NASA Tech Briefs

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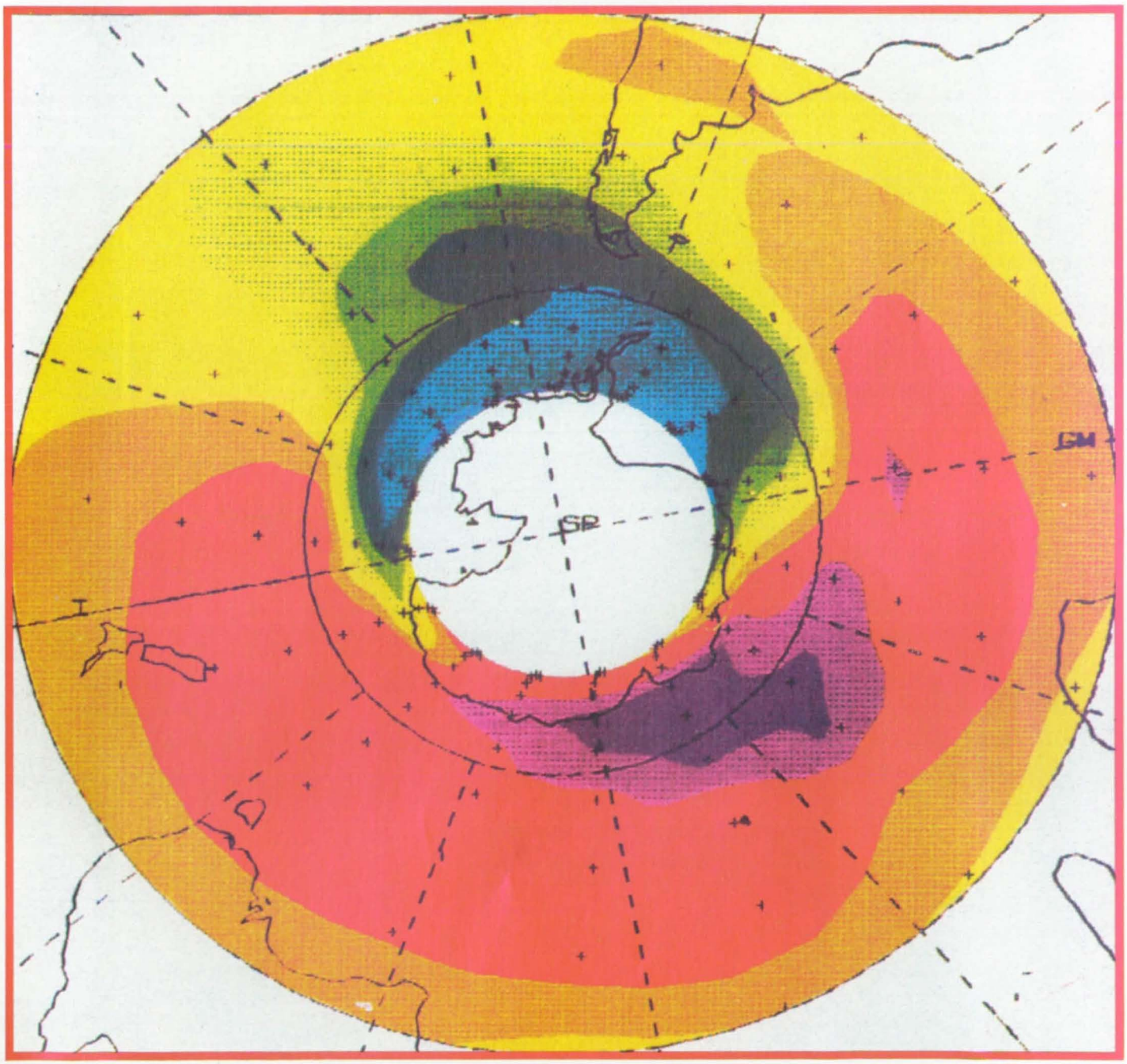
Space Administration
Volume 15 Number 4

Transferring Technology
to Industry and
Government
April 1991

EARTH'S VANISHING OZONE



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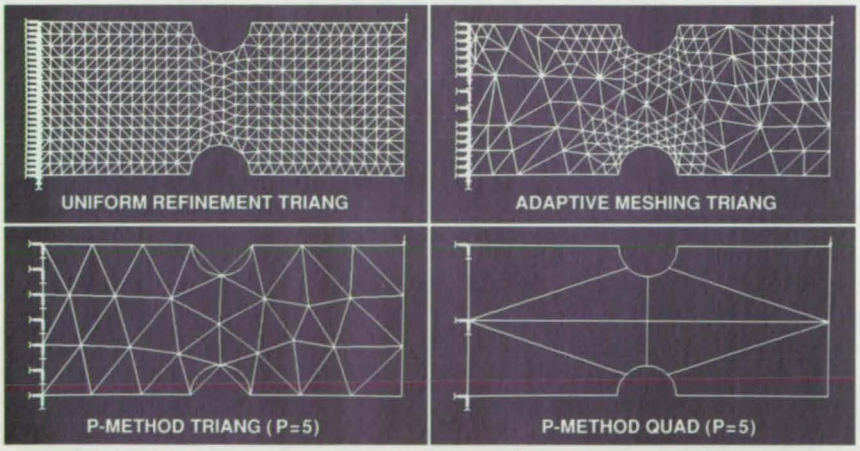

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Nodes per Element	3	6	6	6	8
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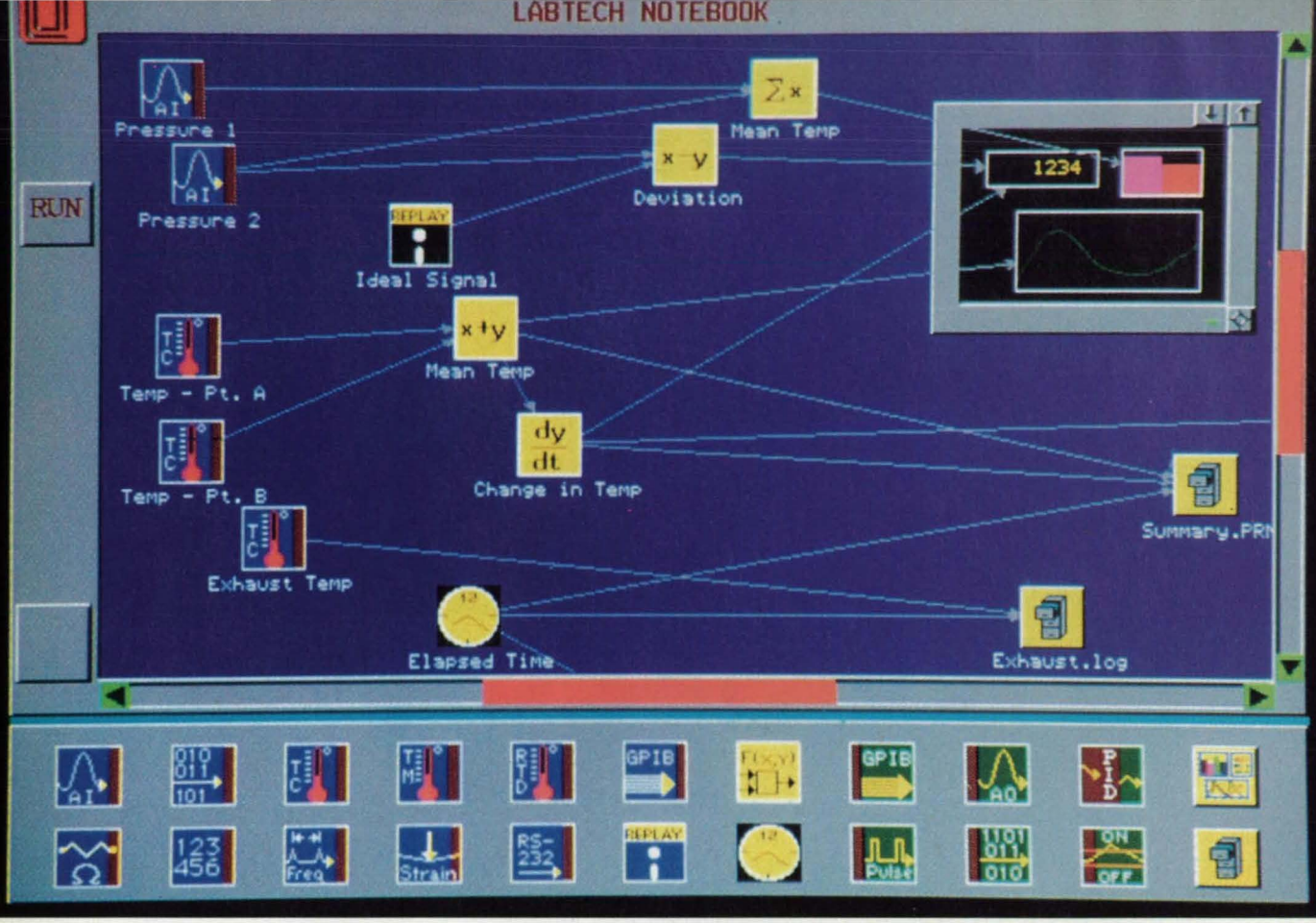

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Transferring Technology to Industry and Government

April 1991
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ABP BPA

Photo courtesy Jet Propulsion Laboratory

A force-reflecting telemanipulator system developed at Jet Propulsion Laboratory features active compliance and damping in the robot hand to soften collisions and improve dexterity. See the tech brief on page 48.

SPECIAL FEATURES

TECHNICAL SECTION

DEPARTMENTS

On The Cover: NASA scientists are using satellite-borne instruments to monitor the hole in the Earth's ozone layer. The computer-processed image on the cover shows 1988 ozone concentrations over Antarctica, with the areas of severest ozone depletion displayed in blue. Turn to page 114.
(Photo courtesy Langley Research Center)

Taking a tip from nature, NASA researchers have designed crescent-shaped wings that reduce drag and improve aircraft performance. See page 79.

Photo courtesy Langley Research Center

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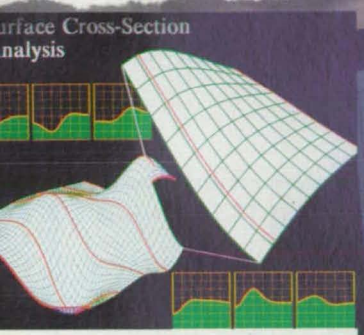

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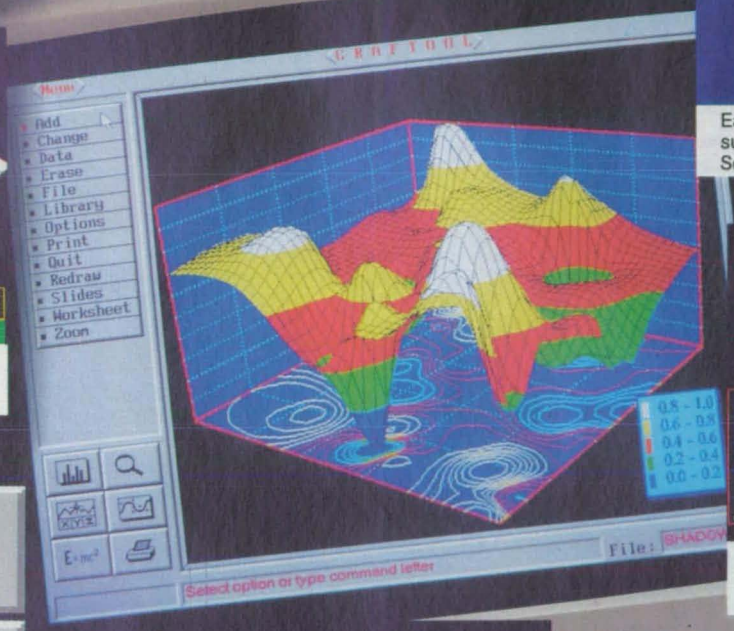

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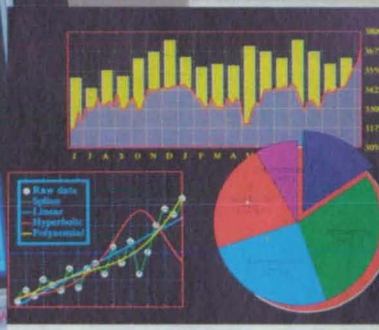

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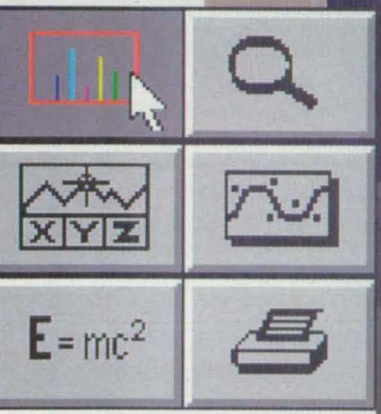

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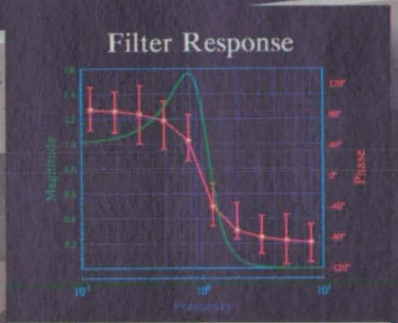

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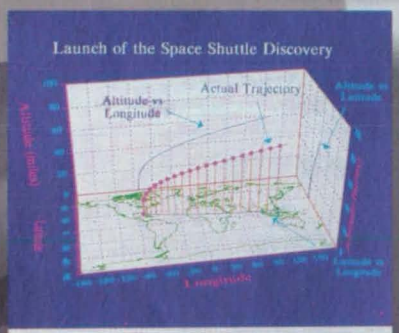

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The 1990 NASA Technology Transfer Awards

Each month we receive hundreds of feedback cards from you, the readers of *NASA Tech Briefs*, telling us how ideas contained in the briefs have helped you solve engineering problems, save time and money in your design and manufacturing processes, or develop new commercial products. NASA estimates that over the past three decades space technology has generated some 30,000 spinoffs, many of which began with an engineer like you reading about an invention in *NASA Tech Briefs* and then putting it to practical use.

While NASA spinoffs in the medical and industrial arenas have garnered much publicity over the years, the originators and gatekeepers of this technology — the NASA employees and contractors who report their innovations in *NASA Tech Briefs* and who work with industry to find commercial applications — have received far too little recognition. There is little appreciation for the painstaking work involved in bringing space technology down to Earth, or for the practitioners of this fine art called technology transfer.

We feel that public acknowledgement of the role these individuals and companies have played over the years is not only fitting, but long overdue. That's why *NASA Tech Briefs*, in concert with NASA and the Technology Utilization Foundation, established Awards of Excellence in Technology Transfer, recognizing outstanding achievement in transferring space-based innovations to the private sector. The first of these awards were presented in November at a dinner held in conjunction with the Technology 2000 conference in Washington, DC. The 15 NASA contractors who have contributed the most tech briefs over the past three decades were presented awards by NASA deputy administrator James R. Thompson. Employees of the 15 firms collectively have written over 3500 briefs, spanning programs from Apollo to space station and covering every area of technology imaginable.

NASA Tech Briefs **publisher Bill Schnirring addresses audience of 250 government and industry executives at the November awards dinner.**

NASA deputy administrator James R. Thompson (left) presents Award of Excellence in Technology Transfer to Steven D. Dorfman, corporate vice president of Hughes Aircraft Company.

The highlight of the evening, however, was the presentation of the Lifetime Achievement Award in Technology Transfer to John Samos, long-time Technology Utilization Officer at NASA's Langley Research Center. No one has contributed more to the success of the agency's technology transfer efforts than John, whose outstanding work is highlighted on the next page.

The following pages describe some of the major R&D projects the winning companies are currently working on for NASA, projects that will be creating tomorrow's spinoff technologies. We have included the name and phone number of a contact at each company who can provide you with further information.

We're planning a bigger, more encompassing awards event for the Technology 2001 show in San Jose, CA this December. The awards dinner will be held the evening of Wednesday, Dec. 4 in the San Jose Fairmont Hotel and will honor tech transfer achievements government-wide. We'll keep you apprised as it unfolds.

Bill Schnirring
Publisher

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Boeing's Aerospace and Electronics Division in Kent, WA, has worked on hundreds of NASA contracts through its Research and Engineering organization and its Space Systems Division. Current projects include the Tank Pressure Control Experiment, investigating how a liquid jet could be used to control pressures in orbiting cryogenic storage tanks; the Space Environmental Screening Laboratory, testing resistance of materials to extreme environments; and the development of aircraft and spacecraft guidance and control technology for NASA Langley.

Boeing Huntsville is developing space station Freedom living modules and other station components, and Boeing Aerospace Operations (BAO) provides spacecraft and missile checkout and launch support for Kennedy Space Center. At the Johnson Space Center, BAO supports the Space Transportation System and manages, refurbishes, and maintains an inventory of thousands of crew-related flight and training items.
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CSC is developing several artificial intelligence (AI) technologies for Goddard Space Flight Center, including:

- GenDEX, a tool to build diagnostic expert systems for radio frequency communications equipment such as that used in NASA's Ground Network;
- REDEX, an expert system that diagnoses hardware failures in the ranging equipment at NASA's Ground Network tracking stations. The system will help technicians identify faulty circuit cards or modules that must be replaced;
- BCAUS, the Backup Control Mode Analysis and Utility System, which will aid the Flight Operations Team in determining spacecraft autonomous mode transition causes. BCAUS uses neural networks, an expert system, and C language functions to pinpoint failures in the attitude control and determination system.

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The Upper Atmosphere Research Satellite, slated for launch later this year, is a new GE spacecraft that will provide a wealth of data on the upper atmosphere. It will be followed later this decade by the first satellite in NASA's Earth Observing System, EOS-A, the most complex GE spacecraft ever produced to study our world. For planetary research, Astro Space is building the Mars Observer, designed to orbit the Red Planet and map it in unprecedented detail.

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Contact: Laura Eberle, (609) 734-9461.

LANGLEY'S EXPERT MATCHMAKER

For nearly a quarter century, John Samos has been helping the American public to reap down-to-Earth benefits from its civil space program. As head of the Langley Center's Technology Utilization and Applications Office, Samos has worked with industry to reapply space-based ideas in hundreds of products and processes that have improved daily life and impacted the national economy. In November, NASA presented Samos with the agency's first Lifetime Achievement Award in Technology Transfer.

"It's a satisfying feeling when you successfully match a technology with a user," said Samos, "particularly when it results in a product that benefits people's lives."

Samos was instrumental in the transfer of astronaut "cool suit" technology to help children born without sweat glands lead more normal lives. The personal cooling system, which is also used by race car drivers and industrial workers, consists of a headpiece and vest lined with a chilled

John Samos (left) accepts Lifetime Achievement Award from NASA's deputy administrator.

recirculating fluid that acts to lower the heart rate and prevent overheating.

He worked with the University of Virginia to develop a lightweight wheelchair incorporating aerospace composite materials. The collapsible chair weighs only 25 pounds but has the same strength and weight-bearing capability as a 50-pound stainless steel wheelchair.

Further, Samos aided in the commercialization of an ultrasonic device which provides quantitative measurements of burn depth, a key factor in diagnosis and treatment of serious burns. Originally developed to detect microscopic defects in aircraft materials, the ultrasound system may also be used in treatment of skin cancer and lymphatic disorders, early detection of bed sores, and plastic surgery.

Samos joined the Langley Center in 1966, after serving for 17 years in the US Air Force. A native New Yorker, Samos studied at the New York Academy of Aeronautics and earned a bachelor of science degree in mechanical engineering from Oklahoma State University. He worked for Langley in its Technology Utilization Office from August 1967 to December 1990, when he retired from government service. He now acts as a technical consultant to Langley, under contract to the Lockheed Company.

Upon receiving the Lifetime Achievement Award, Samos said, "I share this honor with the entire NASA technology utilization infrastructure, especially my comrades at each field center, the Technology Utilization Officers." ❑

Grumman Corporation

The Grumman Space Station Program Support Division, part of Grumman's Systems Group, provides information systems, management services, program assessment, systems engineering, and safety, reliability and quality assurance for the Freedom program. It also develops test requirements for verification, assembly, and overall integration of space station components.

Another unit of the Systems Group, the Space and Electronics Division, is developing the space station habitation module as a subcontractor to Boeing. In addition, the division is building a seventh set of wings for the space shuttle fleet.

Grumman's Technical Services Division is a subcontractor to Lockheed on the shuttle processing contract at Kennedy Space Center. Grumman manages a network of some 300 launch processing computers, along with associated software, ground support, instrumentation, and measurement and calibration laboratories used to prepare and launch each shuttle.

Contact: J. Jeffrey Irons, (516) 575-8700.

Honeywell Inc.

Honeywell's Space Systems Group in Clearwater, FL, is developing the attitude control and determination system,the multiplexer/demultiplexer, and part of the data management system for space station Freedom. Its navigation and control system includes control moment gyros, star trackers, ring laser gyros, and software that will stabilize the orbiting station.

The group also produces controls for the space shuttle, including main engine controllers, flight controls, hand controllers, multiplexers/demultiplexers, shuttle trainer aircraft avionics, steering position transducers and amplifiers, and aerosurface and speedbrake controls.

Honeywell supplies on-board computers and signal processing for a wide range of space applications, and has over 20 years experience in developing control moment gyros. Honeywell is currently applying this technology base to the momentum control subsystem requirements of numerous spacecraft.

Contact: William Fouts, (612) 782-7034.

Hughes Aircraft Company

Hughes' relationship with NASA began in January 1961, when it was awarded a contract to build the Surveyor lunar lander. Since then, the company has developed more than 100 spacecraft, including the Applications Technology Satellites, which carried experiments in communications, meteorology, and satellite stabilization; the Orbiting Solar Observatory, designed to investigate radiation emitted by the sun's chromosphere and corona; and the Pioneer Venus orbiter, a mission to study Earth's closest planetary neighbor.

Technological innovations developed for Pioneer Venus have been refined and carried over into two other NASA interplanetary programs, Magellan and Galileo. The sole scientific instrument on board Magellan is the Hughes radar mapper, which produces images of the Venusian surface ten times clearer than those obtained by Pioneer.

The Hughes-built Galileo probe will become the first spacecraft to enter the atmosphere of an outer planet when it encounters Jupiter in late 1995. Carried on its six-year journey by the Galileo orbiter, the probe will separate as it nears Jupiter and race toward the giant planet. Once slowed by entry forces, the probe will deploy a parachute and float through the atmosphere, gathering data that could hold clues to the solar system's origin.

Hughes is also responsible for the shuttle's Integrated Radar and Communications System, which enables the shuttle crew, without ground assistance, to locate and rendezvous with satellites in low-Earth orbit in order to repair, maintain, or recover them. Further, it allows crews to talk to Earth or transmit pictures, high-speed data streams, or payload telemetry.

Contact: Thomas Brackey, (213) 414-7017.

IBM Corporation

IBM has provided computer hardware, software, systems engineering, and integration services for every US manned space flight program since Mercury. In 1962, IBM developed the central data processing system for the Johnson Center's Real-Time Computer Complex, forerunner of today's Mission Control Center. The company modernized the system as it evolved to serve the Gemini, Skylab, and space shuttle programs. Today, IBM is helping NASA design mission control and flight training and simulation facilities for the space station era and beyond.

IBM produced the shuttle's primary avionics subsystem — the on-board data

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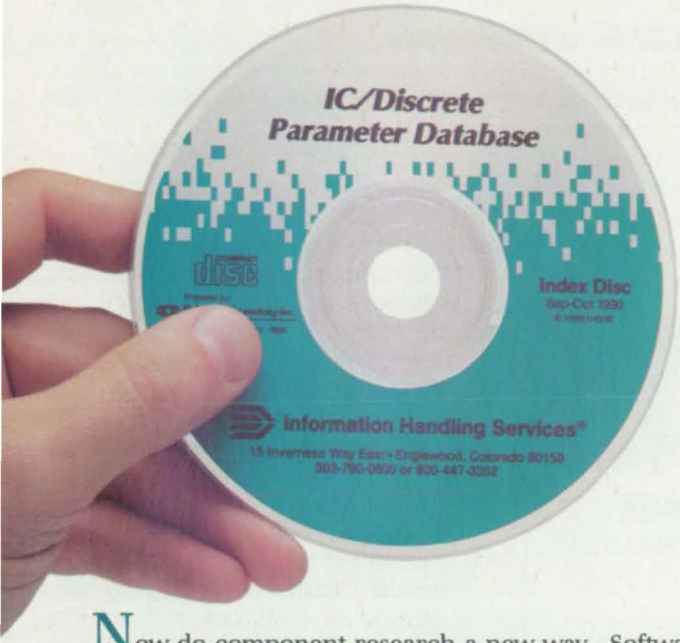

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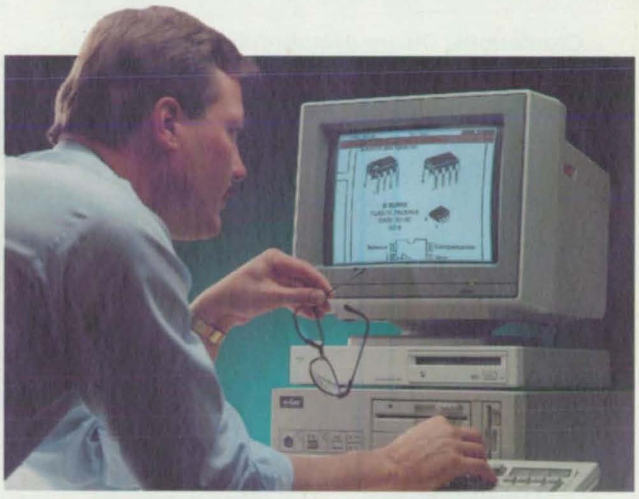

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processing system that guides, navigates, and controls the vehicle in flight. It developed the on-board flight computers and more than two million lines of complex operating system and support software. Today, IBM is applying advanced technologies to the system in the areas of artificial intelligence, computational fluid dynamics, data archival systems, software engineering, and neural networks, and is working to upgrade the shuttle's simulation systems with state-of-the-art interface devices and generic simulation models.

In coordination with McDonnell Douglas, IBM is developing the Freedom station's on-board data management system, a distributed system of compatible processors and other devices connected by a high-speed FDDI network. The system is designed to accommodate the insertion of new technology — such as high-power processors, high-density memory, and optical storage media — as it becomes available.
Contact: Julia Delph, (713) 282-7842

Lockheed Corporation

Lockheed plays a major role in three of the work packages for space station Freedom, and is the program's prime contractor for software development. Under contract to Boeing, Lockheed will supply equipment for the life sciences portion of the US laboratory and will integrate the life-science equipment for the laboratory module. For McDonnell Douglas, Lockheed is designing the station's extravehicular activity system, active thermal control system, and rotary mechanisms. And the company will supply Rocketdyne with photovoltaic solar power array wings that will generate electricity for station payloads and operation.

