March 1988. A year later, Maxwell introduced the first commercial version—the CCDS series of capacitor charging power supplies, offering average output powers from 2 to 8 kJ/s and output voltages of 1 to 50 kv. Meanwhile, the research team has continued work on a power inverter for space applications. ❑

For further information about the technology discussed in this article, contact Ray Askew, Space Power Institute, 231 Leach Center, Auburn University, AL 36849.

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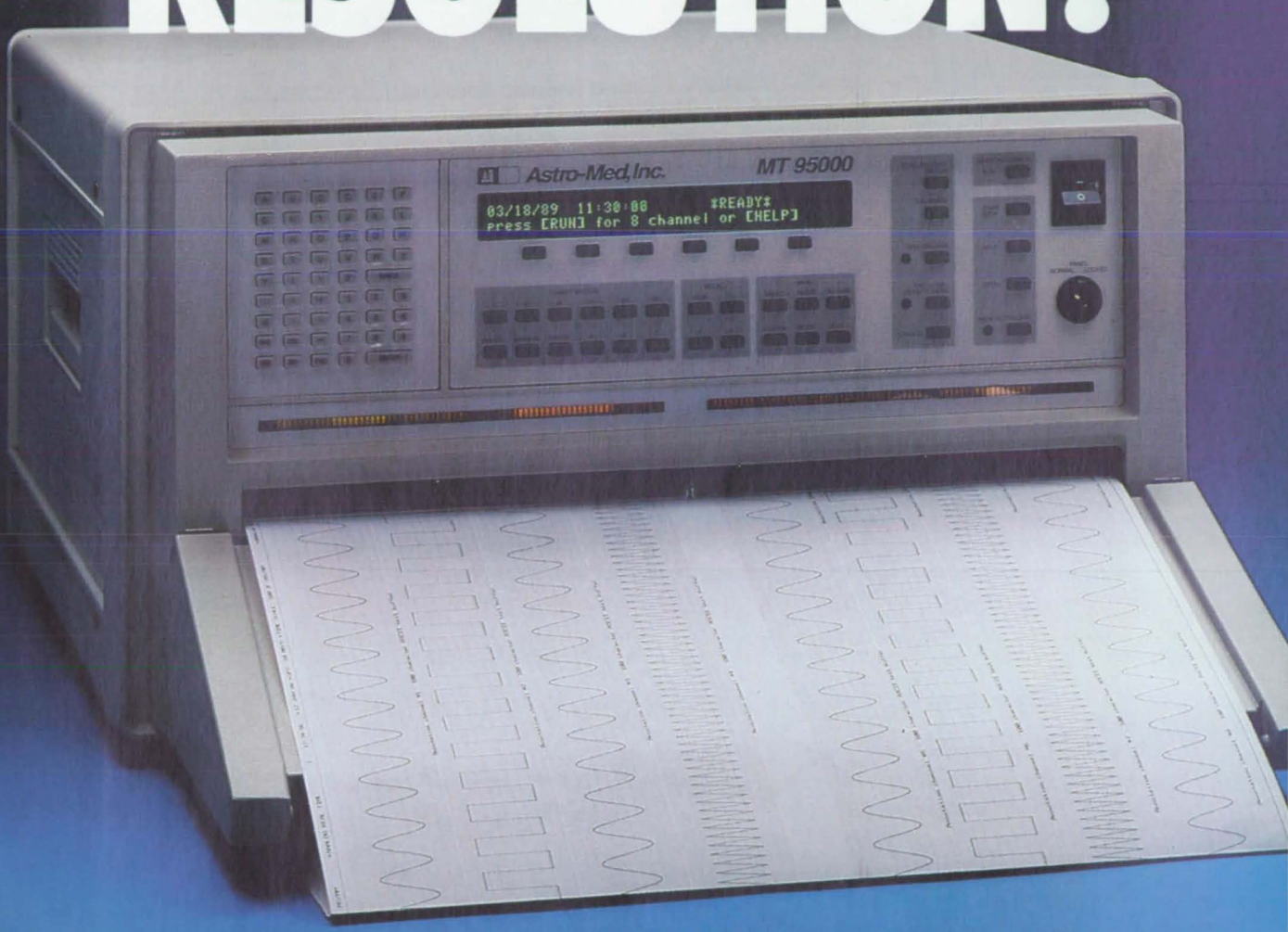

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