Under the Software Support Environment contract for NASA Headquarters, Lockheed will provide the tools, rules, and standards that will enable hundreds of NASA engineers and contractors at different locations to build space station software in a uniform, error-free manner.

Lockheed also serves as systems integrator for the Hubble Space Telescope. The company designed and developed the telescope's Support Systems Module — the structure that encloses the optical telescope assembly and scientific instruments and provides the essential systems to keep the observatory operating in the hostile environment of space.

Last May, the Marshall Space Flight Center awarded Lockheed a five-year contract for the design, development, and testing of the space shuttle advanced solid rocket motor, which will give the shuttle an additional 12,000 pounds of lift capacity.
Contact: Andrea Patterson, (408) 742-6688.

Martin Marietta Corporation

Martin Marietta's Astronautics Group in Denver, CO, designed and developed the Magellan spacecraft that has been mapping Venus since September; provided flight control electronics and scientific instruments for the Galileo mission to Jupiter; and produced a highly-sensitive astronomical spectrograph for the Hubble Space Telescope that will analyze the chemical composition of stars, galaxies, and quasars. The group is now developing a satellite system that will be deployed from and retrieved by the space shuttle using a tether up to 78 miles long. The system will be used to study plasma physics, power generation, and regions of the Earth's upper atmosphere previously accessible only to

sounding rockets.

For space station Freedom, the Astronautics Group is developing the Flight Telerobotic Servicer (FTS), a multi-armed robot that will help astronauts build the station in orbit. The FTS will have dual video cameras for eyes and a computer brain with artificial intelligence, enabling it to perform complex assembly tasks with minimal direction from humans. NASA expects the FTS eventually to be able to carry out tasks such as refueling a satellite or repairing a truss structure with a single command.

New Orleans-based Martin Marietta Manned Space Systems, builder of the space shuttle external tank, has a highly-active technology transfer program in coordination with NASA. One beneficiary of this program is Copeland Industries of Hartselle, AL. A weld torch positioning sensor developed for the shuttle program has been modified and applied to one of Copeland's weld stations used in the manufacture of industrial air conditioning compressors. The sensor improves the precision of the welding operation, reducing the incidence of leaks in the compressor housings.
Contact: Gordon Dyer, (504) 257-0352.

Artwork courtesy Jet Propulsion Laboratory

A team of Martin Marietta engineers operates the Magellan spacecraft which is presently orbiting Venus and mapping its surface. Using synthetic aperture radar to pierce the planet's thick cloud cover, Magellan has captured images of craters large enough to swallow the city of Los Angeles, volcanic lava flows, and pancake-like domes.

McDonnell Douglas Corporation

McDonnell Douglas has a contract with the Johnson Center to develop a laser docking system that would permit spacecraft to rendezvous and dock under a variety of conditions. Applications include docking the space shuttle with space station Freedom and docking unpiloted spacecraft with satellites for servicing or refueling. Within the Space Exploration Initiative, autonomous rendezvous and docking would be used in early robotic missions, such as a mission to collect soil and rock samples on Mars, where the spacecraft would have no contact with Earth during critical rendezvous operations.

The company also is working on a NASA program with MIT called MODE (Middeck Zero Gravity Dynamics Experiment) which looks to determine the differences between the dynamics of large structures on the ground under 1-g test conditions and in space under 0-g conditions. By understanding these differences, researchers will be able to better predict the on-orbit behavior of large structures based on mathematical models and limited ground testing. MODE on-orbit testing will be conducted on a shuttle flight scheduled for September.

McDonnell Douglas is continuing its work in the area of on-orbit assembly of large aerobrakes. A series of neutral buoyancy tests planned for late summer in the company's underwater test facility will utilize an aerobrake mock-up to evaluate refined operations and joint mechanisms. The test data will help define aerobrake vehicles for future lunar and Mars missions, as well as the on-orbit facilities needed to assemble and service them.

As prime contractor for space station work package two, McDonnell Douglas oversees program management, systems engineering and integration, design and development, and manufacturing and testing of hardware for the space facility.
Contact: Anne McCauley, (714) 896-6211.

Rockwell International Corporation

Rockwell's numerous aerospace activities include building the space shuttle orbiters and their main engines, the photovoltaic and solar dynamic power systems for space station Freedom, and rocket engines for expendable launch vehicles; providing logistical and support activities at several NASA field centers; and participating in the consortium designing the X-30 National Aero-Space Plane. Rockwell is also designing elements of NASA's Shuttle-C, a proposed heavy-lift unmanned launch system derived from shuttle technology.

In addition to its contract work, the company is conducting in-house research for the President's Space Exploration Initiative. In one project, Rockwell has teamed with Fluor Daniel, an engineering and construction firm, and Spar Aerospace, builder of the shuttle's remote manipulator system, to study concepts for a proposed lunar base.

Last May, NASA and the Department of Defense approved the formation of a five-contractor consortium led by Rockwell to continue development of the National Aero-Space Plane. Members are General Dynamics, McDonnell Douglas, Pratt and Whitney, Rocketdyne, and Rockwell North American Aircraft. The team will design and build an experimental aircraft that will fly into orbit using a conventional runway for takeoff and landing and reach speeds up to Mach 25 (17,500 miles per hour).
Contact: Elise Nicholson, (213) 922-2314.

TRW Inc.

The Gamma Ray Observatory (GRO), a 17-ton spacecraft built by TRW, will open a new era in astronomy when it is lofted into space by the shuttle later this month. From an orbit 279 miles above Earth's obscuring atmosphere, the GRO will map gamma rays, an invisible form of energy that promises to reveal clues to the formation and fate of the universe. Its instruments will study gamma ray sources 10 to 50 times fainter than those previously observed, enabling scientists to gather data about quasars, pulsars, and other phenomena.

TRW is developing another spacecraft that will look at a different portion of the electromagnetic spectrum, x-ray energy. Called the Advanced X-Ray Astrophysics Facility (AXAF), the free-flying observatory will have 1000 times more capability for spectroscopy than any previous or planned x-ray mission. Scheduled for launch in 1997, AXAF will be used to investigate the existence of stellar black holes and dark matter in galaxies, and to determine the age of the universe.

Data collected by the GRO and AXAF will be relayed to processing centers on the ground via a Tracking and Data Relay Satellite (TDRS) designed and built by TRW. With three satellites now in orbit and a fourth scheduled for launch this summer, the TDRS system provides nearly continuous communications between spacecraft in low-Earth orbit and the Earth. The system's high data rates and large number of antennas enable it to track up to 26 satellites at a time and relay the equivalent of a 20-volume encyclopedia in a second.
Contact: Montye Male, (213) 812-4721.

(continued on page 110)

New Product Ideas

New Product Ideas are just a few of the many innovations 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 18). NASA's patent-licensing program to encourage commercial development is described on page 18.

Platinum/Tin Oxide/Silica Gel Catalyst Oxidizes CO

A heterogeneous catalyst of platinum, tin oxide, and silica gel combines small concentrations of the laser dissociation products, CO and O_2, to form CO_2 during long times at ambient temperature. The catalyst was developed as a means to prevent the accumulation of these products in sealed CO_2 lasers.
(See page 66)

Liquid-Crystal Light Valve Enhances Edges in Images

A liquid-crystal light valve can be made to operate in an edge-enhancing mode by suitably adjusting the bias voltage and frequency. A real-time edge-enhancement technique can increase the discrimination between similar objects.
(See page 54)

Adsorbent Removes Traces of Oxygen

A carbon molecular sieve containing copper oxide effectively removes oxygen from gas mixtures, producing a gas containing less than 1 part per billion of oxygen. The material has a strong affinity for oxygen but rejects larger molecules.
(See page 67)

Fast Magnetoresistive Random-Access Memory

A memory cell is proposed that would use a ferromagnetic material to store the datum and an adjacent magnetoresistive material to sense the datum for readout. This arrangement promises shorter sampling and readout access times.
(See page 32)

Active Compliance and Damping in Telemanipulator Control

An experimental telemanipulator system provides for various combinations of conventional force-reflecting hand control and/or active compliance. Variable simulated springs and shock absorbers soften collisions and increase dexterity.
(See page 48)

Ferroelectric Memory Capacitors for Neural Networks

Thin-film ferroelectric capacitors are proposed as nonvolatile analog memory devices. They could be interrogated without destroying the stored analog data; consequently, memory circuits would be simpler. The devices would be amenable to very-large-scale integration.
(See page 26)

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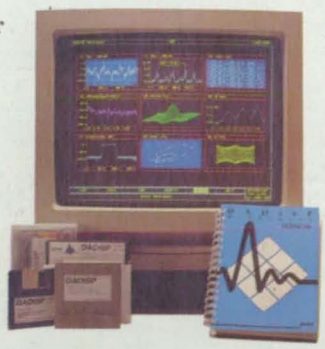

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If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low-and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information 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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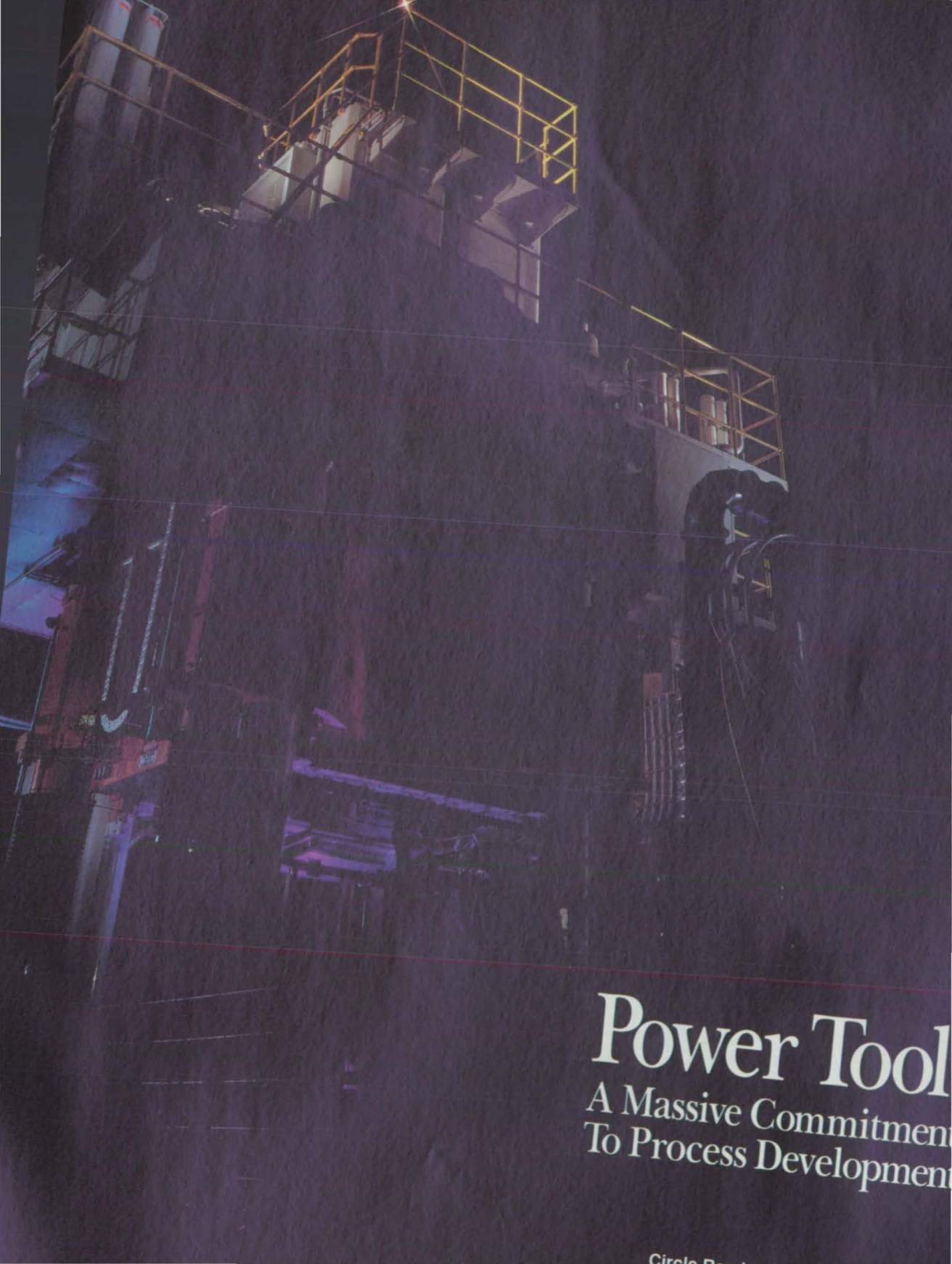

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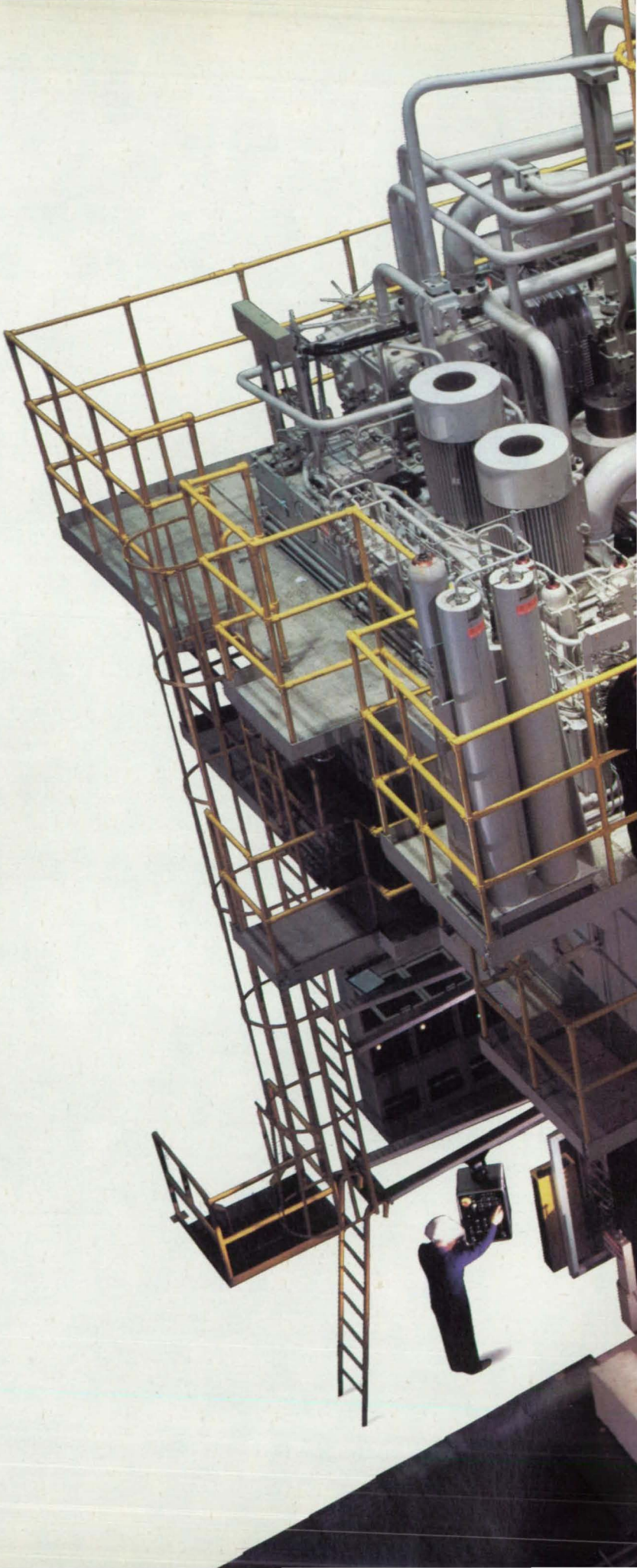

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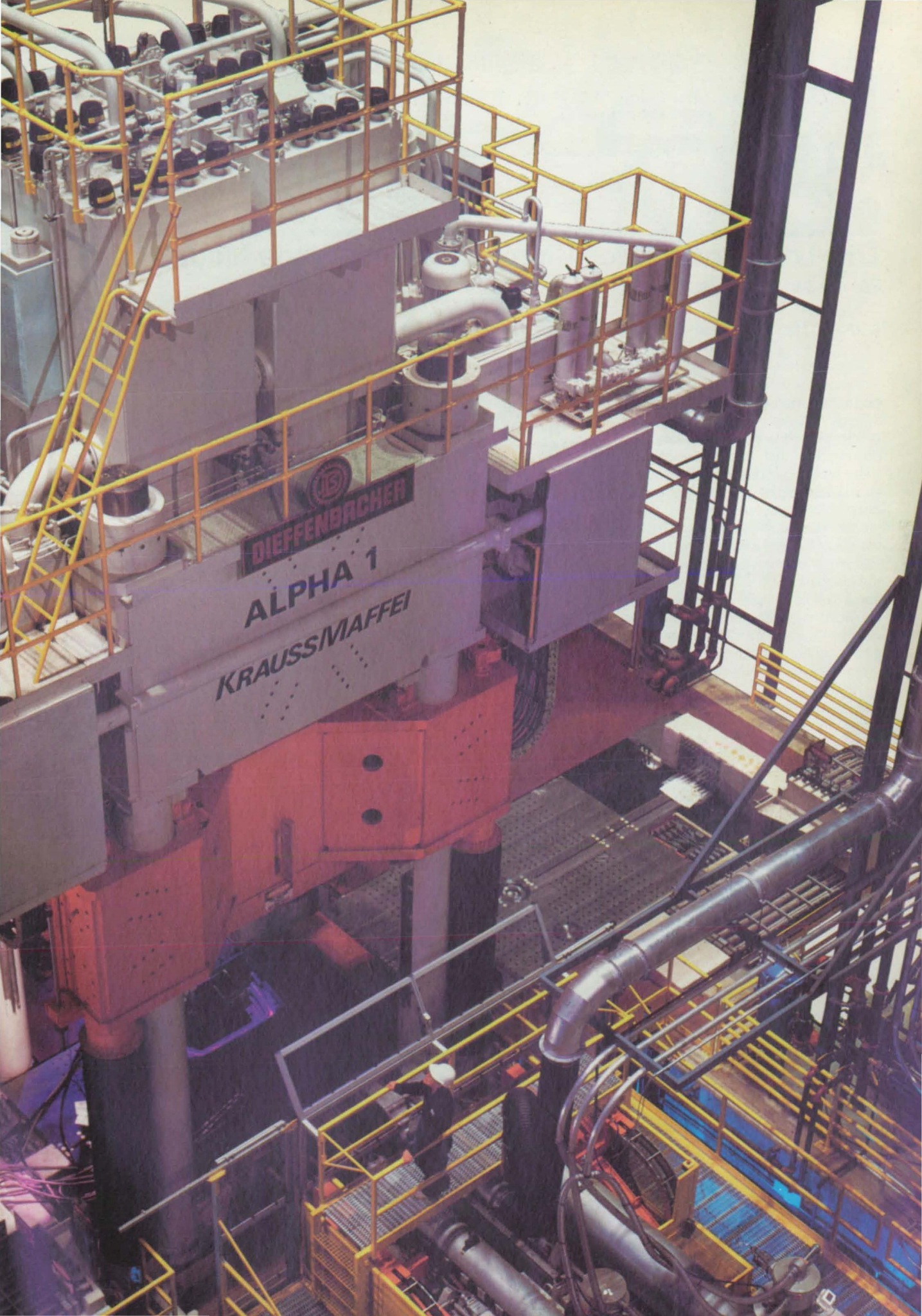
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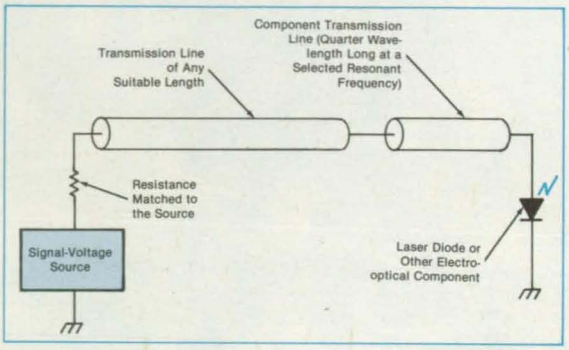
Low-Loss Coupler for Microwave Laser-Diode Modulation

Elimination of a series resistor reduces the loss of radio-frequency power.

Langley Research Center, Hampton, Virginia



A **Quarter-Wavelength Matching Section** connected to a transmission line eliminates the need for a resistor near the laser diode and extends the frequency response of system.

Recent trends in high-bit-rate communication dictate a need for a signal-processing system that can operate in the frequency range from direct current to microwaves. Unfortunately, the outputs of many components, particularly laser diodes, decrease with increasing frequency. To increase operating frequencies, such devices are typically designed to have reduced capacitances. They are mounted such that the lengths of the lead wires are minimized to reduce series inductance. Further, since the resistance of a laser diode is typically about 5 ohms, a resistor of about 45 ohms is placed in series with the device, providing an impedance match when the device is connected to a coaxial cable having a 50-ohm characteristic impedance.

However, resistors generate heat. Typically, a resistor connected to a laser device that is in a package is required to be located outside the package to dissipate the heat. The need to keep lead wires short makes the use of an outside resistor particularly difficult, and the resistor reduces the output of the laser.

Therefore, it is desirable to eliminate the resistor and to extend the frequency response of a laser, the output signal of which decreases with the frequency of the modulation. The figure illustrates a design concept intended to accomplish this. It includes a signal-voltage source and a resistance matched to the source. The resistance is coupled to a transmission line of indefinite length. The other end of the transmission line is coupled to the input end of another transmission line called the "component" transmission line, which has an impedance of about zero ohms. The output end of the component transmission line is coupled to a semiconductor laser diode or other component.

The component transmission line is initially resonant at a second frequency greater than a first frequency at which the output of the component begins to decrease. For a laser diode, the resonant frequency is typically chosen to be about 1.5 to 3 times as great as the frequency at which the output voltage is at the −3-decibel level. Typically, the electrical length of the component transmission line is chosen to be about one-quarter of the wavelength at this resonant frequency.

The magnitude of the resonant peak can be altered by changing the characteristic impedance and the length of the component transmission line, and, if chosen correctly, the peaking effect can compensate for the decrease in the output of the component with increasing frequency. This concept significantly extends the relatively flat frequency response of a laser diode or similar component, while simplifying the design of its package, increasing the amplitude of the output signal, and reducing the dissipation of heat by eliminating a resistance. Further, the phase characteristics are approximately linear and, therefore, any digital information transmitted is not significantly altered.

This work was done by Minoru Toda of the David Sarnoff Research Center, Inc., for **Langley Research Center**. *No further documentation is available.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)] to General Electric Canada, Inc. Inquiries concerning licenses for its commercial development should be addressed to

Raymond A. Eckersley
Manager, Patents and Licensing Services
General Electric Canada, Inc.
23 Meadowvale Boulevard
Mississauga, Ontario
Canada L5N 5P9

Refer to LAR-13788, volume and number of this NASA Tech Briefs *issue, and the page number.*

Lightweight, High-Energy Lead/Acid Battery

Woven electrodes would increase the energy-to-weight ratio.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for a lead/acid battery calls for woven-grid bipolar electrodes. In a high-voltage configuration, the battery would have higher specific energy and power than do conventional lead/acid batteries. It would be rugged, longlived, and maintenance-free. Made from readily available, low-cost materials by standard lead/acid production methods, the battery would be particularly well suited for use in electronic equipment, aircraft, and electric vehicles for industrial and passenger service.

The proposed battery would be composed of stacked cells. Each cell would include a bipolar electrode — an electrode with positive and negative areas. The electrodes would be supported by continuously woven fiberglass yarn. An extruded lead sheath would cover the transverse weave. The longitudinal weave would be merely coated with sizing: because longitudinal conductivity is not needed, the lead covering would be eliminated to save weight. A strip of hot-melt tape would be applied

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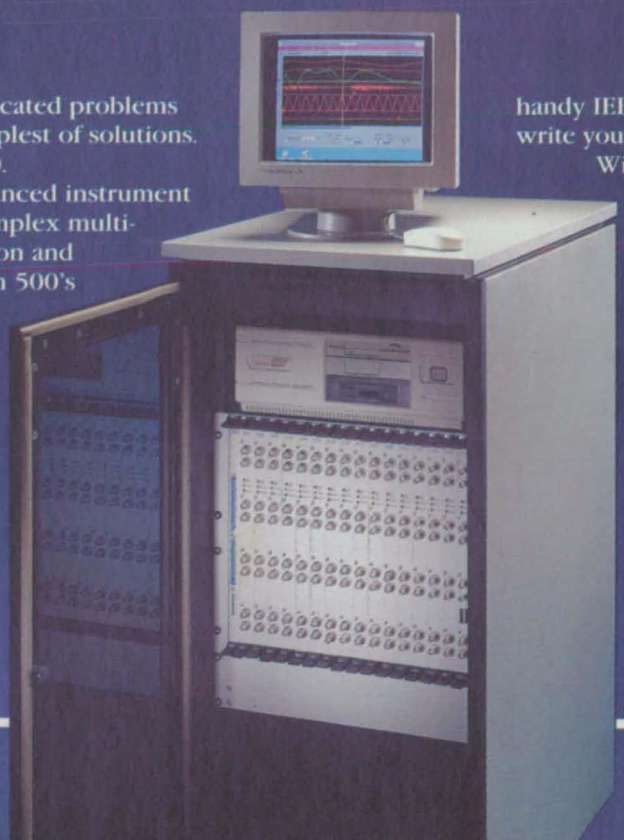

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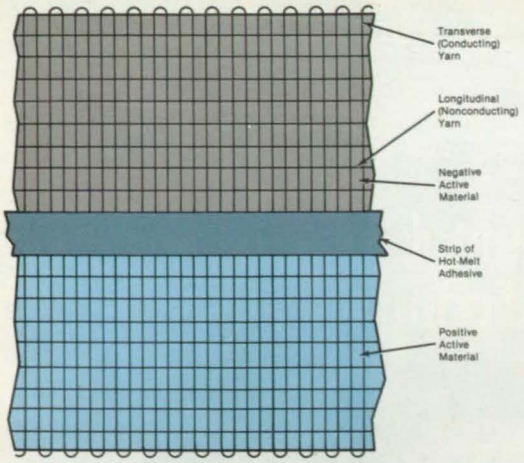


Figure 1. **Pastes on the Woven Electrode** make half negatively active and half positively active.

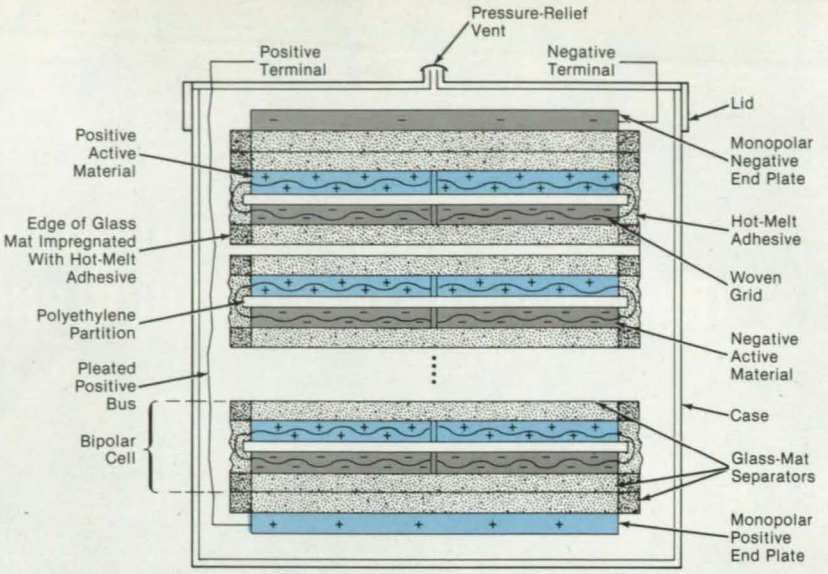


Figure 2. The **Stack of Bipolar Cells** forms a lead/acid battery. Each cell contains a pair of folded electrodes, like the one shown in Figure 1, that are negative on one side of the fold, positive on the other.

along the middle of a woven electrode.

The electrode, while still flat, would be coated on one side of the middle tape with a positive paste and on the other side with a negative paste (see Figure 1). The electrode would then be folded in half along the tape.

A pair of folded electrodes would be slipped over opposite edges of a polyethylene partition sheet, so that the negative halves of the two bipolar strips would be on one side of the partition and the positive halves on the other. The electrode would then be folded in half along the tape. The electrode-and-partition subassembly would be sandwiched between a pair of glass mats and sealed on the edges by an adhesive. Electrolyte would be immobilized within the cell so that acid would not be released if the battery case were damaged. A small tube in each hot-melt border would allow excess gas to be vented.

Final assembly would consist of filling the cells with the electrolyte, placing conventional monopolar electrodes at the ends of the cell stack, connecting the end electrodes to the battery terminals via lead buses, inserting the stack into the case, and sealing a lid on the case. The stack (see Figure 2) would be force-fit into a housing to ensure the optimum cell pressure.

According to design calculations, an assembly measuring 7.12 by 10.5 by 5.25 in. (18.1 by 26.7 by 13.3 cm) and having a mass of 11.8 kilograms would have a capacity of 5.72 ampere-hours. Its specific energy would be 58.6 watt-hours per kilogram at 58-percent positive-plate utilization. The output voltage would be 20 volts per in. of stack height (7.9 volts/cm). The inactive mass would be only 29 percent of the total, compared with about 40 percent for conventional designs. The assembled battery could be operated in any orientation.

This work was done by Wally E. Rippel and Dean B. Edwards of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 108 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

Refer to NPO-16962, volume and number of this NASA Tech Briefs *issue, and the page number.*

Circuit for Current-vs.-Voltage Tests of Semiconductors

The principal virtues are low cost, simplicity, and compactness.

Marshall Space Flight Center, Alabama

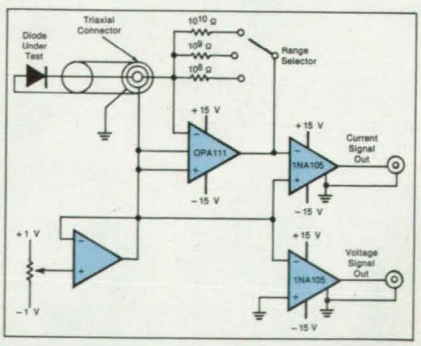
A simple, easy-to-use circuit is designed for measurement of the dc current-versus-voltage characteristics of semiconductor devices. The principal virtues of this circuit are that in comparison with most laboratory testers designed for the same purpose, it is simple, compact, and inexpensive.

The circuit (see figure) would be operated in conjunction with an x–y pen plotter or a digital storage oscilloscope, which would record the data. A ramp-waveform generator could be inserted in place of the potentiometer for automatic testing. If the ramp frequency is great enough to suppress the appearance of flicker but not so great that the current and voltage waveforms become distorted by the capacitances of the device or circuit, then the current-vs.-voltage curves could be displayed on an ordinary oscilloscope.

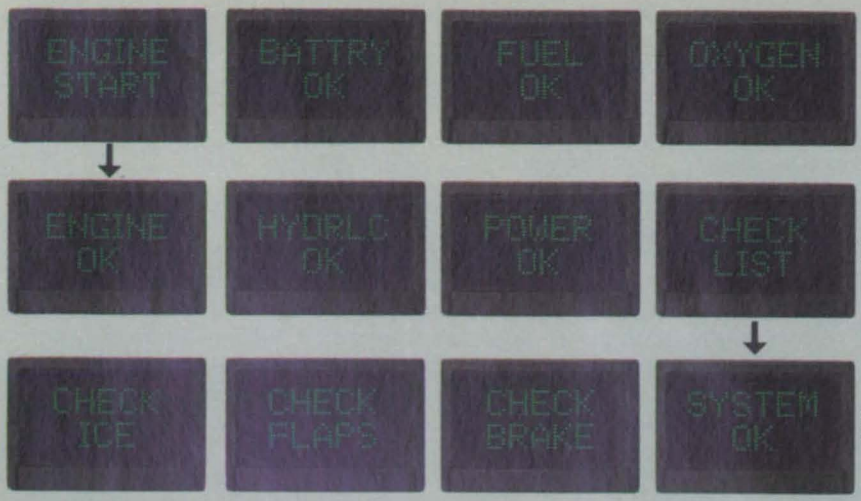
The circuit includes large feedback resistors to prevent high currents that would damage the device under test. A triaxial BNC (or equivalent) connector in a driven-shield configuration that minimizes the capacitance between the inner and outer coaxial leads is used as the port for the device under test. This minimization of capacitance allows a faster scan. If a transistor or other three-terminal device is to be tested, a power supply driven by a digital-to-analog converter can be connected to the third terminal.

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

MFS-29623



The **Current-vs.-Voltage Testing Circuit** can be used to evaluate diodes and transistors.



AN APPLICATIONS EXAMPLE. While the following example is for aircraft, it could apply to any air, land, sea or space system.

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SEQUENCE TWO: The four-pushbutton display now changes to read "ENGINE OK," "HYDRLC OK," "POWER OK," "CHECK LIST." The operator selects "CHECK LIST."

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SERIES

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Ferroelectric Memory Capacitors for Neural Networks

Features would include nondestructive readout, simplicity, and resistance to ionizing radiation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Thin-film ferroelectric capacitors have been proposed as nonvolatile analog memory devices. They are intended primarily for use as synaptic connections in electronic neural networks. Specifically, the connection strengths (synaptic weights) would be stored as the nonlinear remanent polarizations of ferroelectric films. In contrast with older ferroelectric memory devices that store binary data, the proposed devices could be interrogated without destroying the stored analog data; consequently, memory circuits would be simpler because no concurrent memory-refreshing circuitry would be needed. The proposed devices would be amenable to very-large-scale integration. They would allow the use of ac coupling, which would eliminate errors caused by dc offsets in the amplifier circuits of neural networks.

A memory device could be made in a vertical or a lateral configuration (see Figure 1). In the vertical configuration, two thin ferroelectric films would be interspersed with three metal electrodes. The upper ferroelectric film would serve as the dielectric analog memory element of a memory capacitor and would be tailored to have excellent piezoelectric properties. The lower ferroelectric film would serve as the dielectric element of an interrogation (readout) capacitor and would be tailored to have excellent electrostrictive (inverse piezoelectric) properties. An ac interrogating signal would be applied to the interrogation capacitor, acting via the electrostrictive effect to generate an elastic strain wave that would be coupled into the memory capacitor. Acting via the piezoelectric effect, the elastic wave would cause the memory capacitor to put out a signal proportional in magnitude and related in phase to the direction of the remanent polarization in the upper ferroelectric film. Thus, the datum stored as the remanent polarization would be read out without destroying it.

In the lateral configuration, the two capacitors would lie side by side and would share both the same dielectric film and a common electrode. The principle of operation would be similar to that of the vertical configuration. In this case, the interrogating signal would be applied to, say, the left electrode, the elastic wave would propagate along the single ferroelectric film to the right electrode, and the output signal would be coupled out through the right electrode.

A datum could be stored in a memory capacitor optoelectronically. For example, an additional layer of photoconductive hydrogenated amorphous silicon atop the upper electrode in the vertical configuration could be exposed to light in an image (see Figure 2). The local brightness of the light would control the electrical conductivity of the photoconductive layer, causing a bias voltage and, consequently, the remanent polarization, to vary accordingly. Operating in this manner, an integrated-circuit planar array of such devices could store information from an image projected on it.

This work was done by Sarita Thakoor, Alexander W. Moopenn, and Henry L. Stadler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 125 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 18]. Refer to NPO-17973.

Figure 2. A **Photoconductive Layer Modulated by Light** would provide a variable resistance to alter the bias signal applied to the memory capacitor.

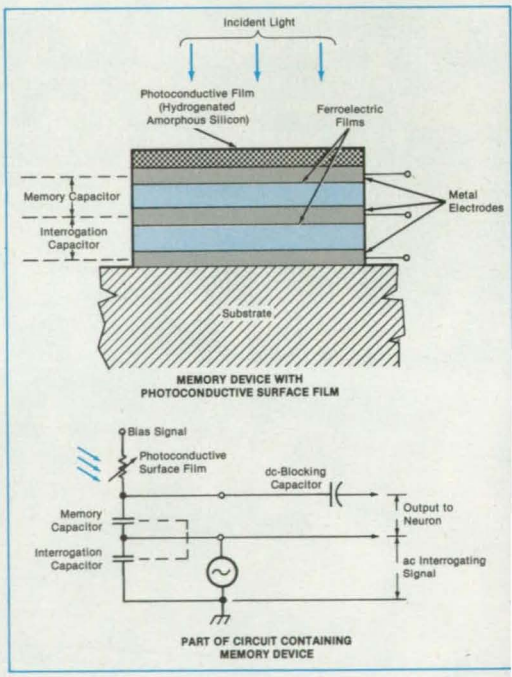
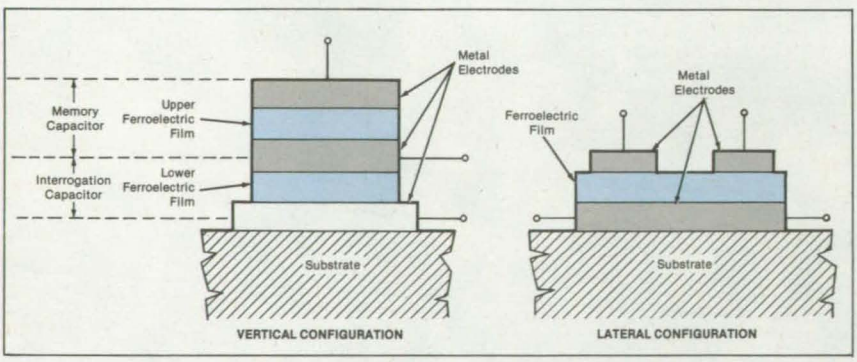


Figure 1. **Ferroelectric Memory and Interrogation Capacitors** would be combined into memory devices in vertical or lateral configurations.



Electromagnetic Gun With Commutated Coils

Greater speeds should be attainable.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed electromagnetic gun would include an electromagnet coil, the turns of which would be commutated in sequence along a barrel. Electrical current would be fed to two armatures by brushes sliding on bus bars in the barrel. The interaction between the armature currents and the magnetic field from the coil would produce the force that would accelerate the armature, and the armature, in turn, would push on a projectile. The commutation scheme would be chosen so that the magnetic field would approximately coincide and move with the cylindrical region defined by the armatures (see Figure 1).

The rail- and coil-gun concepts investigated previously have fixed ratios of magnetic field to armature current. In addition, it is necessary to limit the armature cur-

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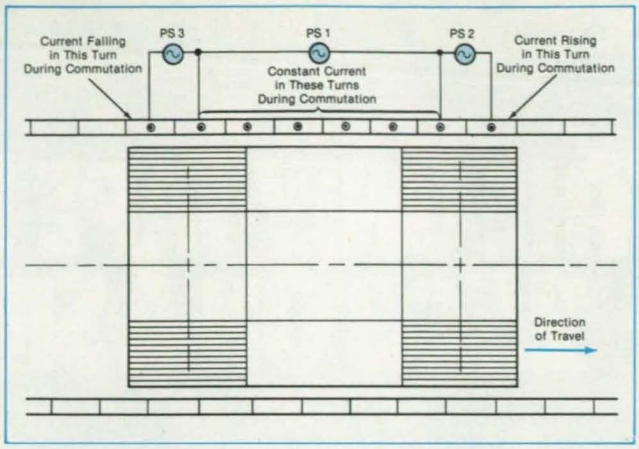

Figure 1. **Power Supplies Would Be Connected** to turns of an electromagnet coil in a sequence that would match the motion of the armatures.

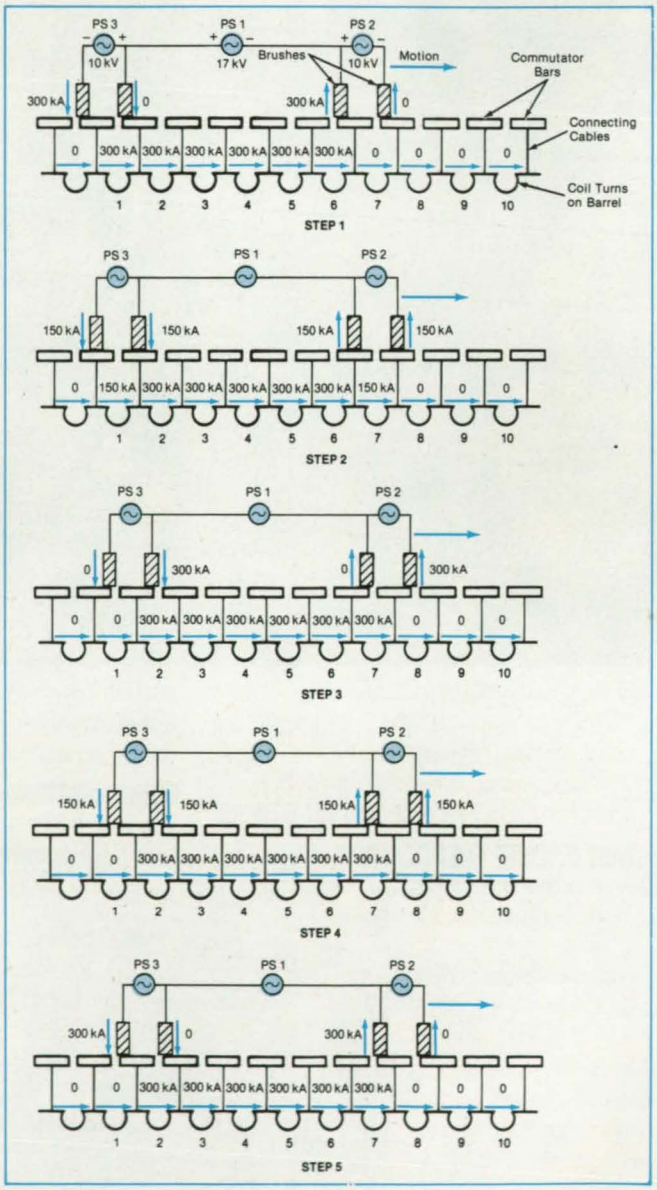

Figure 2. In **One Cycle of the Commutation Sequence** in the system of Figure 1, each brush contact would advance one step to the right.

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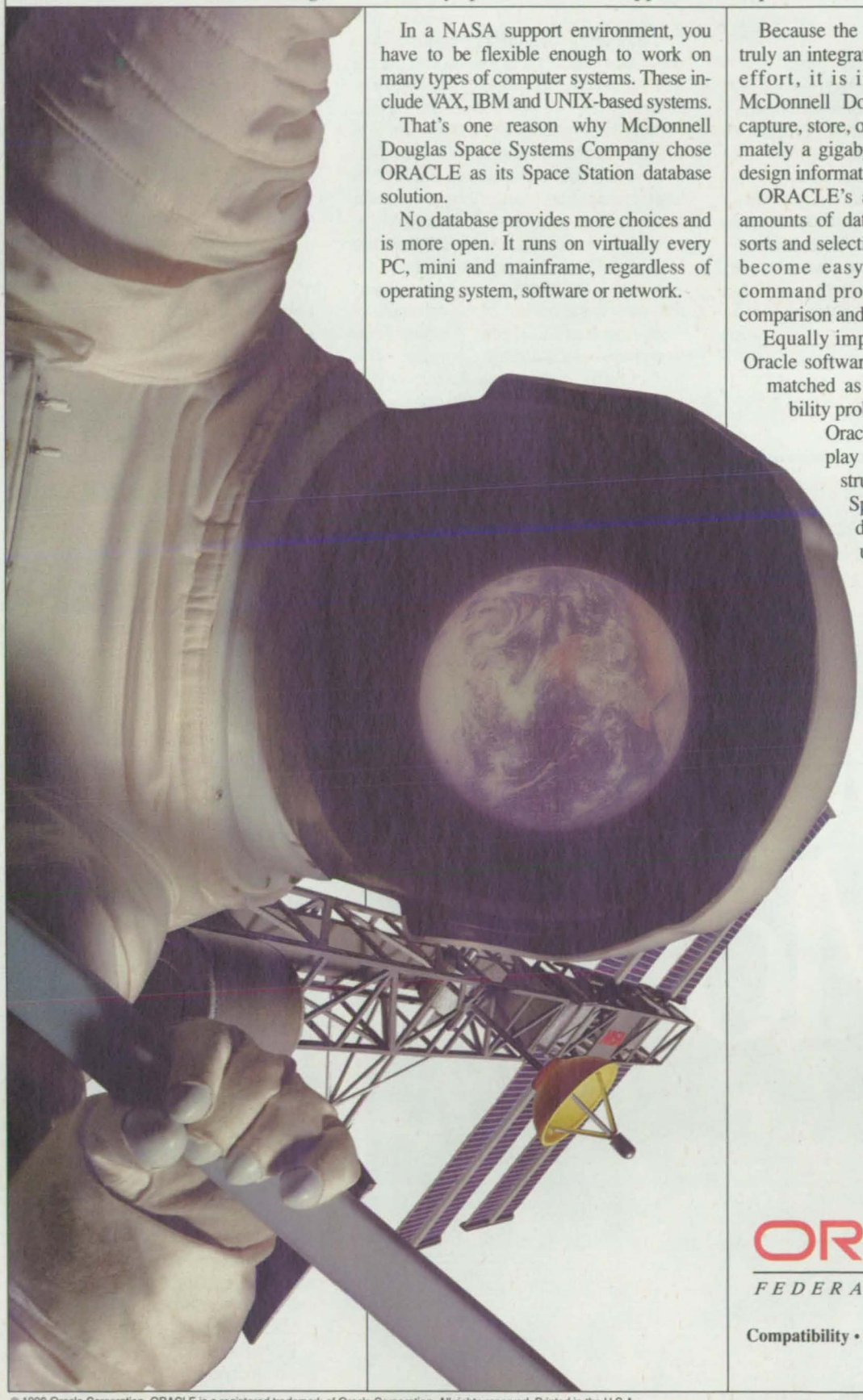

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rent to prevent overheating of the armature. This combination of features limits the attainable accelerating force and, consequently, the muzzle velocity. The proposed scheme has the disadvantage of complexity, but in return, it enables the designer to increase the driving magnetic field without increasing the armature current. In principle, the attainable muzzle velocity could be increased substantially.

The main coil power could be supplied by a pulsed dc generator or a disk-alternator-and-rectifier system. The output of the generator could be fed through electronic switches or brush contacts on a rotating commutator to stationary commutator bars, then through cables from the commutator bars to the turns of the coil. Either the commutator shaft could accelerate or else the spacing between the commutator bars could be decreased in the direction of motion of the brushes to increase the speed of switching as the armature and projectile accelerate. On the basis of feedback from an armature-position sensor, a control subsystem could adjust the armature current in such a way as to keep the armature coincident with the traveling wave of current in the coil. The required increase in coil voltage with travel could be provided by increasing the voltage supplied by the generator.

Figure 2 illustrates a typical commutation sequence for a coil commutated mechanically. In step 1, the main power supply, PS1, would be connected to the two inner brushes, supplying full current (300 kA according to one design) to turns 2 through 6. A smaller power supply or a capacitor, PS2, would cause the current in turn 7 to start to rise from zero. Another smaller power supply or a load, PS3, would cause the current in coil 1 to start to fall from the full value (300 kA in this example).

In step 2, the brushes would have moved rightward to the centers of the commutator bars. The current in turn 7 would have risen halfway toward the full value, while that in turn 1 would have fallen halfway from the full value. PS1 would continue to supply full current to turns 2 through 6.

In step 3, the brushes would have reached the right ends of the commutator bars, the current in turn 7 would have reached the full value, and the current in turn 1 would have fallen to zero. During a brief interval in step 4, each brush would touch two adjacent commutator bars, providing paths for the inductively sustained currents. During this interval, the terminals of PS2 and PS3 would be shorted, allowing the currents in PS2 and PS3 to redistribute themselves in transition to the next step. In step 5, the distribution of currents would be like that of step 1 except that the wave of current, the brushes, and the armatures would all have advanced one turn to the right.

This work was done by David G. Elliott of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 90 on the TSP Request Card.*
NPO-17839

Improved Rotary Transformer for Shaft-Position Indicator

An iron core is replaced by a ferrite core.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved rotary transformer for an Inductosyn (or equivalent) shaft-position-indicating circuit has a pair of ferrite cores instead of the solid-iron cores that would ordinarily be used in such an application. The transformer was designed with a view toward decreasing the excitation power (to the maximum allowable 2 W) supplied to the shaft-position-indicating circuit to increase its output signal and thereby make a tracking system in which it is to be used less vulnerable to electromagnetic interference.

The basic design calls for power to be supplied to the primary winding of the transformer at 5 to 7 V with a frequency of 10 kHz. Under these conditions, a pair of solid-iron cores would act much like a shorted secondary winding of the transformer, requiring extremely high excitation current and imposing high eddy-current losses.

Two rotary transformers were built: one with a pair of solid-iron cores, the other with a pair of ferrite cores. With the exception of the core material, both had the same design: dimensions as shown in the figure, primary winding consisting of 10 turns of No. 22 wire, and secondary winding consisting of 4 turns of No. 18 wire. The primary-to-secondary turns ratio of 2.5 gives an approximate match between the 10-Ω load required by the source of power and the 1.7-Ω load resistance of the shaft-position-indicating circuit.

Both transformers were tested under identical conditions. The expected shorted-secondary effect was observed in the solid-

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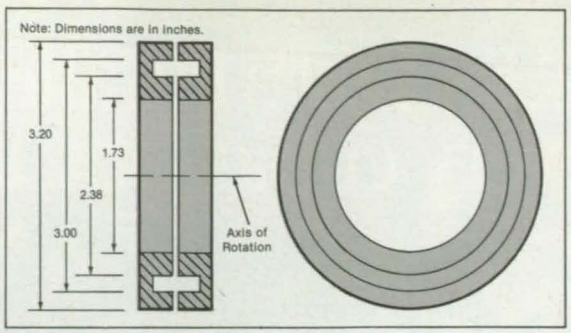
iron-core transformer, and an excitation current of more than 6 A was required to supply the induced eddy currents. This is far too much excitation current to be practical.

In contrast, the ferrite-core transformer required only 0.53 A of excitation and load current combined. The coefficient of coupling between the primary and secondary windings of the ferrite-core transformer was calculated to be about 0.96. The ferrite-core transformer was found to be able to furnish the required 2 W to the shaft-position-indicating circuit with a supply of only 5 V, representing an order-of-magnitude improvement in efficiency over the solid-iron-core transformer. A further reduction of about 20 percent in the full-load input current of the ferrite-core transformer was obtained by resonating the inductive reactance with a 1-μF capacitor connected across the primary winding.



Facing Half Cores of the rotary transformer contain grooves that accommodate the primary and secondary windings.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 141 on the TSP Request Card.*
NPO-17169

Fast Magnetoresistive Random-Access Memory

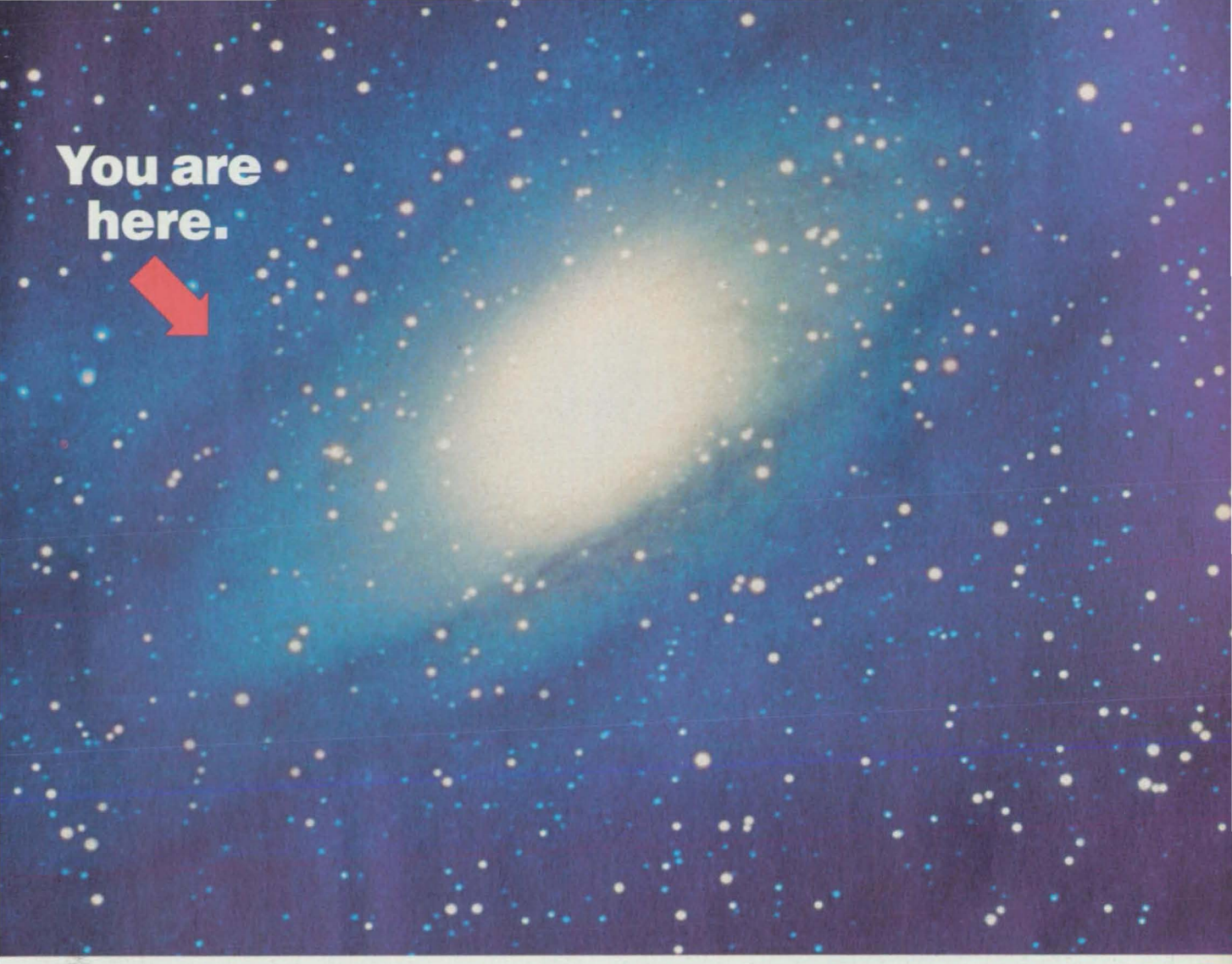
Separate materials would be used for sensing and for storage.

NASA's Jet Propulsion Laboratory, Pasadena, California

Magnetoresistive binary digital memories of a proposed new type are expected to feature high speed (readout access time < 100 ns), nonvolatility, ability to withstand ionizing radiation, high density (>10^6 bits/cm^2), and low power. In prior research on magnetoresistive memories, data have been both stored and read out by devices made of materials that are both ferromagnetic and magnetoresistive. The magnetoresistive signal from the magnetoresistive effect in these materials is weak, necessitating long sampling times and, therefore, unacceptably long readout access times (microseconds in some designs). In some cases, it has been necessary to sacrifice density to increase speed.

In a memory cell of the proposed type, the magnetoresistive effect would be exploited more efficiently by use of a ferromagnetic material to store the datum and an adjacent magnetoresistive material to sense the datum for readout. Because the relative change in sensed resistance between the "zero" and "one" states would be greater, shorter sampling and readout access times should be achievable.

Figure 1 illustrates one version of a proposed magnetoresistive device in a memory cell. A high-resistivity magnetoresistive film (e.g., Bi or InSb) would be sandwiched



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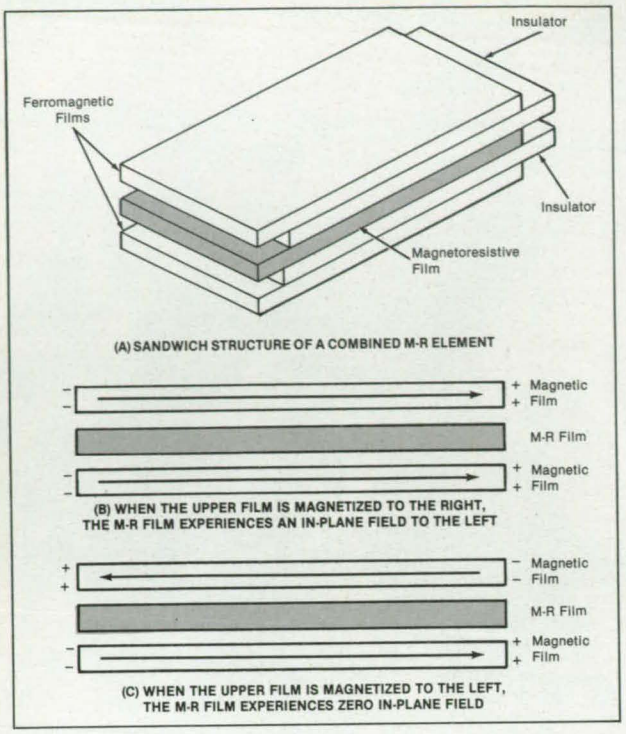


Figure 1. The **Ferromagnetic Recording Medium** would be separate from the magnetoresistive sensing medium in a memory device of the proposed type.

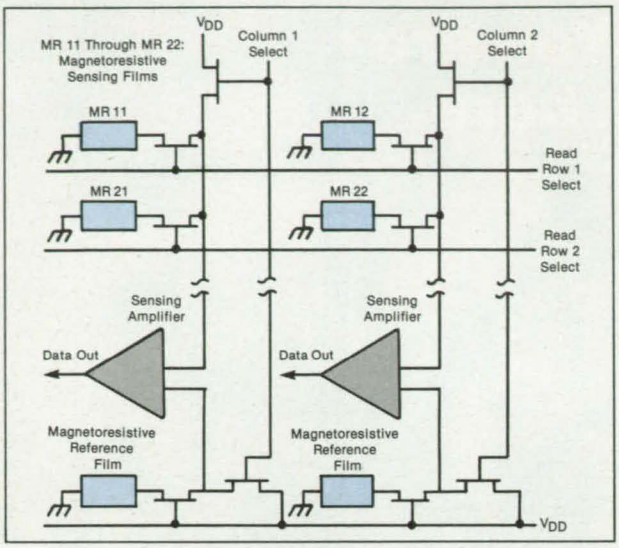


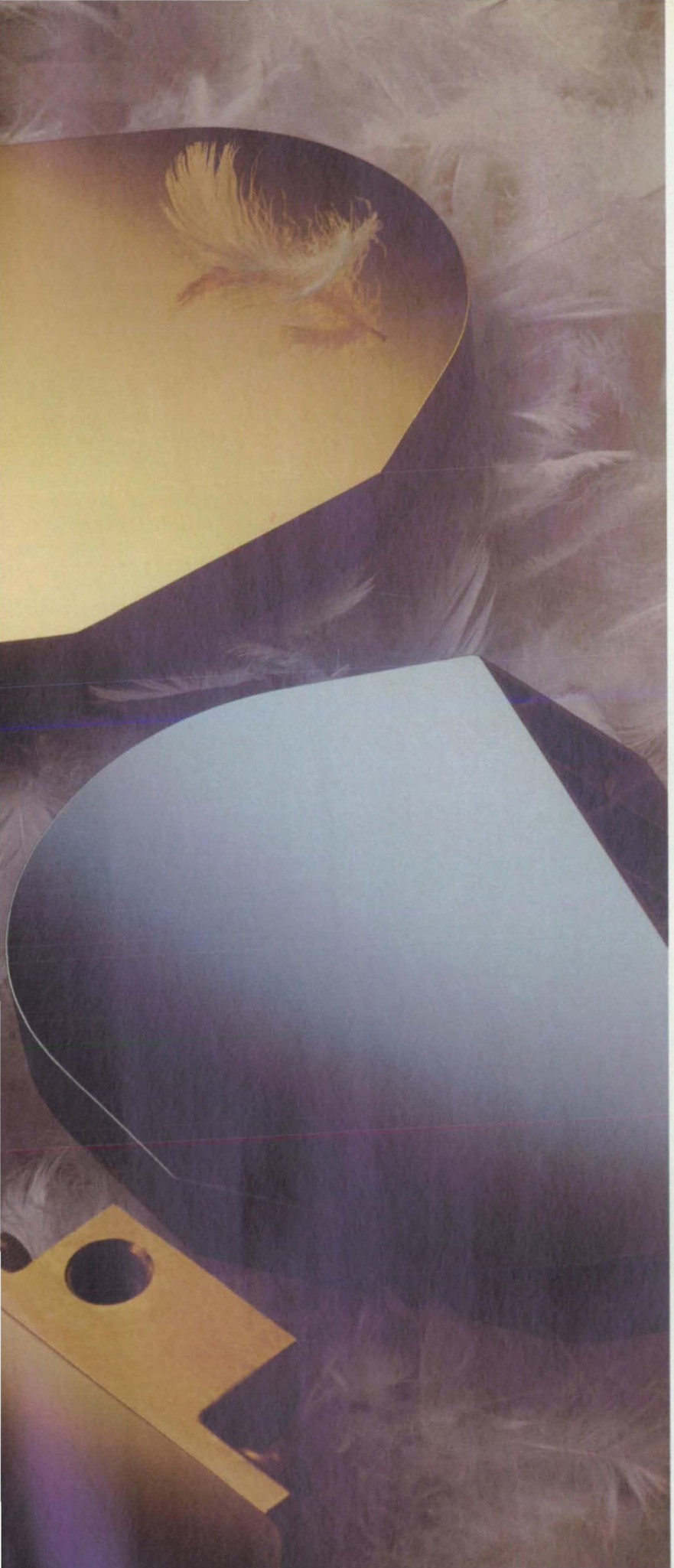
Figure 2. This **Readout Circuit** would include the magnetoresistive films of four devices like that of Figure 1 and would read out the data stored in the upper ferromagnetic films of those devices.

between an upper and a lower ferromagnetic film (e.g., an irón-based nickel alloy or a cobalt-based alloy) separated from the ferromagnetic films by electrically insulating films. In a rectangular planar array of memory cells containing such devices, a datum would be written into the upper ferromagnetic film of one cell by a transistor-matrix row-and-column selection scheme.

In this version, the magnetization field would be parallel to the film planes. The lower ferromagnetic film would be selected to have a coercive force greater than that of the upper magnetic film. The magnitude of the writing magnetic field would be selected to lie between the coercive forces of the upper and lower films so that the polarity of the magnetization in the upper film could be reversed by the writing field (signifying transitions between "one" and "zero"), but the lower film would remain magnetized rightward (or leftward) all the time.

When the upper and lower films were polarized oppositely (signifying "zero," for example), the magnetic fields would oppose each other in the magnetoresistive film, yielding zero net field, and the electrical resistance of the magnetoresistive film would be unaffected. When the upper and lower films were both polarized in the same direction (signifying "one" in this case), the magnetic fields would reinforce each other in the magnetoresistive film, giving rise to a measurable change in its electrical resistance.

A memory of the proposed type would be fabricated by extension and combination of semiconductor-integrated-circuit and magnetic-thin-film technology. Figure 2 shows an example of the readout circuit of a simple memory. Assuming such typical parameters as a supply voltage (V_{DD}) of 5 V and a magnetoresistive coefficient of 0.01, the output voltage indicative of a change in the logic state of one cell of this memory would be 12.5 mV. Such a voltage can be amplified by a simple complementary metal oxide/semiconductor sensing amplifier. The readout access time would be determined primarily by the ability of the associated electronic circuits to drive the row and column lines. Success of this concept would depend on close matching of the electrical characteristics of the tran-



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Young's Modulus (GPa)	303	311	71	68
Microyield Stress (MPa)	35	(**)	98	24
Thermal				
CTE ($10^{-6}\ K^{-1}$)	11.4	2.57	24.0	0.03
Diffusivity ($cm^2\ s^{-1}$)	0.52	0.80	0.96	0.008
Specific Heat ($J\ kg^{-1}\ K^{-1}$)	1,880	670	900	766
Conductivity ($W\ m^{-1}\ K^{-1}$)	180	156	237	1.3
Figures of Merit(***)	**Be**	**SiC(*)**	**Al**	**ULE™**
Structural (higher is better)				
Specific Stiffness (E/ρ)	164	107	26	31
Thermal (lower is better)				
1st Order Distortion (CTE/k)	0.063	0.017	0.101	0.023
Thermal Distortion (CTE/D)	22.2	3.26	25.0	3.92
Dim. Change (CTE • ρ/k)	118	48.1	276	51.0

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sistors and of the magnetoresistive sensing devices.

This work was done by Jiin-chuan Wu, Henry L. Stadler, and Romney R. Katti of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 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 18]. Refer to NPO-17954.

Device Measures Angle of Deployment

A simple circuit gives a positive indication of position.

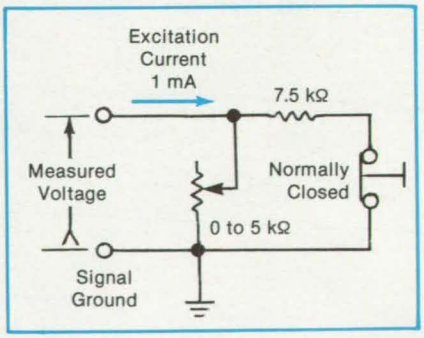
Goddard Space Flight Center, Greenbelt, Maryland

A simple electromechanical device indicates the angular position of an unfolding panel during and after deployment. Designed for use on a panel of solar photovoltaic cells in a spacecraft, the device could be modified for use in other, similar position-indicating applications.

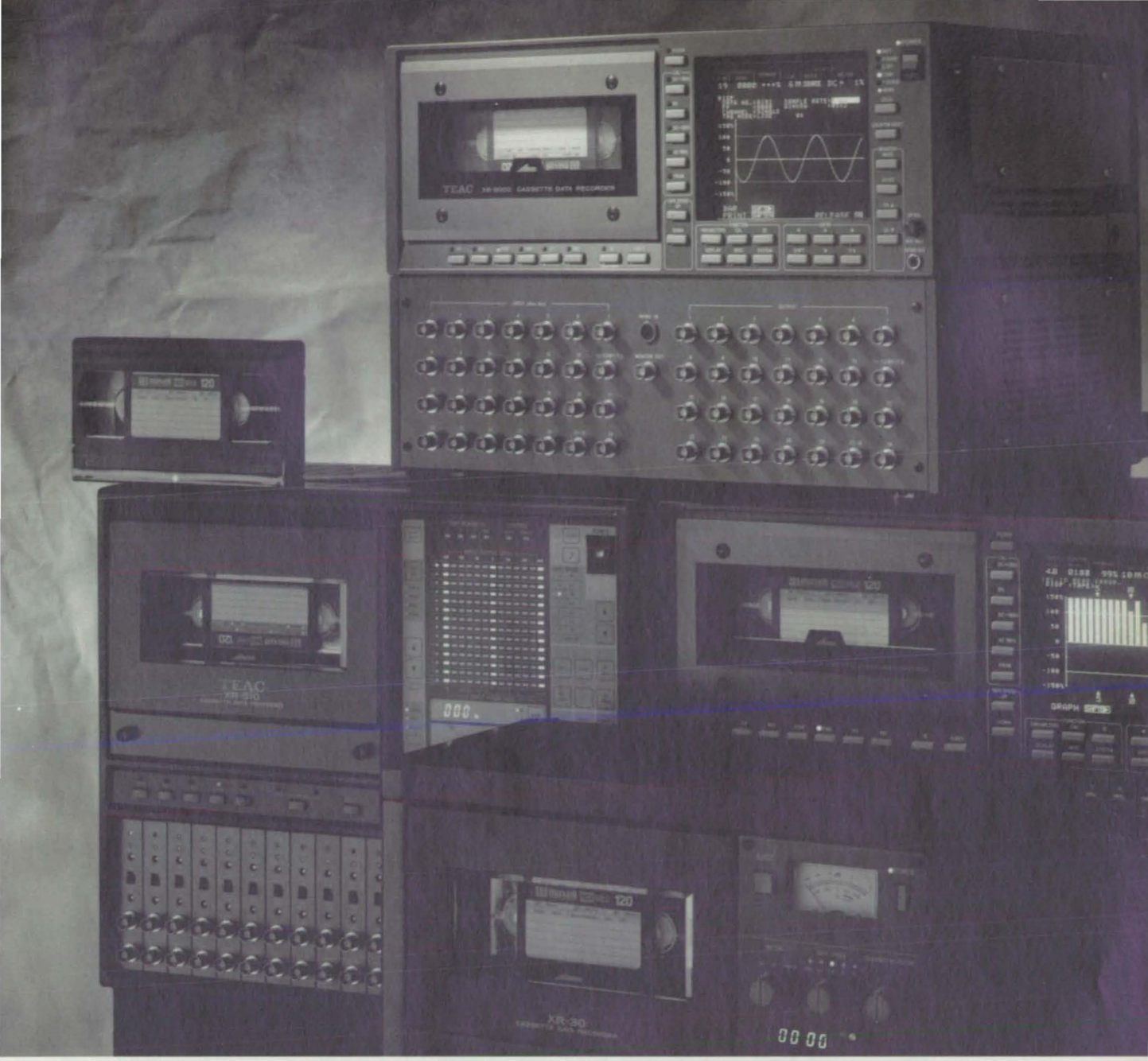
Previously, full deployment of the panel was indicated when the panel locked in place, depressing a small switch at the end of its travel. However, if the switch was not activated after the deployment command had been given, there was no way of knowing the position of the panel or whether the deployment of the panel had even begun at all. An alternative indicator included a series of position sensors to track the movement of the panel, but these devices required additional wiring, which undesirably increased both weight and resistance to the movement of the panel.

In the new indicator, a potentiometer in a simple circuit (see figure) is connected mechanically across the hinge of the panel. The resistance of the potentiometer gradually increases from 0 to 5 kΩ as the hinge opens. A passive analog telemetry system sends 1-mA pulses of current through the circuit and measures the voltage across it. When the panel is stowed, the resistance is 0, and the circuit gives a reading of 0 Ω. While the panel is traveling, the circuit puts out 0 to 3 V. When the panel is fully deployed and locked up, it presses against and thereby opens a small, normally closed switch. This action opens a parallel resistive branch of the circuit, causing the output voltage to rise abruptly to 5 V.

This work was done by Joel B. Jermakian of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13351



The **Resistance of the Potentiometer** gradually increases as the unfolding of a solar panel about a hinge moves the wiper of the potentiometer. At full deployment, the panel pushes and opens the normally closed switch.



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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.

Caustic Singularities of High-Gain, Dual-Shaped Reflectors

Errors that arise in analysis by the geometrical theory of diffraction are discussed.

A report presents a study of some of the sources of error in the analysis, by the geometric theory of diffraction (GTD), of the performance of a high-gain, dual-shaped antenna reflector. These sources exert particularly significant effects on the computed electromagnetic fields in the vicinity of the edge of the main reflector. As a result, the computed spillover past the main reflector and the computed noise figure of the high-gain antenna system can be in error.

The cause of the problem is a ring or ribbon caustic of the GTD field scattered by the subreflector. This caustic is located behind the main reflector. For subreflector-edge illuminations of the order of −20 dB and high-gain distributions across the aperture of the main reflector, the rays in the geometrical-optics approximation ("GO" rays) scattered from the subreflector converge, rather than diverge, toward the edge of the main reflector. This singularity was studied previously to determine its effects upon the far-field computations of scattering from the subreflector, to determine its effect upon errors in the prediction of efficiency, and to calculate corrections, based on physical optics (PO), for the errors of GTD diffraction calculations.

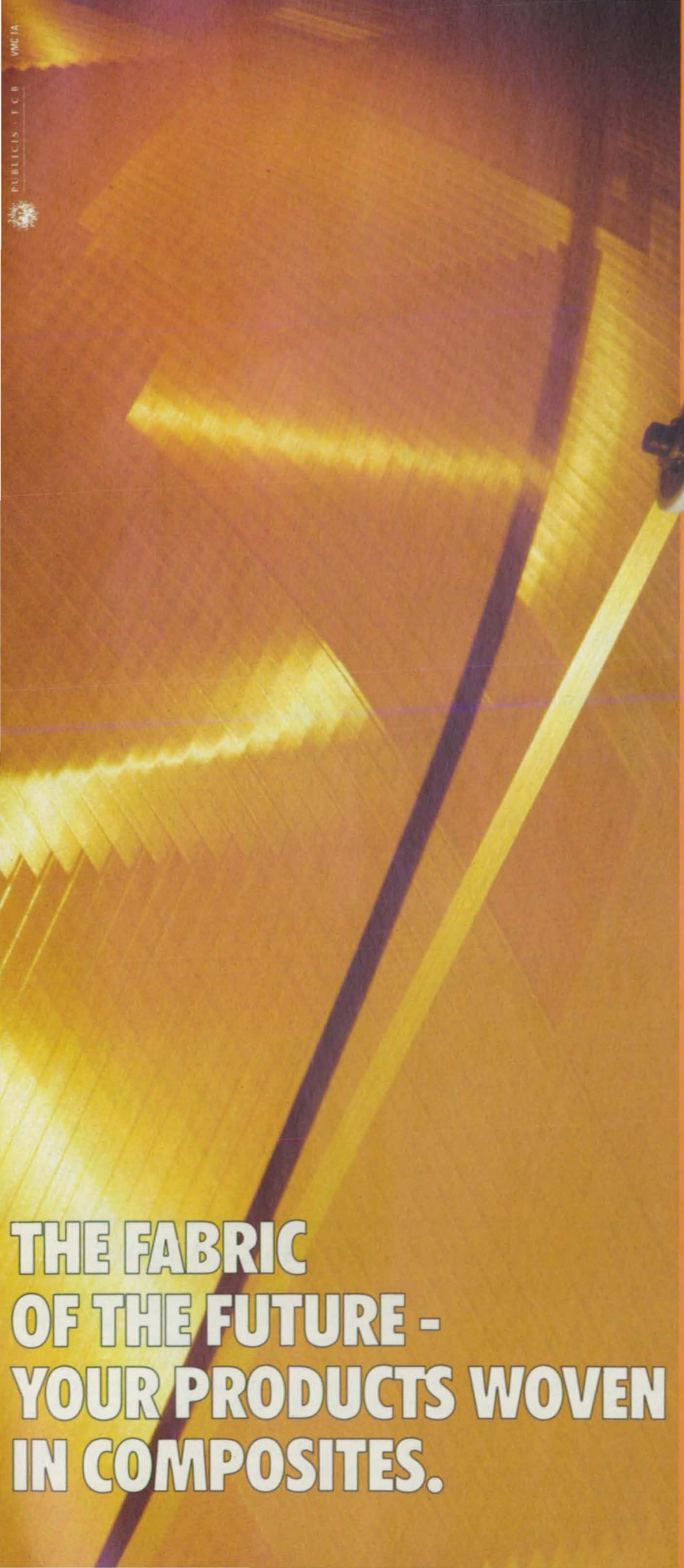
This study probes further into the underlying analytic causes of the singularity, with a view toward devising and testing practical methods to avoid the problems caused by the singularity. The uniform theory of diffraction (UTD) edge diffracted field and the UTD slope-diffracted field have caustics at the same location as that of the GO field. An analysis shows that the slope-diffracted field exhibits the strongest caustic singularity.

Because the caustic is shaped like a ring, the region of stationary phase on the subreflector (for observation points near the caustic) is found to be elongated — narrow in the ϕ (azimuthal) direction and long in the θ (polar-angle) direction (in r, θ, ϕ spherical coordinates) of integration over the subreflector. Therefore, one can compute the field in the vicinity of the edge of the main reflector both accurately and rapidly by use of a stationary-phase evaluation in ϕ and a PO integral in θ. In effect, this reduces the two-dimensional PO integral to a one-dimensional PO integral that is readily computable, even if the subreflector is very large. Thus, one can retain some of the principal advantage (which is speed) of GTD, while gaining the accuracy of PO where GTD breaks down. In the vicinity of the caustic, the integration in θ can be accelerated further by use of an asymptotic physical-optics evaluation technique.

This hybrid PO(with respect to θ)/GO(with respect to ϕ) approach can be used to study the near-field spillover or noise-temperature characteristics of a high-gain reflector antenna efficiently and accurately. The report illustrates this approach and the underlying principles by presenting numerical results, for both offset and symmetrical reflector systems, computed by the GTD, PO, and PO_θ/GO_θ methods.

This work was done by Victor Galindo, Thavath W. Veruttipong, and William A. Imbriale of Caltech and Sambiam Rengarajan of Cal State Northridge for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Inflection Point Caustic Problems and Solutions for High-Gain Dual-Shaped Reflectors," Circle 138 on the TSP Request Card.*

NPO-18046



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Weld-Bead Profilometer Rejects Optical Noise

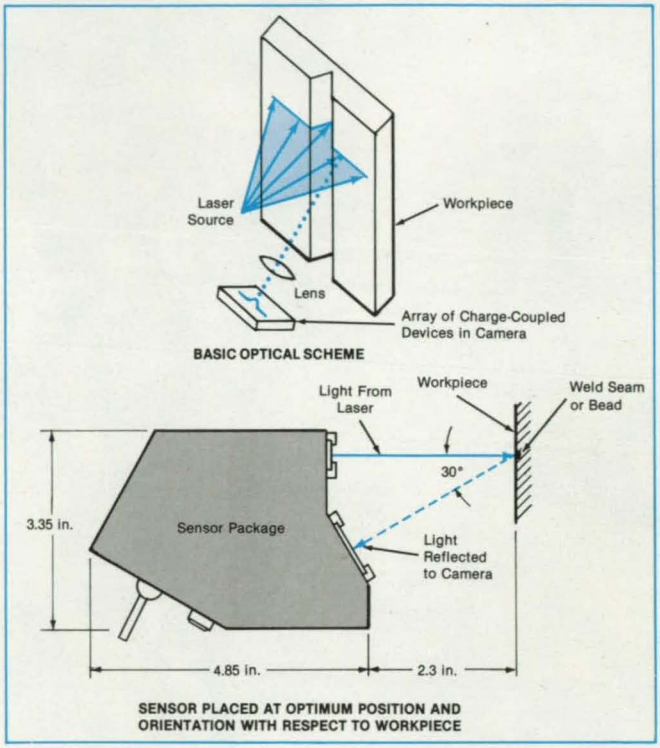
The effect of ambient light is reduced by pulsed illumination and shuttering.

Marshall Space Flight Center, Alabama

An optoelectronic sensor measures the profile of a weld seam or weld bead along a line perpendicular to the seam. It is intended to be part of a highly automated welding system, in which it will be used in automatic tracking of the seam or automatic profiling of the weld bead for immediate evaluation and assurance of quality during the welding process. In comparison with prior welding optoelectronic profilometers, this sensor is compact and much less affected by such optical noise as the light from the welding arc.

The sensor (see figure) illuminates a line across the weld bead with a pulsed, fan-shaped beam of light from a laser diode. The pulses are 200 ns long, with a peak power of 200 W. Light reflected from the illuminated area is imaged in a charge-coupled-device camera, the shutter of which can be opened during times as short as 100 ns. The laser pulse is synchronized with the opening of the shutter to maximize the amount of laser light integrated. On the other hand, keeping the opening time short reduces the amount of arc light integrated. The net effect is to decrease the noise level to 1/600 that of prior sensors.

The sensor operates in conjunction with a video digitizer and a computer. By use of a geometric transformation based on the position and orientation of the camera with respect to the fan of light and the workpiece, the computer generates a transverse profile of the weld from the image in the camera. The profile has a depth resolution of <0.001 in. (0.025 mm) and a transverse resolution of <0.002 in. (0.05 mm).



A **Line Across a Weld Seam or Bead** is illuminated by a fan of laser light. The image of the line is digitized and converted to a profile of height or depth versus transverse position.

The sensor weighs only about 1.5 lb (0.7 kg). It acquires 30 profiles per second. It can operate in the presence of strong electromagnetic interference that is typical of a manufacturing environment. The laser can be controlled manually or automatically. The sensor requires little maintenance other than cleaning the glass windows that protect the laser and the camera. Periodic recalibration is necessary but adds little to the task of maintenance, in that it is performed automatically by the computer on the basis of a known test pattern.

This work was done by Larry Z. Kennedy of Applied Research, Inc., for **Marshall Space Flight Center**. *For further information, Circle 52 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 18]. Refer to MFS-26115.

System Would Keep Telescope Reflector Segments Aligned

Actuators would adjust segments in response to sensed positions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed actuation system would maintain the alignments of the reflector segments of a large telescope. Although the system is intended for use on an orbiting 18.4-m Cassegrain telescope reflector composed of 90 2-m hexagonal mirror segments, the system concept is also applicable to such large segmented space-based reflectors as those used in communication and in the collection of solar energy.

Mirror fabrication technology and launch vehicle cargo volume limit the size of a single mirror. Constructing an array of mirror segments in space is one means of achieving a large-diameter reflector. The task then becomes one of maintaining the correct optical figure and alignment of the reflector array in the face of both support-truss vibration (caused by reaction wheels, solar array drives, and other mechanisms on the telescope) and thermal distortions (e.g., those caused by temperature change as the telescope goes in and out of the Earth's shadow).

The proposed system, shown in Figure

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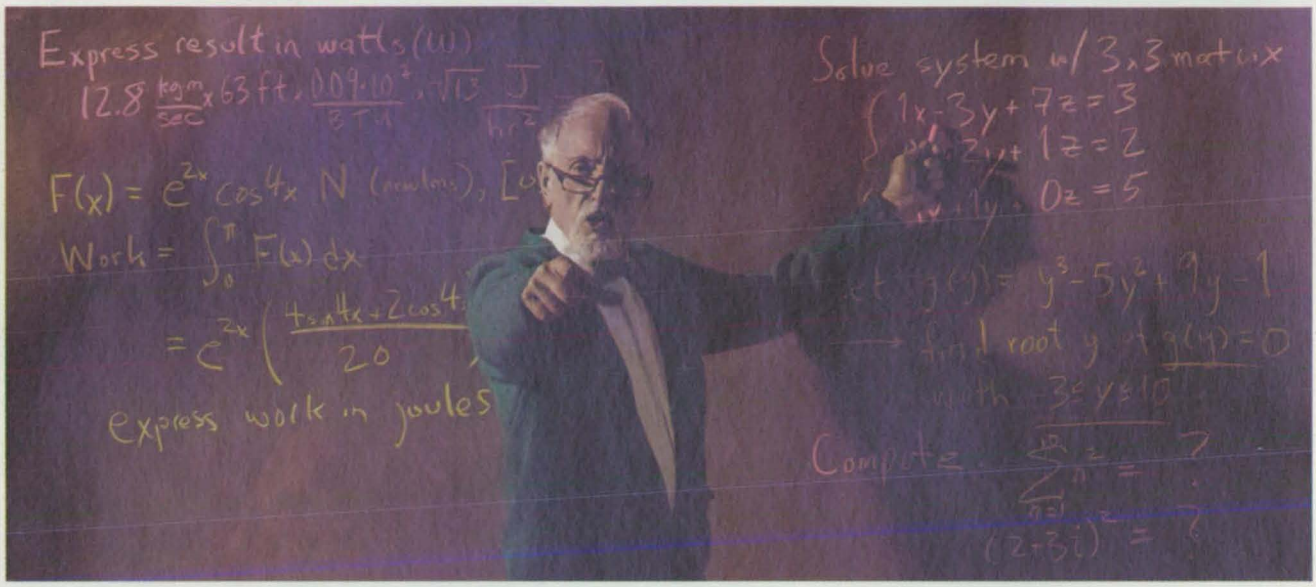

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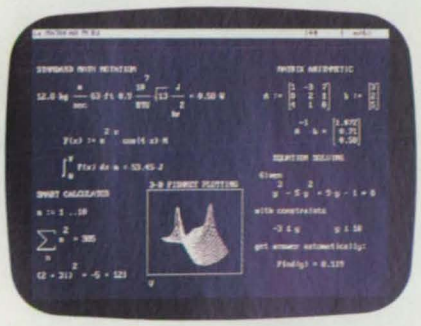

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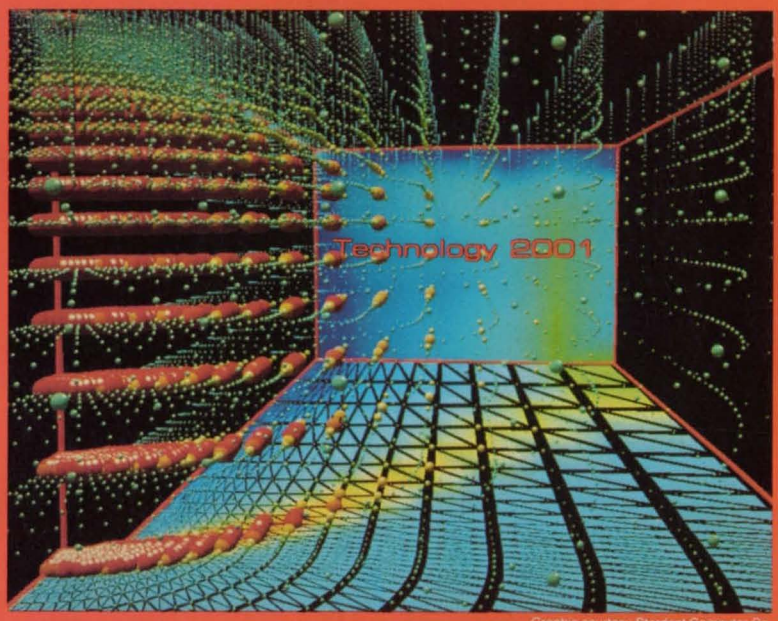
The Road To The Future



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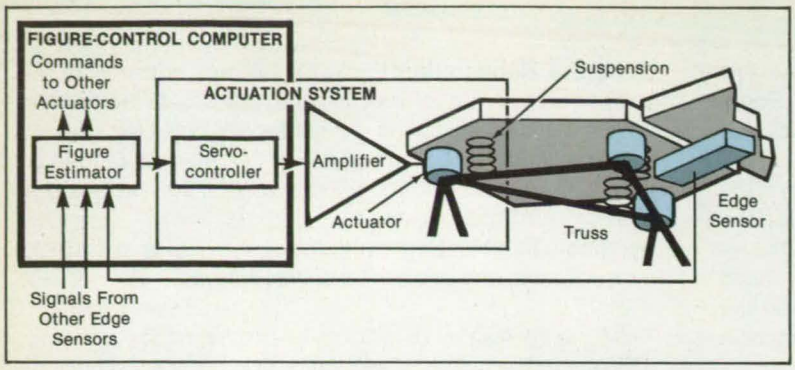

Figure 1. **The Control System** would adjust the alignment of a single mirror panel in the array.

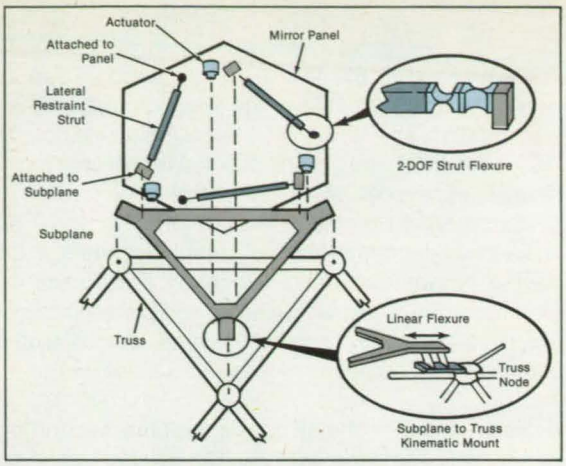

Figure 2. This **Exploded View** illustrates the Unit Cell, which is a suspension subsystem. A breadboard of this subsystem has been built and tested.

1, would perform this task. Sensors would measure the positions and orientations of the segments. A figure-control computer would calculate the orientation and figure of the overall reflector surface from the sensor data. Responding to the computer output, the servocontroller for each actuator would correct the piston (displacement along the optical axis of the segment) and tilt errors of each segment. No attempt would be made to correct for errors of translation perpendicular to, or rotation about, the optical axis of the telescope, and the segments would be restrained against motion in these degrees of freedom.

The piston displacement and the two tilt angles of each panel would be measured relative to those of the adjacent panels by a system of edge sensors. The edge sensor for each pair of adjacent reflector segments would include four three-wavelength interferometers that would measure the distances between a sensor block behind the segments and two retroreflectors on the back of each segment.

Three electrodynamic (voice coil) actuators would correct the piston and tilt error of each segment. The actuators would be part of a suspension subsystem, called the Unit Cell, as shown in Figure 2. The mirror segment and actuators would be attached to a subplane rather than directly to the telescope support truss, so that the suspension could be assembled, aligned, and calibrated before launch. The Unit Cell is designed so that it can easily be attached to the truss during space assembly. The suspension would consist of three struts, as shown in the figure. The suspension would act as a kinematic attachment between the panel and subplane, allowing motion only in the controlled degrees of freedom as well as allowing independent thermal growth of the panel and subplane. The suspension would also act as a me-

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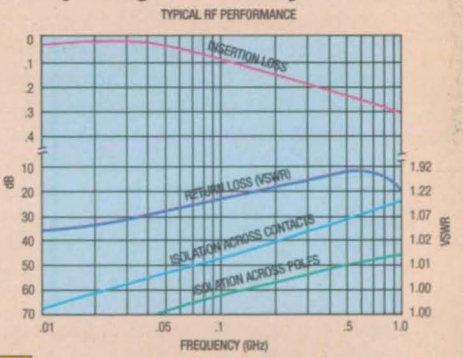

DETAILED ELECTRICAL SPECIFICATIONS (@ 25°C)

GENERIC PART NUMBERS		172-5	172-12	172-26
Coil Voltage (VDC)	Nom.	5.0	12.0	26.5
	Max.	5.8	16.0	32.0
Coil Resistance (ohms ± 20%)		64	400	1600
Pick-up Voltage (VDC, Max.) Pulse Operation		3.8	9.0	18.0
Coil Operating Power at Nominal Voltage (Milliwatts)		405	360	440
Contact Load Ratings (DC)	Resistive: 1 Amp/28VDC Inductive: 200 mA/28VDC (320mH) Lamp: 100 mA/28VDC			
Contact Load Ratings (AC)	Resistive: 600 mA/115VAC, 400 Hz (Case ungrounded); 400 mA/115VAC, 60 Hz (Case ungrounded) 200 mA/115VAC, 60 and 400 Hz, (Case grounded)			

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chanical low-pass filter to isolate the panel from truss vibrations. The subplane would have its own kinematic attachment to the truss, consisting of three linear flexures that point toward the center of the cell. This would ensure that the subplane is not structurally redundant with the truss. The attachment would be stiff to rigid body truss motion but would allow for initial misalignments and independent thermal growth of the two structures without distortion.

A breadboard of the Unit Cell has been built and tested to demonstrate the position control and disturbance isolation capabilities of the actuation system.

This work was done by Edward Mettler, Daniel B. Eldred, Hugh C. Briggs, Michael L. Agronin, and Taras Kiceniuk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 114 on the TSP Request Card.*
NPO-17903

Half-Tone Video Images of Drifting Sinusoidal Gratings

Gratings appear to move smoothly at low speeds.

Ames Research Center, Moffett Field, California

A digital technique for the generation of a slowly moving video image of a sinusoidal grating avoids the difficulty of transferring the full image data from disk storage to image memory at conventional frame rates. The technique makes the motion appear smooth (instead of jerking one picture element after a certain number of frame periods), even at speeds much less than one-tenth picture element per frame period.

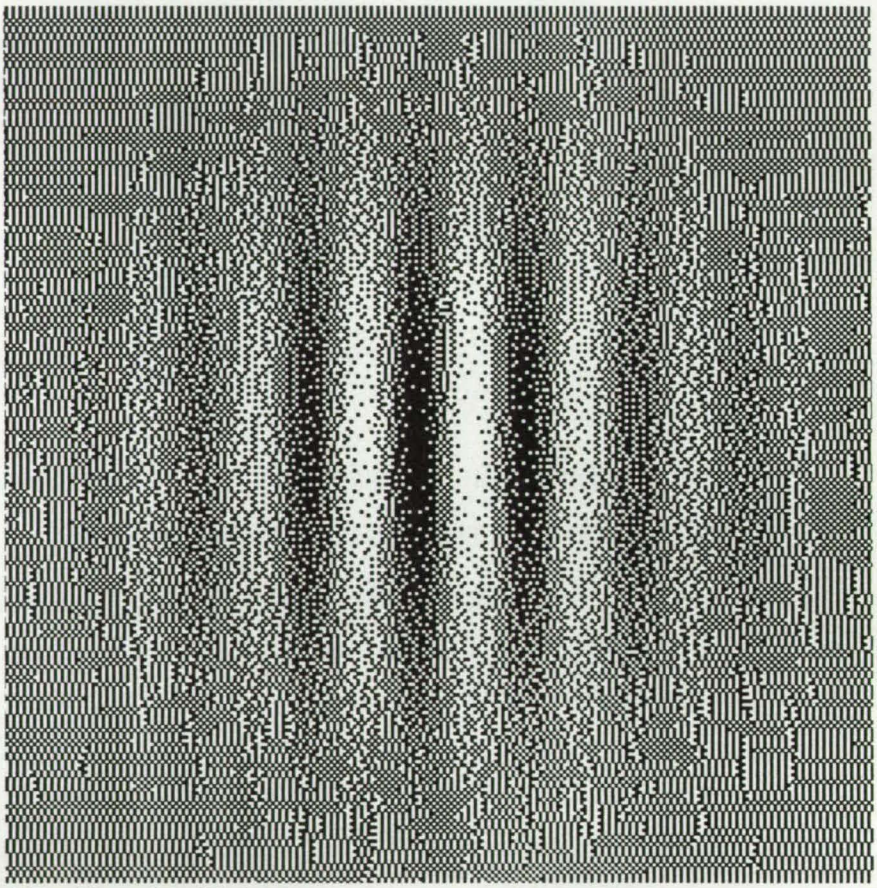
The technique is applicable to a digital video system in which (1) the image memory consists of at least 2 bits per picture element, and (2) the final brightness of a picture element is determined by the contents of a "lookup-table" memory that can be programmed anew each frame period and that is indexed by the coordinates of each picture element. Frame-by-frame programmability is important because it involves the transfer of fewer data than are necessary to specify an ordinary image and, therefore, the operation of the system is not restricted by input/output rates.

The technique depends partly on a trigonometric identity by which a moving sinusoidal grating can be decomposed into two stationary patterns that are spatially and temporally modulated in quadrature. For example, for a grating of vertical stripes moving horizontally

$$\sin[(2\pi/\lambda)(x+vt)] = \sin(2\pi x/\lambda)\cos(2\pi vt/\lambda) + \cos(2\pi x/\lambda)\sin(2\pi vt/\lambda)$$

when v = the speed, t = time, and λ = the wavelength. The sine and cosine spatial patterns are first reduced to 1 bit per picture element by any of several available digital half-toning techniques. The resulting pair of 1-bit images is loaded into a pair of bit planes in the display memory. During each successive frame period, the contents of the "lookup-table" memory are modified to display the current weighted sum of the bit-plane patterns, in which sum the current weights are the instantaneous values of the sinusoidal and cosinusoidal temporal modulations.

The image memory could include several different pairs of bit planes, each of which could contain the half-tone bits of a horizontal or vertical grating of different wavelength. Furthermore, each pair of bit planes could be temporally modulated at a different frequency and could be used to spatially modulate a grating of a different color. The resultant image could contain several horizontal and vertical gratings of different colors moving at different speeds — in effect a moving sinusoidal plaid.



A **Two-Dimensional Gabor Patch** — a one-dimensional sinusoidal grating modulated by a two-dimensional Gaussian window — is displayed here in half tone on a 256 by 256 grid.

Although the technique involves a substantial amount of computation in the generation of the half-tone images, once that computation has been performed for a given horizontal or vertical wavelength the bit-plane data for that wavelength can be used to produce gratings that have many different contrasts and that drift at many different velocities. A window function can also be made to spatially modulate the drifting grating(s) (see figure). This presents no major problem because the product of the window and grating spatial modulations is computed before the half-toning computations.

This work was done by Jeffrey B. Mulligan and Leland S. Stone of **Ames Research Center**. *Further information may be found in NASA TM-101022 [N89-13171], "Efficient Use of Bit Planes in the Generation of Motion Stimuli."*

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-12414

Optoelectronic Shaft-Angle Encoder Tolerates Misalignments

Active read heads track grooves and pits on a disk.

Goddard Space Flight Center, Greenbelt, Maryland

An optoelectronic shaft-angle encoder measures the angle of rotation of a shaft with high precision while minimizing the effects of eccentricity and other misalignments. In simplest terms, it measures rotation by recording the passage of grooves on a reflective disk attached to the shaft. Incorporating many features of compact-disk recording and playback technology, the optoelectronic shaft-angle encoder contains two active optical read heads at approximately diametrically opposite positions. These contain optical elements that move both perpendicularly to the surface of a disk to track (to maintain focus upon) its surface and along the diameter between them to track the radial positions of the grooves.

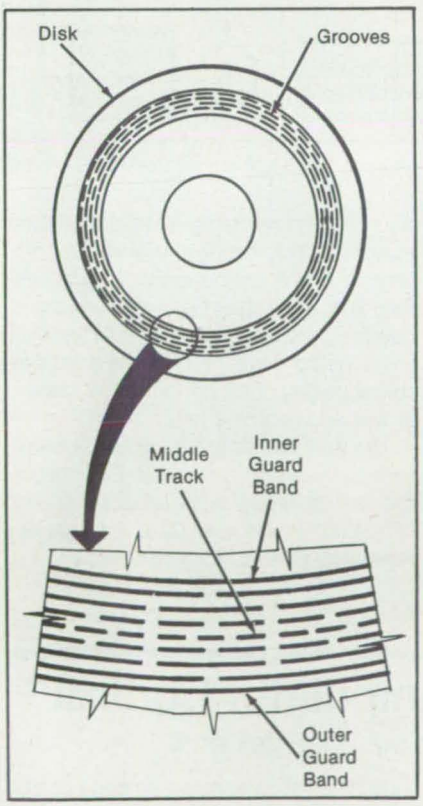


Figure 1. **Grooves on a Disk** serve as reference marks to locate the reading heads and measure increments of rotation of the disk.

The grooves on the disk (see Figure 1) include a continuous inner and a continuous outer circular groove that serve as guard bands. Between the two guard bands are circular data tracks consisting of grooves interrupted at even circumferential intervals. The middle track is divided into a maximum number of intervals, and the number of intervals in each of the other tracks decreases as one moves radially inward or outward toward either guard band. As the shaft is rotated at a constant rate or dithered, the outputs of each read head are processed to determine the radial position of the optical elements within the head with respect to this pattern of grooves and adjust their position accordingly. Thus, regardless of its initial radial position, each head can acquire and lock onto a view of the middle track, which is the one used to measure the smallest increments of rotation.

Each read head includes a small laser, beam-steering optics, and an array of photodetectors (see Figure 2). One of the optical components is a lens mounted on a bobbin that can be moved up or down electromagnetically to track the surface of the disk. The lens distorts the reflected light in such a way that variations in the distance from the surface give rise to vari-

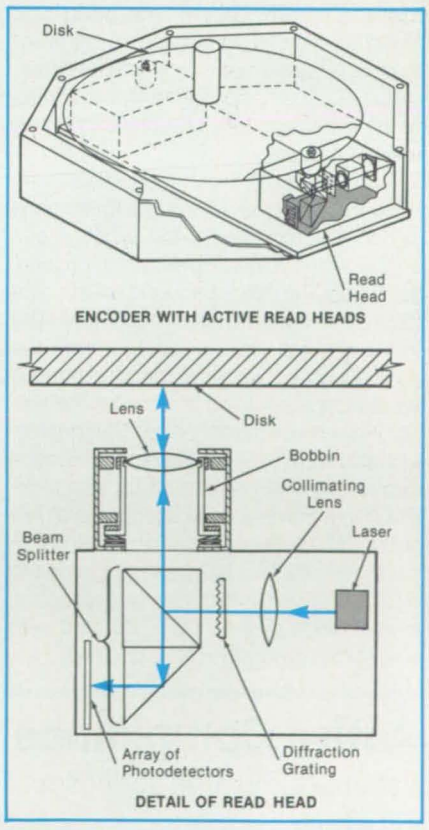


Figure 2. The **Shaft-Angle Encoder**, resembling an optical compact-disk drive, includes two tracking heads that illuminate the grooves on the disk and measure the reflections from them.

ations among the illuminations of the individual photodetectors. These variations are processed into feedback signals that are used to maintain the vertical position of the lens at the focal distance from the surface.

A beam splitter directs the illuminating light through the lens toward the disk and directs the light reflected from the disk toward the photodetectors. Actually, the illuminating light consists of three beams, rather than one: a diffraction grating breaks two flanking beams off the main beam and is oriented in such a way that one flanking beam strikes the disk slightly circumferentially forward and radially outboard of the main beam, while the other flanking beam strikes the disk at equal distances circumferentially rearward and radially inboard of the main beam. The array of photodetectors includes two flanking elements that receive the reflections of the flanking beams. The radial position of the optical elements within the head or "the bobbin" relative to that of the groove in view is determined by comparison of the illuminations falling on these two flanking elements, and this position is adjusted to keep the optical elements within the head or "the bobbin" at the radius of the groove by a feedback scheme conceptually similar to the one used to keep the lens in focus.

Once the encoder has been set up and its automatic-alignment features have caused it to lock on to the middle groove, the variations in outputs from the two read heads are averaged and interpreted as increments of rotation. Unlike prior optical shaft-angle encoders, which do not include active read heads, this one can take advantage of the high resolution available in compact-disk or laser-optical-disk technology.

This work was done by Eric P. Osborne of **Goddard Space Flight Center**. *For further information, Circle 147 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, Goddard Space Flight Center [see page 18]. Refer to GSC-13175.

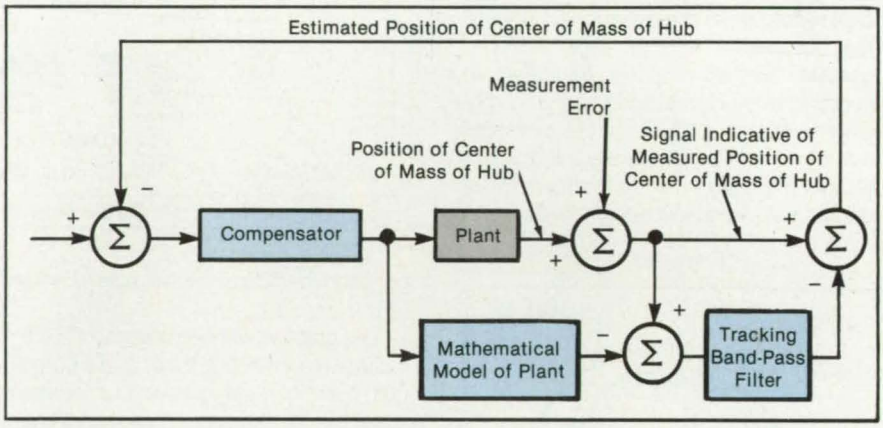
Improved Notch Filter for Synchronous-Response Control

A tracking differential notch filter has both good synchronous-response performance and vastly improved stability.

Langley Research Center, Hampton, Virginia

The use of magnetic bearings to support rotating elements without contact has received increased attention during the last 10 years, primarily because of improvements in magnetic materials and advances in low-cost, reliable, power and control electronics. Magnetic bearings offer advantages of frictionless support, long life, and high rotational speeds. They are also being used to achieve better rotordynamic behavior than is possible with conventional bearings. One such application is the control of the synchronous vibrations caused by unbalanced rotors.

One of the most common ways to reduce the response to mass unbalance is to add a notch filter at the synchronous frequency (rotational speed) into the feedback loop. The notch frequency of this filter tracks the synchronous frequency. The tracking notch filter eliminates, from the control loop, all signals at the synchronous frequency. In so doing, it removes the synchronous measurement error. Unfortunately, it also eliminates desirable synchronous control signals, thereby giving rise to instability, which limits the usefulness of this approach. Therefore, a tracking differential-notch filter (TDNF) has been developed to retain the good synchronous-response performance of the notch filter, but with vastly improved stability properties.



The **Measurement Error Is Perfectly Filtered** from the feedback signal used to drive the compensator.

In the TDNF (see figure), the desirable control signal is reinjected into the feedback control loop. The tracking notch filter is implemented in a special way. The signal that represents the measured position of the center of mass of the rotor is notch-filtered by subtracting, from the signal, a synchronous tracking-band-pass-filtered version of itself. The effect is that of a synchronous tracking notch filter. Therefore, the measurement error is perfectly filtered from the feedback signal used to drive the compensator. The output of the compensator, which is simple lead/lag, is used to produce the input force that drives the plant. A relatively simple implementation includes mainly circuit-chip-level subcomponents and a low-bandwidth digital section. The TDNF has been shown to provide the good stability of a simple lead/lag compensator combined with the good synchronous-response performance gained by the addition of a notch filter.

This work was done by Bruce G. Johnson, James R. Downer, David B. Eisenhaure, Richard Hockney, and Kathleen Misovec of SatCon Technology Corp. for **Langley Research Center**. *For further information, Circle 106 on the TSP Request Card.*
LAR-14173

Active Compliance and Damping in Telemanipulator Control

Variable simulated springs and shock absorbers soften collisions and increase dexterity.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental telemanipulator system of the force-reflecting-hand-controller type provides for active compliance and damping in the remote, robotic manipulator hand. Active compliance can help to soften collisions between the manipulator and objects. The compliance parameters can be adjusted to suit the task at hand. In addition, active compliance becomes essential to successful telemanipulator control when the communication delay between

SHIN-ETSU LAUNCHES NEW PRODUCT TO MEET MIL A-46146 TYPE III

New High Strength RTV Silicone Provides Key Properties for Aircraft/Aerospace Market

DATA SHOWS NEW MATERIAL 'RIGHT ON SPECS'

LOS ANGELES—According to Mr. Shibata, President of Shin-Etsu Silicones of America, Inc., "When comparing our new KE 4899 RTV to Dow's 3145 RTV on a property-for-property basis, there is no clear winner. Both materials pass the Mil Spec requirements and both are of equal caliber."

The data shows Shin-Etsu's KE 4899 RTV to meet all of the requirements of MIL A-46146 TYPE III and to compare equally with Dow Corning's 3145 RTV. Both materials are non-corrosive, high strength, low odor, one part adhesives.

THE MATCH-UP

PROPERTY	MIL A-46146 TYPE III	SHIN-ETSU KE 4899*	DOW RTV 3145**
HARDNESS (Shore A)	25 min.	33	33
TENSILE (psi)	500 min.	780	700
ELONGATION %:	500 min.	660	675
TEAR STRENGTH (ppi):	NR	150	125
SPECIFIC GRAVITY:	NR	1.08	1.12
CORROSION ON: Brass, steel, aluminum	None	Passes	Passes
COLORS:	NR	Grey/clear	Grey/clear

*KE4899 data as tested.
**RTV 3145 data as reported — Dow Corning USA Form No. 10-024-82

A COMMITMENT TO RESEARCH

Shin-Etsu Chemical Co., Ltd., founded in 1926, is a leading world class manufacturer of silicones, offering over 2,800 different products serving a broad spectrum of industrial markets, worldwide. Included in these product lines are many innovative one and two-component RTV silicones, gels, greases, fluoro and fluid silicones with their own revolutionary curing systems.

At the very core of these technological accomplishments is Shin-Etsu's commitment to research. Shin-Etsu's Technical Service Center, located in Torrance, California, provides standard elastomeric testing, including physical and chemical constituents. Its small batch production includes the synthesizing of polymers and compounding them in the latest state-of-the-art mixing equipment. The facilility is dedicated to researching all aspects of silicones, including synthesis, property alteration, applications, forming and working, process improvement and complete product evaluation.

LOS ANGELES—Shin-Etsu Silicones of America released the above data today, showing the actual published data of both Dow's 3145 RTV and Shin-Etsu's new KE 4899 RTV.

Based upon the direct property-for-property comparison above, it has been determined that the Shin-Etsu material is a direct challenge to Dow's 3145 RTV and should prove an excellent first or second source material. According to Mr. Tomisato, RTV Marketing Manager, "We are accepting requests for samples now."

For more information on the Shin-Etsu Silicones of America KE 4899 RTV, or to receive a sample, contact Doug Bower or John Heitler at:

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LOS ANGELES—According to Doug Bower of Shin-Etsu Silicones of America, Inc., "We've been working on coming up with this product for a very long time. We always knew that Dow's 3145 RTV was the one we had to meet or beat. We also knew that when we introduced this product it had to be right on the money. 'Close' or 'almost' was not about to cut it. As you can see by the comparative data, our RTV KE 4899 was worth the wait."

Mr. Shibata, President of Shin-Etsu Silicones of America, believes that the introduction of their new product will have a dramatic effect on the aircraft/aerospace industry. "Let's face it," said Mr. Shibata, "Dow has an excellent product that has not only been the industry standard for years, but a product without peers. Their 3145 RTV virtually had the market all to itself. As of today, all of that has changed. Now the aircraft/aerospace industry has a choice. Now there is a second one-component RTV silicone available that is every bit as good as Dow's 3145 (RTV) and meets MIL A-46146 Type III to the letter."

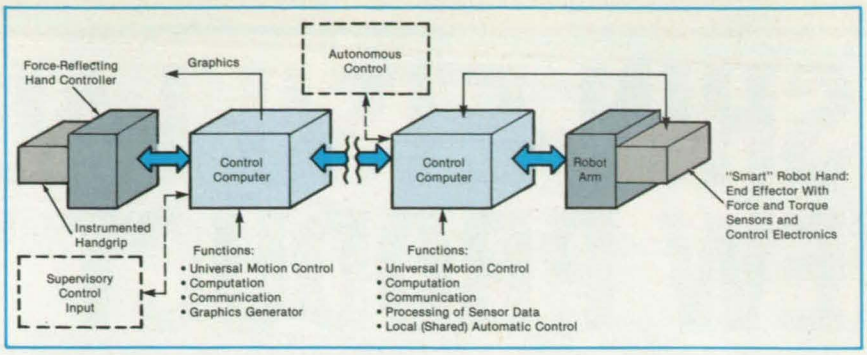


Figure 1. The **Experimental Telemanipulator System** is a distributed-computing and -control system for research in various combinations of force-reflecting and active-compliance control regimes.

the master-control and remote-manipulator stations exceeds 1 s.

In a typical current industrial force-reflecting telemanipulator, the force of contact between the robot hand and an object is, strictly speaking, neither sensed nor controlled. Instead, the remote manipulator is activated according to hand position commands, while the contact force fed back through the hand controller to the human operator is made to increase with the feedback signal that indicates the error between the actual and the commanded position of the manipulator. In such a system, the manipulator hand is prone to hard bumps against objects, and small errors in the execution of position commands can give rise to undesired large contact forces and torques. Such errors, forces, and torques increase with the communication delay; in practice, they render conventional (noncompliant) force-reflecting hand control unusable at delays greater than about 1 s.

In the experimental telemanipulator system (see Figure 1), the control task is shared by subsystems in both the control station and the remote-manipulator station. The robot hand is equipped with force and torque sensors. A control subsystem at the remote-manipulator station implements active compliance — in effect, it simulates springs and shock absorbers — by low-pass filtering the outputs of the force and torque sensors and using these signals to alter the position commands (see Figure 2). The active-compliance feature is semi-autonomous, in that it resides in the remote-manipulator station but can be programmed from time to time by commands from the human operator at the master control station. From a software menu, the operator can select the force-feedback gains and the damping time constants of the hybrid position/force-feedback subsystem to obtain the desired spring stiffness (or its reciprocal, compliance) and damping.

The experimental telemanipulator system provides for various combinations of conventional force-reflecting hand control and/or active compliance. It accommodates a spectrum of operations that range from full manual through shared manual and automatic (in the sense of remote autonomous) to full automatic control. Shared manual and automatic control is implemented by freezing the output of the master controller in some task-space coordinates that are selectable by the operator from a menu. Motion about the set point in the frozen task-space coordinates can then be controlled by a computer algorithm that can be referenced to force-, moment-, or proximity-sensor information.

Control by active compliance alone (that is, without force reflection), can be extremely useful when the communication delay is long. This was demonstrated by using the experimental telemanipulator system to insert a peg in a hole. The task proved impossible without active compliance when the delay exceeded 0.5 s. With active compliance but no delay, it took almost a minute. With a delay of 4 s, it took 3 min. With a delay of 8 s, it took 7 min.

This work was done by Won S. Kim, Antal K. Bejczy, and Blake Hannaford of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 40 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 18]. Refer to NPO-17969.

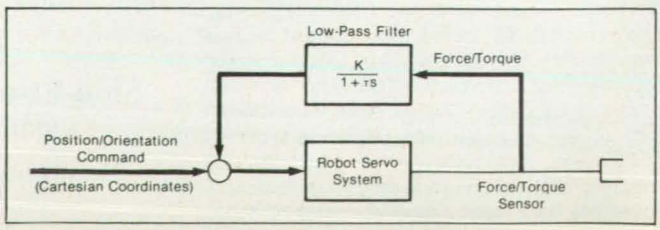
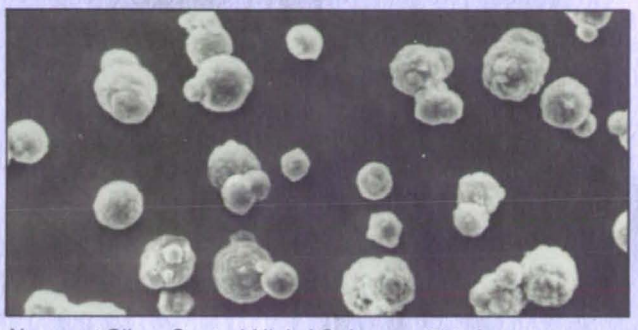


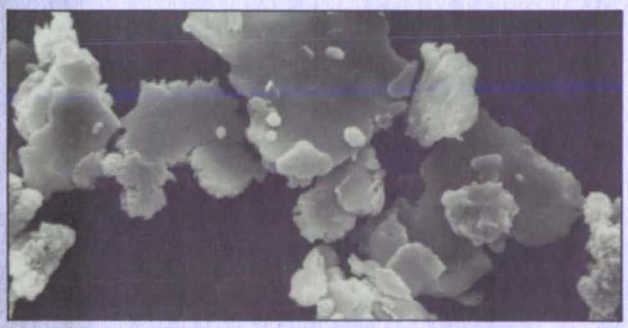
Figure 2. **Shared Compliance Control** is implemented by low-pass-filtered force/torque feedback.

SPECIFY INCO SPECIALTY POWDERS FOR WIDE RANGE OF ELECTRONIC APPLICATIONS

Inco Type T 287 Filamentary Powder, particle size (FSSS) 2.6-3.3 microns, apparent density 0.75-0.95 g/cc, relative surface resistivity 0.30 ohms per square (□).



Novamet Silver Coated Nickel Spheres, 15% Ag, 2.5 g/cc apparent density, particle size 10 microns, screen mesh 99%-250, surface resistivity 0.03 Ω/□.



Novamet HCA-1 Flake, screen mesh 98% minus 400, apparent density 0.90 g/cc, thickness 1.0-1.1 microns, surface resistivity 0.25 Ω/□.

Novamet Nickel Coated Graphite, 60% fully encapsulated Ni, apparent density 1.6 g/cc, particle size (FSSS) 100 microns, screen mesh 63% −150/+250, surface resistivity 0.3 Ω/□.

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Circle Reader Action No. 452

Physical Sciences

Vacuum Chuck Holds Filter Pad for Counting Particles

The chuck is mounted on a microscope stage.

Marshall Space Flight Center, Alabama

A microscope-stage holder keeps a filter pad flat to keep it in focus as the stage is moved to count particles in different areas. In a microscope system equipped with a video camera, an image-analyzing/particle-counting computer, and automatic focus, the use of the stage can speed the count considerably by eliminating the need to stop frequently for manual refocusing. The technician is free to perform other tasks while the computer controls the translation of the stage and takes the count automatically.

Previously, it was standard practice to hold a filter pad with a ring, which maintains the edge flat against the microscope stage but does not force the rest of the pad to remain in focus. The new holder relies on suction to pull the entire pad hard against a flat surface. The holder is essentially a vacuum chuck. The vacuum is applied to a small plenum under a screen that serves as the flat holding surface (see Figure 1). The screen is made of stainless-steel sheet 0.010 in (0.25 mm) thick perforated with a square array of thousands of suction holes 0.0039 in. (0.10 mm) in diameter. A circular framework in the plenum under the screen helps to support the screen against the suction force.

The holder is mounted on the microscope stage, the filter pad is placed on the holder (see Figure 2), the vacuum is applied, the system is focused, and the count is begun. Often, the count can be completed before refocusing is necessary.

This work was done by Anthony Berry and Billy H. Herren of **Marshall Space Flight Center**. *For further information, Circle 74 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 18]. Refer to MFS-28420.

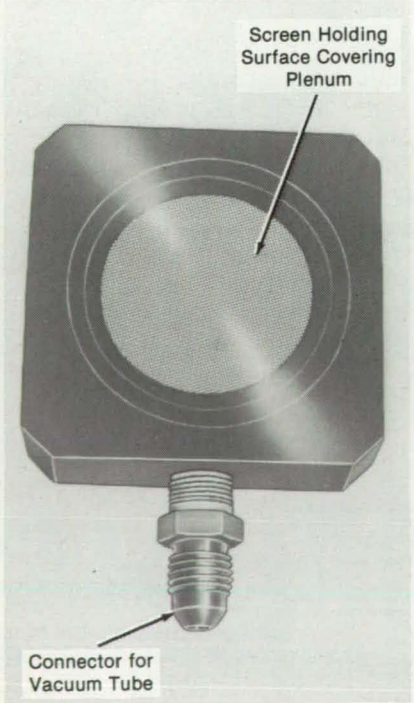

Figure 1. The **Specimen Holder** is a special vacuum chuck that applies suction through a flat screen.

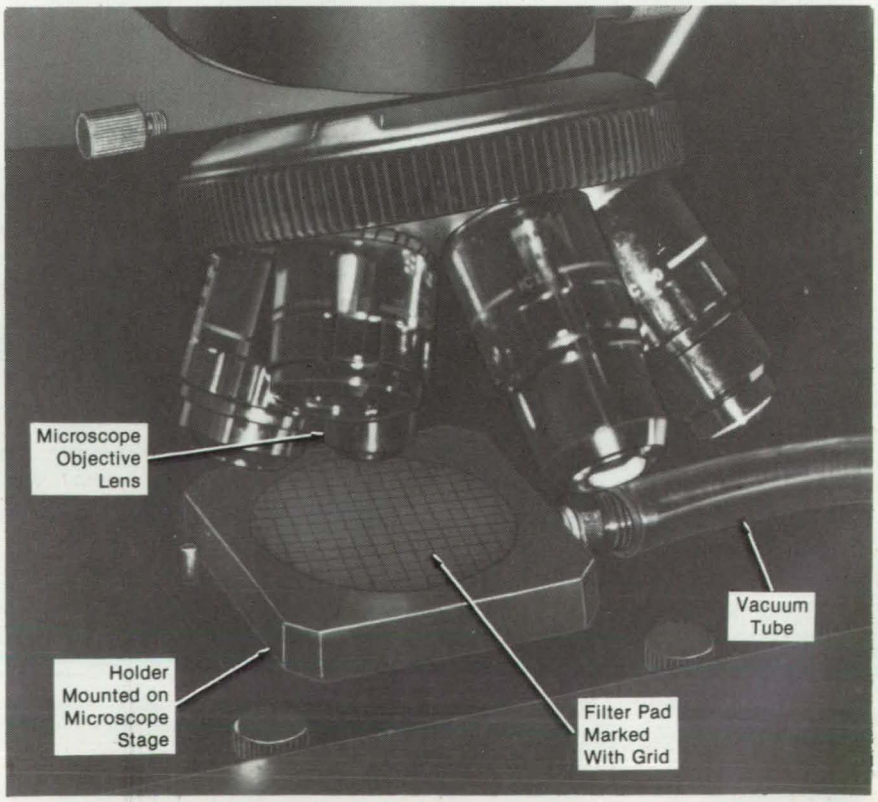

Figure 2. **Suction Keeps the Filter Pad Flat** against the specimen holder while the microscope stage is moving to scan the areas denoted by the grid.

CAJON Products for Vacuum Service...

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VCR® Coupling

All metal gasket seal

Patented

- Zero-clearance for disassembly
- Critical vacuum
- Choice of end connections from 1/16″ to 1″
- Connects to various weld, SWAGELOK Tube Fitting, NPT and straight thread components
- Variety of configurations
- Sold as individual components to minimize inventories
- 316L & 316 stainless steel
- Helium leak tested to 4.0 x 10^{-9} atm. cc/sec.
- Pressures — vacuum to 11,000 psi
- Temperatures to 1000°F (537°C)

VCO® Coupling

O-Ring face seal

Patented

- Zero-clearance for disassembly
- Variety of configurations
- Connects to various weld, SWAGELOK Tube Fitting, NPT and straight thread connections
- Sold as individual components to minimize inventories
- Brass & 316 stainless steel
- 1/8″ to 2″
- Helium leak tested to 4.0 x 10^{-9} atm. cc/sec.
- Pressures — vacuum to 10,000 psi
- Temperatures to 450°F (232°C)
- Fast make-up

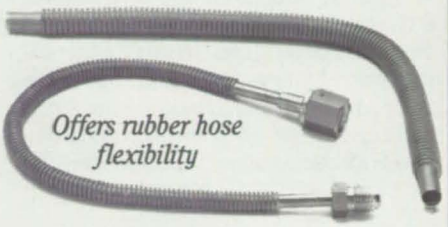
Ultra-Torr® Fitting

Provides vacuum-tight seal on glass, metal or plastic

Patented

- Quick finger-tight assembly, reuseable
- Helium leak tested to 4.0 x 10^{-9} atm. cc/sec.
- 1/16″ to 1-1/2″
- Use with undersize tubing
- Variety of configurations
- Brass & 316 stainless steel
- Temperatures to 450°F (232°C)

Flexible Tubing



- 321 stainless steel construction
- Compressible by 20%, extendable by 50%
- Absorbs vibration, relieves thermal expansion, compensates for misalignment
- 1/4″ to 1-1/2″ tube O.D.
- Nominal lengths 1″ to 36″

Flexible Glass End Tubing

Isolates vibration in glass systems

- Relief for thermal expansion
- Compressible by 20%, extendable by 50%
- 1/4″ to 1″
- Nominal lengths 2″ & 3″
- 321SS fused to 7740 Pyrex glass
- Ultra-high vacuum to 25 PSI
- Single or double end glass

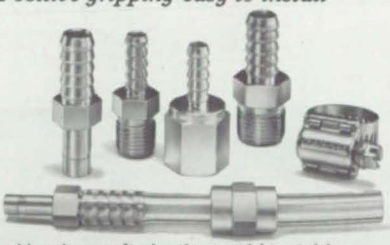
Glass/Metal Transition Tube

One step glass to metal transition eliminates graded seals

- Converts a glass system to a metal system
- Smooth internal surface for high conductance
- Non porous transition area to prevent absorption & outgassing
- Metal, 304SS — Glass, 7740 Pyrex
- Temperature to 960°F (515°C)
- Ultra-high vacuum to 25 PSI
- 100% Helium leak tested
- 1/4″, 3/8″ & 1/2″ sizes
- 6″ lengths

Hose Connectors

Positive gripping-easy to install



- Used on soft plastic or rubber tubing
- NPT & Tube Adapter ends
- Hose clamps for safety
- Reuseable
- 316SS and brass
- 1/8″ to 3/4″

Weld Fittings

For automatic or manual welding

- High conductance
- 316L & 316 stainless steel construction
- 1/4″ to 1″
- Pressures to 5100 psi
- Thin wall design for cleaner, lower profile appearance

Vac Goop®

Anti-gall lubricant for use on threads, O-Rings, gaskets, glass seals and metal parts

- Low vapor pressure minimizes outgassing problems
- Compatible with system materials
- Use on temperatures to 400°F (204°C)
- Impervious to moisture

SWAGELOK/VAC GOOP — TM Crawford Fitting Company
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Circle Reader Action No. 380

Liquid-Crystal Light Valve Enhances Edges in Images

A real-time edge-enhancement technique can increase the discrimination between similar objects.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that a liquid-crystal light valve (LCLV) exhibits an operating mode in which it enhances edges in images projected on it. The enhancement of edges is one of the most important preprocessing steps in optical pattern-recognition systems. The LCLV can be incorporated into an image-processing system to enhance edges without introducing excessive optical noise, as optical Fourier-transform high-pass-spatial-filtering techniques tend to do.

In the LCLV (see Figure 1), a thin layer of nematic liquid crystal is sandwiched between two transparent electrodes. Basically, the LCLV is said to be a longitudinal spatial light modulator (SLM) in the sense that in normal operation (at a bias frequency of 10 kHz and a bias voltage of 10 Vrms), the liquid-crystal molecules are oriented parallel to the surfaces of the parallel electrodes. The surfaces of the electrodes are treated in such a way that, when no electric field is applied, the liquid-crystal molecules are twisted continuously by 90° in going from one electrode to the other. In such a longitudinal device, the readout light is proportional to the writing light. This is suitable for continuous-tone spatial light modulation.

As the frequency of the bias voltage is decreased from 10 kHz, the molecules start to align themselves along the direction of the applied electric field. Thus, the LCLV is gradually converted from a longitudinal SLM to a transverse SLM.

Prior to the experiments, it was known that a two-dimensional longitudinal SLM is sensitive to the longitudinal electro-optic field component $E_z(x,y)$ (the component perpendicular to the surfaces of the electrodes). In a transverse SLM, the electro-optical response is sensitive to the field components $E_x(x,y)$ and $E_y(x,y)$ (parallel to the surfaces of the electrodes). Thus, when the LCLV is operated normally in the longitudinal configuration, the readout image intensity is proportional to the writing image intensity, but when it is operated in the transverse configuration, the readout light intensity becomes proportional to the spatial gradient of the input light intensity. Thus, the investigators theorized that real-time spatial differentiation or enhancement of edges can be achieved by decreasing the bias frequency to obtain the transverse configuration.

In one of the experiments, an Air Force resolution chart was illuminated by a 514.5-nm argon laser beam. When the bias frequency was lowered to 2 kHz, edge enhancement started to appear. This effect was optimized at a bias frequency of 500 Hz. A sharp, binary-looking edge-enhanced resolution chart was obtained as the bias voltage was reduced from 10 Vrms to about 6 Vrms and the LCLV was rotated counterclockwise by 30° (see Figure 2). Other experiments have shown that the use of the LCLV as an edge-enhancing preprocessor can increase the autocorrelation signal (between identical images) and decrease the cross-correlation signal (between similar but different images) in an optical correlator; that is, it can increase the ability of the correlator to distinguish between or recognize different patterns.

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 32 on the TSP Request Card.* *NPO-17768*

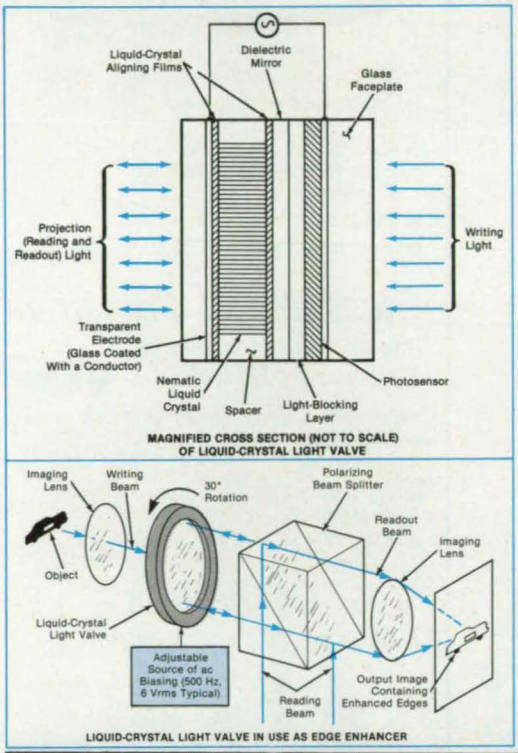


Figure 1. The **Liquid-Crystal Light Valve** can be made to operate in an edge-enhancing mode (or in a combination of edge-enhancing and normal modes) by suitably adjusting the bias voltage and frequency.

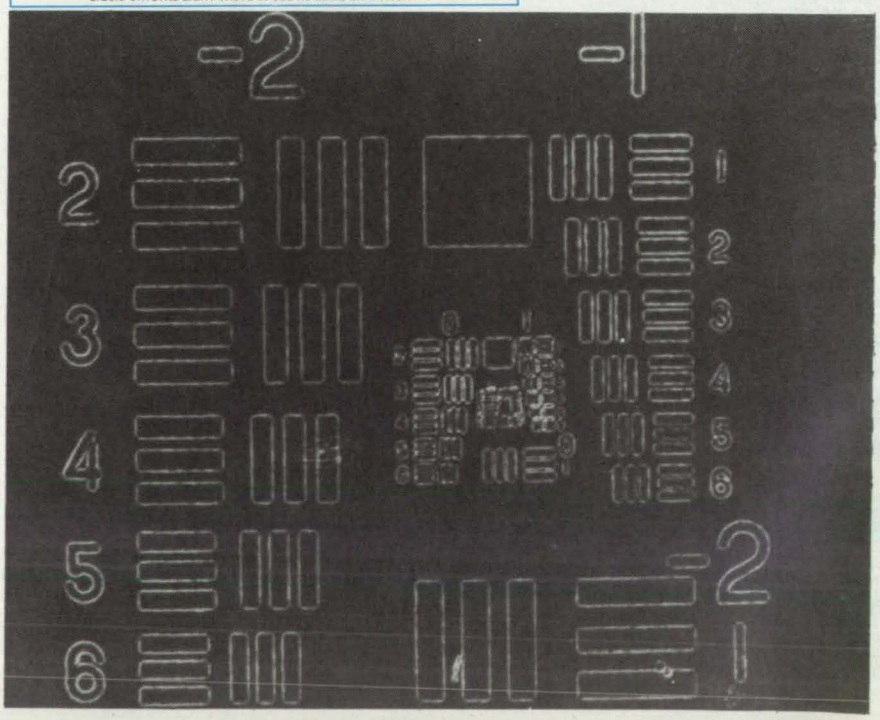


Figure 2. The **Edges Are Enhanced** in this output image of an Air Force resolution chart processed through an apparatus like that of Figure 1.

FTIR Spectroscopic Characterization of II-VI Semiconductors

Transmission spectra are acquired and processed semiautomatically.

Marshall Space Flight Center, Alabama

The combination of a commercial Fourier-transform infrared (FTIR) spectrometer with a computer and special-purpose software constitutes a highly automated facility for the acquisition and processing of infrared transmission or reflection spectral image data. The facility is intended principally to acquire transmission spectra of some compounds of elements in groups II and VI of the periodic table. The compounds are intended for use in infrared detectors, and maps of the infrared transmission spectra (and data derived from the spectra) of specimens are important in quantitatively establishing the spatial uniformity or nonuniformity of properties that affect responses to infrared photons. Of particular interest are maps of transmission edges of specimens of such compounds as HgCdSe and $Hg_{1-x}Cd_xTe$, because a transmission edge is directly related to the composition parameter, x.

In the spectrometer, approximately black-body radiation from an infrared source (e.g., a heated bar of silicon) is focused on the specimen through an aperture 100 μm in diameter. The radiation passes through the specimen to the detecting and spectrum-analyzing equipment. With minimal intervention by the technician, an x–y translation stage driven by stepping motors scans the deserved area of the specimen in increments as small as 50 um along each axis, acquiring the spectrum at each step.

The computer controls the spectrometer and processes its output. The software processes the raw output data into spectra, then manipulates spectra by smoothing, integrating, differentiating, or finding peaks in them. The software provides for a header file, which includes many parameter settings for proper scanning and the collection of spectra, e.g., the number of data points, the shape and size of the specimen, and the type of detector in the spectrometer. The computer reads additions to the header file and commands the x–y stage to translate the specimen according to specifications.

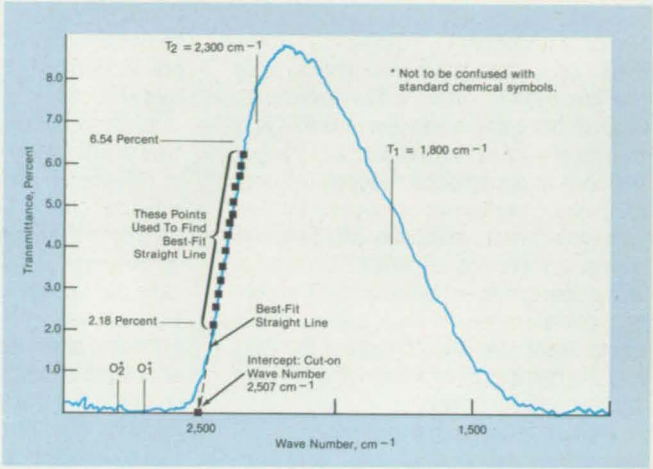
One important feature of the software is the part that automatically extracts a cut-on wavelength or wave number (presumably, a close approximation to the transmission edge) from the spectrum at a given location on a specimen. It involves (1) the designation, in the header file, of wavelengths O_1 and O_2 (not to be confused with standard chemical symbols) between which the specimen is deemed to be opaque and wavelengths T_1 and T_2 between which it is deemed transparent; (2) locating the portion of the spectrum in which the transmittance lies between 25 percent and 75 percent of the span from the level of transmittance designated as "opaque" to the level designated as "transparent"; (3) fitting a straight line to this part of the spectrum; and (4) finding the cut-on wavelength or wave number, which is the intercept of this line with the wavelength or wave-number axis (see figure).

The system has been used to characterize specimens of II/VI alloy semiconductors grown by directional solidification and quenching. Transmission-edge maps have been helpful in studies of flows, gradients of temperature, and coefficients of diffusion in the solidifying melts. The data acquired by this system include optical characteristics, and they both verify and complement data obtained by such other techniques as measurements of density and x-ray-dispersion analysis.

This work was done by G.L.E. Perry and F.R. Szofran of **Marshall Space Flight Center.** *Further information may be found in NASA TM-100379 [N89-29512], "Highly Automated Optical Characterization With FTIR Spectrometry."*

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.

MFS-27234



The **Cut-on Wavelength** of a specimen of HgCdSe is extracted from data on a transmittance peak and in a nearby spectral range of low transmittance.

Solar Concentrator Has Wider Cone of Acceptance

Tolerance to manufacturing and aiming errors is increased.

Marshall Space Flight Center, Alabama

A reflector assembly for the concentration of Sunlight onto a photovoltaic cell is based on a Cassegrainian optical system that has been modified to increase the allowable error angle between the aim and the line of sight to the Sun. This widening of the cone of acceptance reduces the degradation of performance caused by surface-slope errors, misalignments between optical components, and non-fully-specular (i.e., partly diffuse) reflectance. The consequent relaxation of aiming and manufacturing tolerances should reduce the cost and the number of rejects in manufacturing and simplify operation.

Unlike a reflector in an astronomical telescope, a solar concentrator is not required to form a good image of the Sun. The slightly different task of the concentrator is to reflect the available Sunlight fairly evenly onto the finite area of the photovoltaic cell in the focal plane, with or without scrambling of the image. In effect, this amounts to allowing the image to be blurred to a finite extent, and this, in turn, allows some flexibility in the choice of the reflector configuration to increase the amount of light reflected into the blur.

In this concentrator as in a common type of Cassegrainian system, the Sunlight is reflected from a primary paraboloidal reflector onto a secondary reflector and then onto the photovoltaic cell (see Figure 1). However, in this system the secondary reflector is not entirely a hyperboloid, which it would have to be to eliminate spherical aberration and thereby help assure a good image.

Instead, a relatively small part of the secondary reflector consists of the minimal hyperboloid that would form an image from all the specularly-reflected incident parallel light in a perfectly aimed, perfectly manufactured version of the system. Light rays that are up to 3° off axis due to the finite size of the Sun and errors in aiming and manufacturing are reflected onto the photovoltaic cell or a "light catcher" mirror by reflector extensions that blend into the hyperboloidal portion at its inner and outer edges. (The half cone angle could also be designed to be greater or less than 3°, depending on the reflector material, manufacturing process, and other factors. The light catcher is a tertiary mirror consisting of a conic section of revolution that directs stray light onto the photovoltaic cell.)

The performances of the unmodified and modified concentrators are shown in Figure 2. As the test data clearly indicate, a small misalignment does not seriously degrade the performance of the modified concentrator, whereas misalignment has a profound effect in the unmodified concentrator. The performance of the modified concentrator is degraded much less than is that of the unmodified concentrator at aiming errors greater than 3°.

This work was done by Mark A. Kruer of TRW Space & Technology for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-28295*

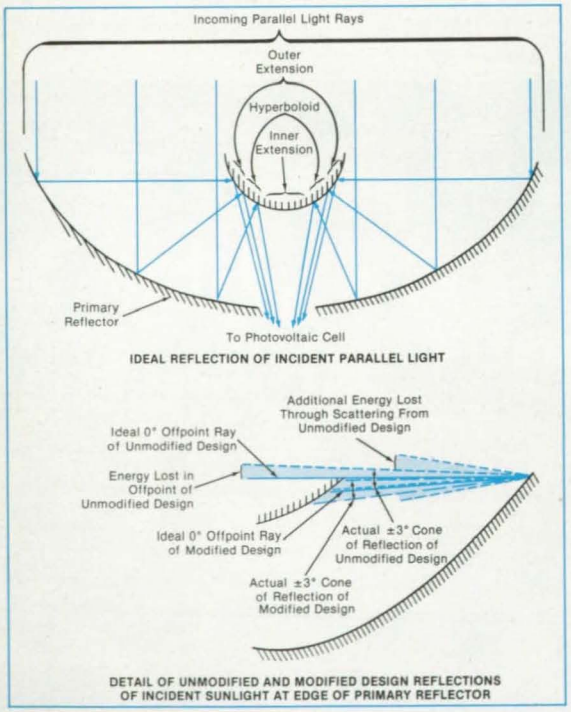


Figure 1. The **Modified Cassegrainian Reflector System** includes a secondary reflector equipped with extensions to utilize off-axis light rays.

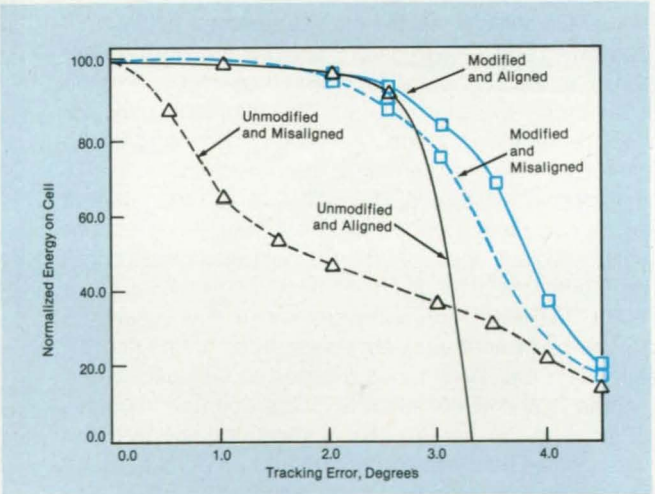


Figure 2. The **Performances of Unmodified and Modified Reflector Systems** are measured in terms of the normalized solar power falling on a photovoltaic cell as functions of the aiming error.

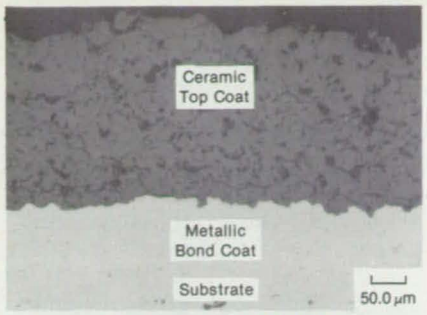
Improved Metallography of Thermal-Barrier Coatings

Pores induced by the metallographic treatment can be distinguished from those already present.

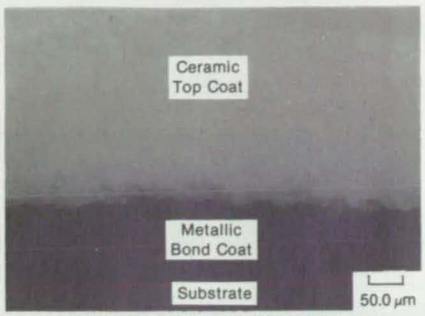
Lewis Research Center, Cleveland, Ohio

A new technique for the preparation of metallographic samples makes the interpretation of images of pores and microcracks more reliable. The technique was developed for the inspection of plasma-sprayed ceramic thermal-barrier coatings on metals but is applicable to other porous, translucent materials, including many important ceramics.

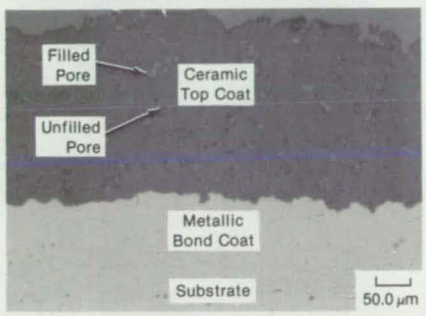
All metallographic techniques pull some material out of the surface of the thermal-barrier coating sections during preparation.



BRIGHT-FIELD ILLUMINATION



INFILTRATED WITH FLUORESCENT EPOXY



INFILTRATED WITH EPOXY AND COATED WITH INTERFERENCE FILM

All Pores in This Metallographic Specimen viewed by conventional illumination appear dark. When the specimen is infiltrated by fluorescent epoxy, pores are masked by the fluorescence. When the specimen is prepared by the epoxy-infiltration-and-interference-film technique, unfilled pores appear dark while filled pores (those produced during manufacture) appear bright.

Previously, this pull-out damage was difficult to distinguish from pores produced during plasma-sprayed manufacturing. Therefore, estimates of the shape and amount of porosity in a coating, factors closely related to coating durability, were subject to uncertainty.

The new technique involves the use of vacuum epoxy infiltration and interference-film coating to reduce the uncertainty. A specimen is first infiltrated with epoxy in a vacuum to fill the interconnected pores induced during manufacture. The specimen is then sectioned, mounted in epoxy and polished according to procedures designed to minimize damage. Finally, the specimen is coated with an optical-interference film.

The film increases the contrast between the various phases in the polished section, making it easier to distinguish between epoxy-filled (manufacturing-induced) pores and unfilled (metallographically damaged or manufacturing-induced but unconnected) pores. The appearance of the phases in the polished section depends on the thickness of the interference film.

As the figure shows, micrographs of the same specimen made by two other techniques show less than does a micrograph made with the infiltration-and-interference-film technique. In the bright-field-illumination micrograph, at the top of the figure, all porosity appears dark, and there are no distinctive features to guide the interpretation of the image. To make the image at the middle of the figure, the specimen was infiltrated with fluorescent epoxy, the fluorescence of which combines with the translucence of the coat to obscure the structure of the coat. The new technique was used to make the image at the bottom of the figure, in which the epoxy-filled interconnected pores and microcracks appear bright and only the unfilled pores appear dark.

This work was done by William J. Brindley of **Lewis Research Center** *and Todd A. Leonhardt of Sverdrup Technologies. No further documentation is available. LEW-15006*

Polarization Filtering of SAR Data

Optimum filtering can maximize the signal-to-noise ratio and aid in discrimination between targets.

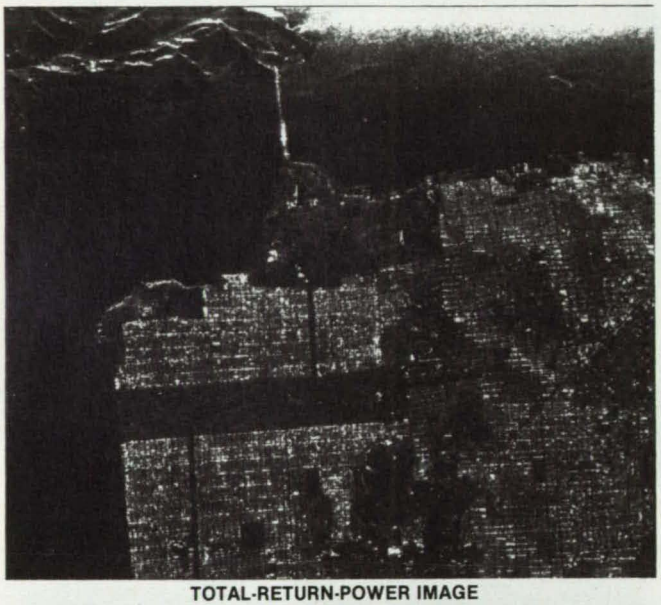
NASA's Jet Propulsion Laboratory, Pasadena, California

Theoretical analysis of the polarization filtering of synthetic-aperture-radar (SAR) returns has provided a hybrid method that can be applied to either (1) maximize the signal-to-noise ratio of the return from a given target or (2) enhance the contrast between targets of two different types (that have different polarization properties). The method is valid for both point and extended targets and for both monostatic and bistatic radars as well as SAR.

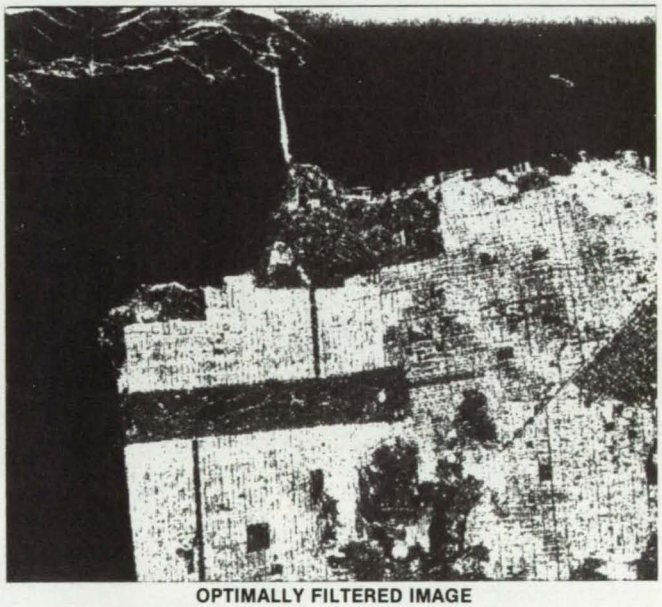
The analysis applies to a radar system that alternatively transmits horizontal and vertical polarizations and receives both horizontal and vertical polarizations simultaneously. The polarization information in the return signals provides a more complete description of the radar-scattering properties of targets than do conventional scalar returns (measured without regard to polarization of the transmitted and received signals) and can be used to obtain additional information about the targets for use in classifying them, discriminating between them, or enhancing the features of radar images.

The optimal-polarization-filtering method is derived from the Stokes-matrix representation of the polarization characteristics of a target. For both the signal-to-noise-maximization and contrast-enhancement cases, the analysis yields equations for the optimal receiving-antenna polarizations as functions of the transmitting-antenna polarizations. However, the transmitting-antenna polarizations must first be determined numerically. For the signal-to-noise maximization case, one chooses the transmitting polarization that yields the maximum return-signal power. For the contrast-enhancement case, one chooses the transmitting polarization that maximizes (or minimizes) the ratio between the powers of the return signals from the two different targets in question.

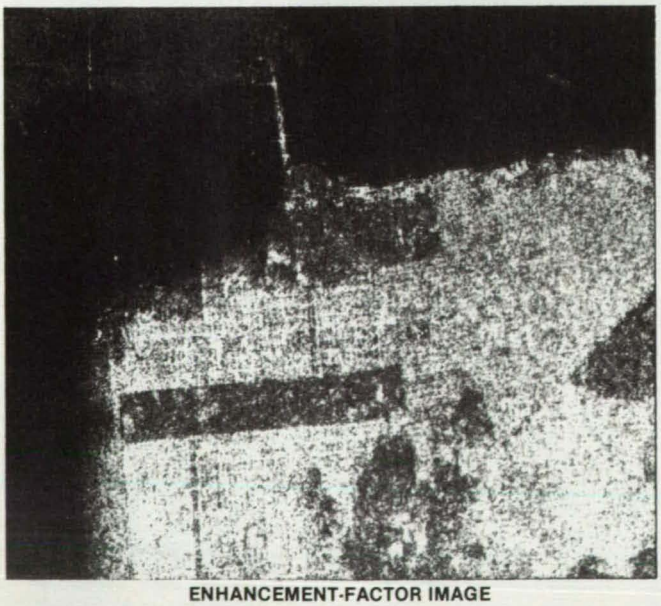
The method was tested by using it to derive a polarization filter that maximizes the contrast between urban and natural



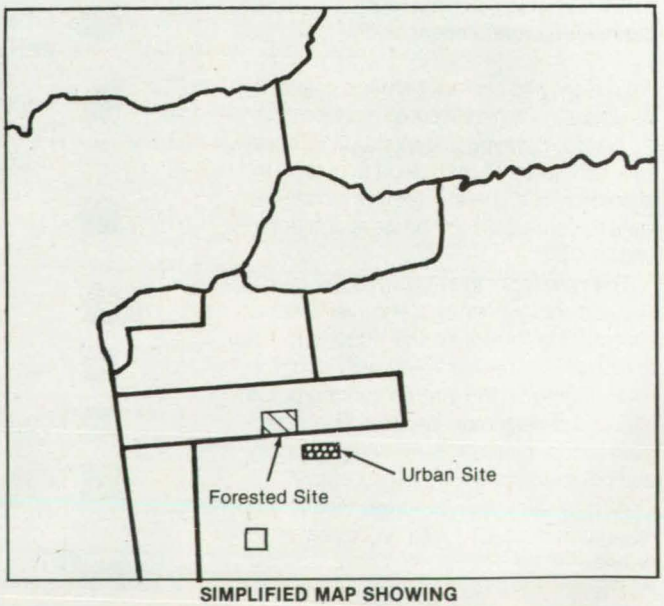
TOTAL-RETURN-POWER IMAGE



OPTIMALLY FILTERED IMAGE



ENHANCEMENT-FACTOR IMAGE



SIMPLIFIED MAP SHOWING SITES USED FOR COMPARISON

Three **SAR Images of the San Francisco Bay** area illustrate the use of optimal polarization filtering to enhance the contrast between a forest and an urban site.

targets (see figure). In this case, it turns out that the same filter is optimum whether the natural target is water, forest, or grass field. This filter increases the contrast ratio between the targets by about 3 dB.

This work was done by Pascale C. Dubois and Jakob J. Van Zyl of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 41 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 18]. Refer to NPO-17904.

Optical Receiver Based on Luminescent Light Trapping

An expensive telescope would not be necessary to gather light over a large area.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experiment has demonstrated the feasibility of an optical-communication receiver based on luminescent light trapping. Usually, faint optical signals are captured over a large area by a large, cumbersome, expensive telescope that can accept only light incident along a direction parallel or nearly parallel to its optical axis. A receiver of the new type is not subject to these limitations. It is simple, inexpensive, and can accept light from almost any angle.

The light-gathering element of the new receiver is a plate of transparent material impregnated with a laser dye. Light from the distant laser transmitter falls on the plate and is absorbed by the dye molecules, which thereby become excited and reradiate. Most of the reradiated light is confined within the plate by total internal reflection as it propagates toward the edge of the plate. Light that arrives at the edge escapes from the plate and is detected by small, high-speed, high-gain photomultiplier tubes or other photosensitive devices.

For a plate that is thin in comparison with its surface area, the light emitted by the edge is concentrated, relative to the incident laser flux, by a factor of $\rho\eta\frac{A_f}{A_e}L$, where ρ is the fraction of light confined by total internal reflection (0.74 when the index of refraction of the plate is 1.5); η is the quantum yield of the dye molecules; A_f is the area of the area of the receiving face (usually, the area of the plate); A_e is the area of the edge; and L is a lumped loss factor that accounts for Fresnel reflection of light entering the plate, reabsorption and scattering of the reradiated light, Fresnel reflection of light leaving the plate and entering the photodetector, and incomplete absorption of the incident light.

The maximum data rate that can be coupled through the receiver is determined by three effects: fluorescence of the dye chromophores, dispersion caused by delays

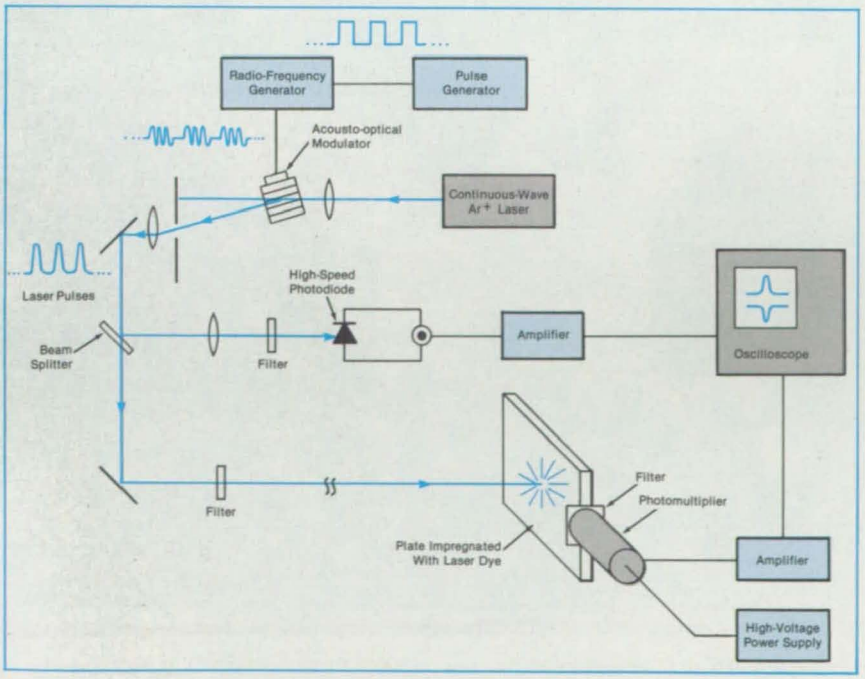


Figure 1. This **Experimental Apparatus** was used to demonstrate the crude luminescent-light-trapping receiver consisting of the dye-impregnated plate and the adjacent photomultiplier.

in transit across the plate, and reabsorption of the reradiated light by the chromophores during propagation to the edge of the plate. The interval between data pulses should be at least three times the characteristic duration of the slowest of these three effects.

In the experiment (see Figure 1), the light collector was a 15-cm by 15-cm by 3-mm sheet of poly(methylmethacrylate) impregnated with Rhodamine 6G laser dye at a concentration of $\sim 1 \times 10^{-3}$ moles/liter. Laser pulses (7 ns full width at half maximum, repetition rate 13 MHz) were generated from a continuous-wave argon-ion laser by an acousto-optical modulator and monitored via a high-speed photodiode. The pulses emitted by the edge of the plate were monitored via a photomultiplier, and the outputs of the photomultiplier and the high-speed photodiode were displayed on an oscilloscope. The measurements show that although the output pulses were broadened somewhat with respect to the input pulses (see Figure 2), a receiver of this configuration could support the reception of data at a rate of 13 MHz and possibly higher.

This work was done by Joseph W. Perry, Terry Cole, and Ahmed H. Zewail of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 25 on the TSP Request Card.*
NPO-17916

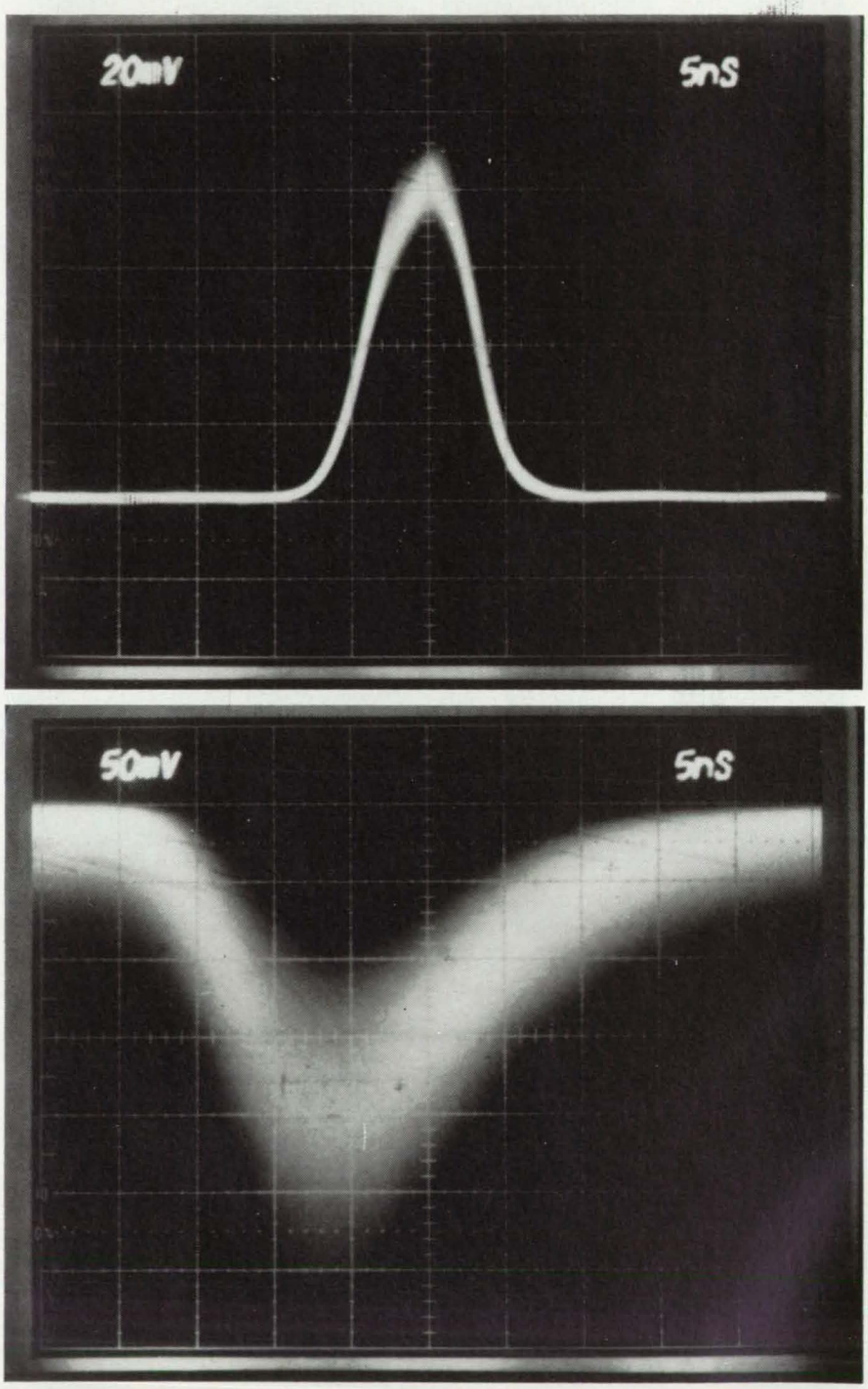


Figure 2. These are **Representative Input and Output Pulses** (a laser pulse detected by the high-speed photodiodes and a luminescence pulse detected by the photomultipler) in the apparatus of Figure 1.

Equal-Path, Phase-Shifting, Sample-Point Interferometer

Sensitivity to vibration and air turbulence would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

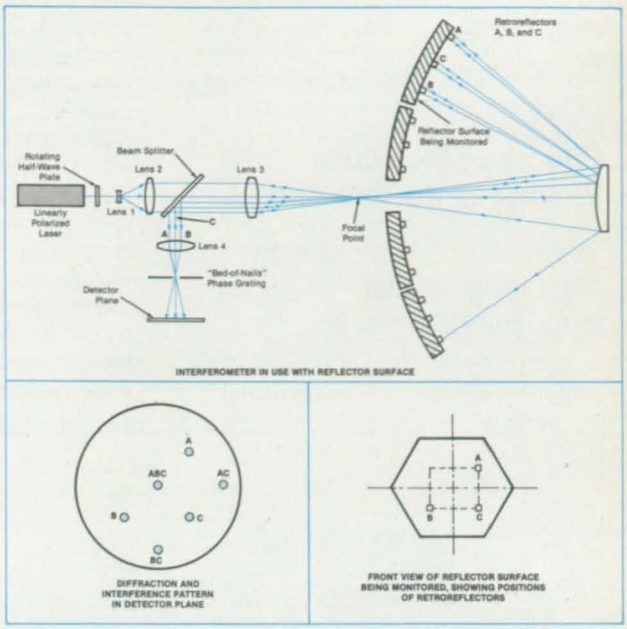
A proposed interferometer would be a combination of a sample-point interferometer and an equal-path interferometer. The new interferometer would be used to monitor the optical figures of arrays of mirrors or of segmented mirrors. The incorporation of phase shifting with part of an equal-path interferometer would render the new interferometer insensitive to vibration and air turbulence. Thus, this instrument could be used over large distances, on the ground, or on vibrating structures.

The figure shows the proposed instrument in conjunction with a segment of a reflector to be monitored. The linearly polarized light from a laser would pass through a half-wave plate that would rotate at a constant rate. The direction of polarization of the emerging light would rotate at twice that rate. The light would then be diverged by lens 1, collimated by lens 2, and passed through a beam splitter to be focused by lens 3. Beyond the focal point, the light would expand and illuminate the optical surface to be monitored.

Corner-cube retroreflectors A, B, and C with weak positive lenses mounted in front would be placed on the surface to be monitored at three corners of a square centered at the center of that surface. C would include a half-wave plate across its aperture. The retroreflectors would return narrow beams of light back through the focal point to lens 3, where they would be collimated and sent to the beam splitter. Because the rotating polarized beam would pass twice through the half-wave plate on C, the beam reflected from C would be continuously shifted in phase between 0° and 360° with respect to the beams reflected from A and B.

The beams from A, B, and C would be reflected by the beam splitter and focused by lens 4 onto a "bed-of-nails" phase grating. The emerging beams would be diffracted into orders symmetric with respect to the A, B, and C beams. Some of the diffracted components would overlap, resulting in phase-shifting interferometry between A and C and between B and C.

Photodetectors would be located in a plane below the bed-of-nails grating at the AC and BC interference spots, to measure the interferometric signals, which would be shifted in phase with respect to each other. Changes in these signals would indicate changes in the surface being monitored. From measurements of these signals and knowledge of the positions of the retroreflectors, one could derive information on the magnitudes and directions of changes in the orientation of the surface being monitored.



The **Equal-Path, Phase-Shifting, Sample-Point Interferometer** could be used to monitor optical surfaces; for example, a segment of a reflector as shown here. The output of the instrument would be interferometric signals from photodetectors AC and BC in the output plane.

This work was done by Paul K. Manhart of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 57 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 18]. Refer to NPO-17913.

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 Molecular Processes on Trim Angles

Vibration and dissociation of molecules alter aerodynamic effects.

A report discusses preliminary calculations of the effects of vibrational excitation and dissociation of air molecules on the trim angle of attack on a blunt body flying at suborbital speed. (The trim angle of attack is the angle of attack that the body assumes, in the absence of deliberate corrective measures, by virtue of equilibrium among the aerodynamic torques acting on it.) The work described in the report is intended as a study of the feasibility and utility of such calculations, motivated by the fact that the trim angle of attack at suborbital and higher speeds is an important aerodynamic parameter for spacecraft reentering the atmosphere and for future hypersonic aerospace vehicles.

The need for this study arises because effects not seen at lower speeds become increasingly important as speeds rise into the suborbital range. Vibrational and electronic excitation, dissociation, and ionization processes absorb energy and thereby cause the temperature to be lower than in a perfect gas. The decrease in temperature contributes to and accompanies an increase in density. The increase in density in turn causes the shock layers around a hypersonic vehicle to be thinner than in a perfect gas. A thinner shock layer causes the shock angle to be smaller than in a perfect gas. This leads to a change in the distribution of pressure over the body, resulting in changes in lift and drag. The changes in lift and drag are usually small. However, substantial changes occur in the pitching moment around the center of gravity of the body, causing the trim angle of attack to change appreciably. As the trim angle of attack changes, the flight characteristics of the body also change.

To start with a relatively simple problem, this study limits itself to speeds $\lesssim 8$ km/s, at which ionization phenomena are weak and, consequently, the changes in aerodynamic characteristics can be calculated by accounting only for vibrational excitation and dissociation. For this reason, air is assumed in this study to consist only of the neutral species (O, N, NO, O_2, and N_2). Because vibrational and electronic excitations contribute significantly to the change in density and tend to be in nonequilibrium states, they are calculated independently. The energies of these excitations are assumed to be characterized by a single temperature T_v, which can be different from the translational/rotational temperature T. The nonequilibrium vibrational/electronic temperature T_v and the concentration of the gas species are determined by integrating the rate equations simultaneously with the equations of flow.

The resulting two-temperature mathematical model of nonequilibrium thermochemistry is incorporated into the previously developed perfect-gas computer code CENS2D (Compressible-Euler–Navier–Stokes Two Dimensional). The resulting code, tentatively named CENS2H (where H signifies hypersonic), is applied to a flow around a two-dimensional body that has the same profile as that of the Apollo Command Module. The solutions are obtained for the forebody shock layer. The lift, drag, pitching moment, and trim angle of attack are calculated from the computed distribution of pressure. The results show that the trim angle of attack changes on account of the high-temperature real-gas effects. The magnitude of the shift in the trim angle of attack is of the same order as that observed during the flights of the Apollo vehicles.

This work was done by Chul Park of **Ames Research Center** *and Seokkwan Yoon of MCAT Institute. Further information may be found in AIAA paper 89A-28447, "Calculation of Real-Gas Effects on Blunt-Body Trim Angles."*

Copies may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

ARC-12566

Nitrous Oxide in the Antarctic Stratosphere

Data are reported for the southern ozone hole.

A paper reports on measurements of nitrous oxide (N_2O) in the upper atmosphere of the Southern Hemisphere. The measurements were made by a tunable-laser absorption spectrometer on an airplane at latitudes from 42° to 72° south and at altitudes from 14 to 21 km during late winter and early spring. The measurements fill a gap in information about the distribution of N_2O over Antarctica while the ozone hole — the annual depletion of ozone — is forming.

N_2O plays three important roles in the stratosphere:

- It is the major source of nitrogen oxides that destroy ozone and maintain photochemical balance.
- It is a "greenhouse" gas, trapping radiation from the surface of the Earth.
- It can be used to trace motions of air.

The southern region in which the measurements were made is unique in the austral winter. The zonal symmetry and radiative cooling of the region create a strong vortex that separates the stratospheric air over the pole from the surrounding air. A strong sinking motion brings air from as high as 50 km down to 20 km.

The paper presents average winter vertical profiles of the concentration of N_2O (using potential temperature as the altitude variable) at 72°, 54°, and 42° south latitude and compares them with equivalent summer profiles. The paper includes plots of latitudinal gradients of the concentration of N_2O on isentropic surfaces. It examines the implications of these gradients for the inhibition of horizontal mixing near the polar vortex. Finally, the paper presents a large-scale distribution of N_2O between 72° and 42° south latitude.

This work was done by J. R. Podolske, M. Loewenstein, S. E. Strahan, and K. R. Chan of **Ames Research Center**. *To obtain a copy of the report, "Stratospheric Nitrous Oxide Distribution in Southern Hemisphere," Circle 62 on the TSP Request Card.*

ARC-12223

Materials

Hardware, Techniques, and Processes

Books and Reports

Silicon Carbide Threads for High-Temperature Service

New thread material outperforms silica.

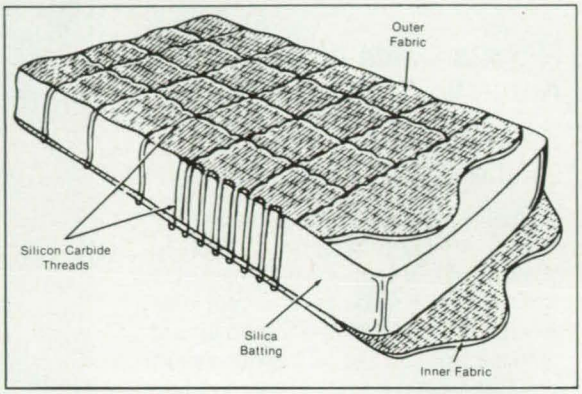
Ames Research Center, Moffett Field, California

Sewing threads containing silicon carbide (SiC) yarn can withstand temperatures of more than 1,100 °C. The new SiC threads are intended for use in stitching thermally insulating blankets, replacing silica threads, which cannot withstand temperatures $\gtrsim$650 °C.

Silicon carbide seemed an attractive thread material for such service from previous studies, which showed that SiC fabric surfaces can survive higher heating loads than silica fabric can. For example, exposure to a heating rate of 37 W/m^2 produced no observable deterioration of SiC fabric, while silica fabric became brittle after exposure to 10 W/m^2. The higher emissivity of SiC is a further advantage, allowing the material to radiate heat at a higher rate than silica can.

A 900-denier (0.1 g/m) SiC yarn was used to make a series of test threads that were two-ply-twisted to various degrees. The tests showed that a SiC sewing thread requires a combination of the following:

- Optimum twist level for strength and balance (a balanced thread hangs in a loop without kinking, doubling, or twisting on itself); and
- A suitable processing aid — a sizing or overwrap of service yarn — to minimize damage to the thread and fabric during machine sewing.



Silicon Carbide Threads were evaluated partly by using them to sew quilted insulating blankets.

A twist level of 122 turns per meter was found to offer the highest strength attainable simultaneously with acceptable thread balance. Two processing treatments — sizing with polytetrafluoroethylene and overwrapping with rayon/dacron service yarn — were evaluated for use as aids to machine sewing. Threads thus treated maintained higher break strengths than did untreated threads, over the entire temperature range at which the threads were tested (room temperature to 1,200 °C). Both types of treated thread were acceptable in sewing trials, although the use of rayon/dacron-served thread resulted in a quilted blanket (see figure) in which the threads retained greater strength and there was less damage to the fabric.

This work was done by Paul M. Sawko of **Ames Research Center** *and Anand Vasudev of San Jose State University. For further information, Circle 127 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, Ames Research Center [see page 18]. Refer to ARC-12406.

Electrochemical Deposition of Conductive Copolymers

Adherent films have desirable electrical and mechanical properties.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that electrically conductive films can be deposited on glassy carbon or indium tin oxide substrates by the electrochemical polymerization of N-[(3-trimethoxy silyl) propyl] pyrrole (monomer I; see Figure 1) or copolymerization with pyrrole. Pure polymer I has relatively low electrical conductivity but adheres well, forming covalent chemical bonds with the substrates. On the other hand, pure polypyrrole is a better conductor but does not adhere as well. Though the method of deposition has yet to be optimized and the characteristics of the deposited films have not yet been determined completely, the experimenters expect that the copolymers of monomer I and pyrrole will exhibit the desired electrical conductivity as well as the desired adhesion and other mechanical properties. When fully developed, the new copolymerization process should be useful in making surface films of selectable conductivity; for example, to drain off electrostatic charges or protect against electromagnetic interference.

The electrochemical deposition of polypyrrole had been studied previously, and it was known that monomer I could be used to improve the adhesion of polypyrrole. However, little was known about the copolymers of pyrrole and monomer I. In these experiments, the solution for the deposition of a polymer or copolymer consisted of the appropriate amount(s) of monomer I and/or pyrrole mixed with an electrolyte of anhydrous tetra n-butyl ammonium perchlorate supported by the solvent acetonitrile. The polymers and copolymers were deposited on glassy carbon or indium tin oxide electrodes, using a platinum counterelectrode.

The deposited films were tested by cyclic voltammetry, which showed that the anions diffuse differently in films of different composition. Infrared spectra of the films indicated the presence of molecular linkages of the type that occur in the copolymer but not in either pure polymer. The equality of two-probe electrical-resistance measurements before and after the immersion of the films in the solvent indicates that each monomer is locked into a polymer matrix and not merely deposited loosely in a polymer matrix formed from the other monomer. The electrical conductances of the films were found to depend on composition (see Figure 2).

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Interlaminar Shear Strength - KSI (4-Pt)	9.1	4.
Open Hole Compression - KSI	44	2

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PHILLIPS 66

This work was done by Ganesan Nagasubramanian, Salvador DiStefano, and Ranty H. Liang of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 131 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 18]. Refer to NPO-17826.

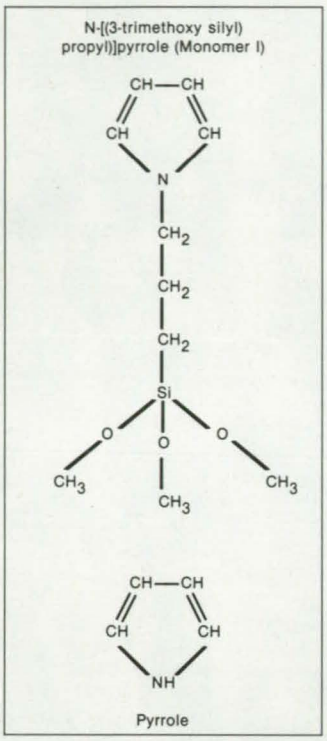


Figure 1. **Copolymers of Pyrrole and Monomer I** can be formed by electrochemical deposition from a mixture of these monomers with the electrolyte tetra n-butyl ammonium perchlorate in acetonitrile solvent.

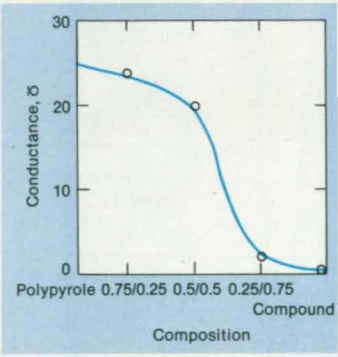


Figure 2. The **Conductances of Copolymer Films** were found to vary with composition. (The conductance is given instead of the conductivity because the exact thickness is not known.)

Platinum/Tin Oxide/Silica Gel Catalyst Oxidizes CO

High surface area and chemisorption of water contribute to effectiveness and long life.

Langley Research Center, Hampton, Virginia

A heterogeneous catalyst of platinum, tin oxide, and silica gel combines small concentrations of the laser dissociation products, CO and O_2, to form $CO_2$2 during long times at ambient temperature. The catalyst was developed as a means to prevent the accumulation of these products in sealed CO_2 lasers. (CO_2 lasers are operated sealed in many applications.)

In a sealed CO_2 laser, a small amount of CO_2 gas is decomposed in the electrical-discharge zone into corresponding quantities of CO and O_2. As the laser continues to operate, the concentration of CO_2 decreases monotonically, while the concentrations of CO and O_2 increase monotonically. As a result, laser power decreases rapidly because fewer CO_2 molecules can be boosted to higher energy levels by the electrical discharge. The increasing concentration of O_2 also reduces laser power because O_2 scavenges electrons in the electrical discharge, thereby causing arcing and depleting the supply of energetic electrons that boost CO_2 molecules to lasing energy levels.

Many catalysts must be heated to elevated temperatures to combine the products of dissociation of CO_2 efficiently. Such heating is not allowable in the laser envelope because the gas in this envelope must be maintained at ambient temperature for efficient operation. A catalyst that must be heated must be

located in a recirculating loop external to the laser; this requires a pump, heating system, and cooling system, all of which add to the operating cost. The additional equipment also adds weight—a severe disadvantage in airborne or spaceborne applications.

The new catalyst, however, is effective at ambient operating temperatures and can be installed directly in the laser envelope. The catalyst was formulated to have a very high surface area and to chemisorb controlled quantities of moisture: chemisorbed water is contained within and upon its structure, making it highly active and very longlived so that only a small quantity of it is needed for long times. The end result is an effective catalyst for the reaction of CO and O_2 to form CO_2 without introducing, into the CO_2 gas, amounts of water that are deleterious to the operation of the laser.

This work was done by Billy T. Upchurch, Patricia P. Davis, and David R. Schryer of **Langley Research Center;** *Irvin M. Miller of Science and Technology Corp.; and David Brown, John D. Van Norman, and Kenneth G. Brown of Old Dominion University Research Foundation. For further information, Circle 65 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive licence for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-14155.

Adsorbent Removes Traces of Oxygen

Specially treated carbon extracts oxygen from gas mixtures.

NASA's Jet Propulsion Laboratory, Pasadena, California

An adsorbent selectively removes oxygen from gas mixtures, producing a gas containing less than 1 part per billion of oxygen. The adsorbent can be used to help prevent the oxidation of chemicals being prepared in dry boxes or to extract undesired traces of oxygen from inert-gas chambers in which flammable gases are stored.

The adsorbent is a carbon molecular sieve containing copper oxide. In a reduced state, the material has a strong affinity for oxygen but rejects larger molecules.

The experimental preperation of a specimen of the material began with the addition of a solution of 1.0 g copper acetate in 200 mL of methanol to 2 mL polyfurfuyl alcohol (PFA). The mixture was stirred, then the methanol was allowed to evaporate at room temperature for 16 h. The resinous residue left after evaporation was baked in flowing nitrogen for 6 h at temperatures that increased in 100°C steps from 100°C to 600°C. Pyrolysis took place during the baking, yielding the carbon molecular sieve with copper oxide additive.

The material was reduced in a mixture of 5 percent hydrogen and 95 percent argon for 12 h at 220°C. The material was then ready for testing as an adsorbent for oxygen. When the molecular sieve was exposed to a mixture of 1.2 percent oxygen and 98.8 percent argon at a temperature of 220°C, its weight increased by 1.8 percent (see figure). The gain in weight is attributable solely to oxygen, inasmuch as the adsorption of argon at that temperature is negligibly small. Similar tests with gases that have large molecules showed much less adsorption.

Methods for the preparation of the material have not yet

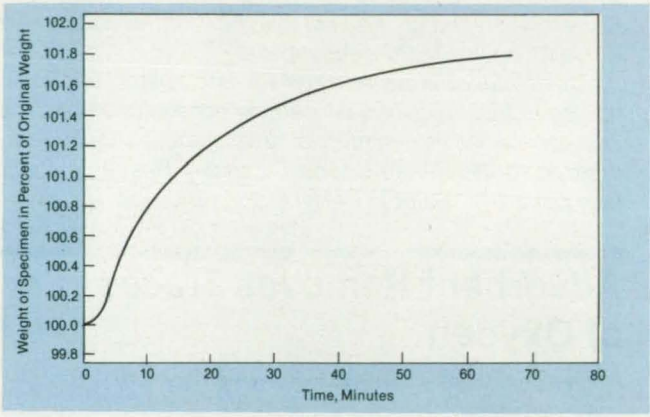
been optimized. Improvements that disperse the copper oxide better in the carbon matrix are expected to increase the uptake of oxygen.

This work was done by Pramod K. Sharma and Panchalam K. Seshan of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 98 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

Refer to NPO-17947 volume and number of this NASA Tech Briefs *issue, and the page number.*



The **Weight of the Carbon Adsorbent Containing CuO** rises steadily in a mixture of argon and oxygen.

Zeolites Remove Sulfur From Fuels

Extraction proceeds at atmospheric pressure and moderately high temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

Zeolites can remove substantial amounts of sulfur compounds from diesel fuel under relatively mild conditions—atmospheric pressure below 300°C. With suitable pretreatment, a zeolite can extract up to 60 percent of the sulfur content of a high-sulfur fuel. It is likely that even more sulfur can be extracted by new, larger-pore zeolites.

The zeolite method is applicable to petroleum refineries, natural-gas processors, electric powerplants, and chemical-processing plants. The method is simpler and uses considerably lower pressure than does the current industrial method, hydro-desulfurization. By removing sulfur, the method not only yields cleaner emissions from the combustion of petroleum fuels but also protects catalysts from poisoning by sulfur.

The best results to date have been obtained with zeolite 13X in which sodium ions have been replaced by copper and lanthanum ions. In a demonstration of the method, diesel fuel and zeolite beads were placed in a laboratory reflux apparatus in an inert atmosphere of flowing nitrogen. The contents were heated to a temperature of 245 to 265°C. After about an

hour of heating, the reflux reaction began. It was allowed to continue for an hour, then the contents cooled for another hour.

In two such refluxes—one with a copper-exchanged zeolite, the other with zeolite that had been lanthanum-exchanged, then copper-exchanged—56 percent of the sulfur content of the fuel was removed. A third reflux—with zeolite that had been copper-exchanged first, then lanthanum-exchanged—removed a little additional sulfur, bringing the total amount removed to 60 percent.

The spent zeolite can be regenerated after each use. The beads are packed in a quartz reactor and first heated to 400°C in flowing nitrogen. Then the flow is changed to a mixture of 70 percent nitrogen and 30 percent air. After about 2 h, the color of the beads changes from black to light blue, the same color they had before the reflux reaction.

The sulfur-removal capacity of the beads falls only 5 percent after the first two regenerations. Thereafter, there is no substantial reduction in capacity.

Metal-exchanged zeolite is prepared by exchanging the sodium in the original zeolite with ammonium, then exchanging the ammonium with higher-affinity metal ions. A long soak in an ammonium nitrate solution produces the ammonium exchange. Another soak in copper nitrate solution produces the copper exchange. A soak in lanthanum nitrate before (or after) the copper exchange produces lanthanum/copper (or copper/lanthanum) zeolite.

This work was done by Gerald E. Voecks and Pramod K. Sharma of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 109 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive licence for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17480.

Passivation of High-Temperature Superconductors

Simple wet chemical processes create protective surface layers.

NASA's Jet Propulsion Laboratory, Pasadena, California

The surfaces of high-temperature superconductors can be passivated with native iodides, sulfides, or sulfates formed by chemical treatments after the superconductors have been grown. The passivating compounds are nearly insoluble in and unreactive with water and, therefore, protect the underlying superconductors from the effects of moisture. Thus far, passivating layers of cuprous iodide (CuI) and of barium sulfate ($BaSO_4$) have been grown. Experiments on the growth of layers of cupric sulfide (CuS), cuprous sulfide (Cu_2S), and mixed CuS and Cu_2S are planned.

The passivating layers have been formed on 1-μm-thick films of $YBa_2Cu_3O_{7-x}$ superconductor by wet chemical processes. Layers of this type are also expected to be compatible with other high-temperature superconductors. Those passivating compounds that contain copper, in particular, should give almost identical protection on the other superconductors, inasmuch as most currently known high-temperature superconductors are cuprates.

In the first step of each of the still-experimental passivation processes, a superconducting film is etched in a solution of

bromine and absolute ethanol to produce a clean surface of nearly ideal composition. In the second step in one of the processes, the superconductor is then dipped in absolute ethanol containing 1 percent hydrogen iodide (HI) to form a CuI layer on the surface. If the superconductor is then immersed in water, a very thin film of copper hydroxide [$Cu(OH)_2$] forms on its surface, but the underlying CuI remains intact and thus remains an effective passivating layer. CuI has the additional advantage of being a semiconductor, so electrical contact can be made directly to it instead of to the superconductor.

In the second step of another of the processes, a surface layer of $BaSO_4$ is formed by dipping a superconducting film in an aqueous solution of 1 percent sulfuric acid (H_2SO_4). The subsequent immersion of the treated superconductor in water produces no changes, as measured from x-ray photoelectron spectra; the sulfate is chemically inert with respect to water. The sulfate layer is an insulator

In the second step of another process, yet to be tried, a film of Cu_2S and/or CuS is expected to be formed when a superconducting film is dipped in an aqueous solution of a sulfide such as sodium sulfide (Na_2S) or ammonium sulfide [$(NH_4)_2S$]. Cu_2S is known to be virtually insoluble in water, and CuS has very low solubility.

Other candidate passivating surface films are iodides and sulfides of bismuth, strontium, and thallium. Other proposed techniques for the formation of passivating layers include deposition and gas-phase reaction.

This work was done by Richard P. Vasquez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 78 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 18]. Refer to NPO-17949

Protecting Helmets and Visors From Chemicals

An outer layer stops chemical attack.

Lyndon B. Johnson Space Center, Houston, Texas

A thin layer of polysulfone on polycarbonate safety helmets and visors protects them from attack by chemicals. Developed to protect space-suit helmets from spacecraft propellants like hydrazine and nitrogen tetroxide, the polymer coat may also be useful in industrial safety helmets.

The polysulfone/polycarbonate laminate has high resistance to creep under tension load. It retains its dimensional stability when exposed to moisture. The added polysulfone layer does not adversely affect the optical properties of polycarbonate visors.

The lamination is prepared by vacuum heat molding. The configuration can be varied to accommodate such special requirements as high impact strength or protection against moving particles and debris.

This work was done by Joseph J. Kosmo and Frederic Dawn of **Johnson Space Center**. *For further information, Circle 99 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, Johnson Space Center [see page 18]. Refer to MSC-21503.

Mechanically Oriented, Low-Curie-Temperature Materials

Stronger permanent magnets would be made by metallurgical techniques.

Marshall Space Flight Center, Alabama

A proposed fabrication process would produce permanent magnets of greater flux density, intended for use at temperatures far below room temperature. Such magnets are parts of electrical motors and other electromechanical actuators that operate in cryogenic systems. The performances of actuators increase with the flux densities available from their magnets.

Permanent magnets made of the familiar materials that have Curie temperatures above room temperature can function in cryogenic systems. However, cryogenic applications open up the opportunity to use newer magnetic materials that have higher magnetic moments but that do not ordinarily act as permanent magnets because their Curie temperatures are below room temperature. One such material is Dy_3Al_2, single crystals of which have exhibited an energy product of 73 MG•Oe at a temperature of 4.2 K. This represents a substantial increase over the best currently available permanent-magnet material, $Pr_2Fe_{14}B$, which has an energy product of 49 MG•Oe.

Until now, permanent magnets have been made from the familiar materials by standard processing techniques in which powders destined to be formed into magnets are aligned in magnetic fields at room temperature. Other processing techniques must be devised for the newer materials, because at room temperature, they lose their magnetism as soon as the aligning magnetic fields are removed. The proposed process is based on the use of mechanical metallurgical techniques (e.g., die upsetting and extrusion) to make oriented magnets of Dy_3Al_2, because these techniques can produce alignment above the Curie temperature. In recent years, these techniques have been applied successfully to $Nd_2Fe_{14}B$, yielding (in the case of die upsetting) magnets that have energy products comparable to those of their field-aligned counterparts.

The proposed process entails two difficulties. The first is that die upsetting and extrusion, when applied to uniaxial materials, produce complementary orientations, and only one of these processes can produce a uniaxial texture (the other being two-dimensional isotropic). Which of these processes produces the desired uniaxial texture, the degree of alignment, and the necessary processing conditions (temperature, deformation rate, and the like), remains to be determined. The second difficulty is that, because of their low Curie temperatures, the new magnets must be magnetized at low temperatures. This can be done by applying a magnetic field to a magnet-to-be via coils while the magnet-to-be is cooled. This technique can succeed because Dy_3Al_2 becomes magnetically soft well above the Curie temperature.

This work was done by Edwin B. Boltich of Advanced Materials Corp. for **Marshall Space Flight 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, Marshall Space Flight Center [see page 18]. Refer to MFS-26110.

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.

Reactions of Atomic Oxygen [O(^{3}P)] With Polybutadienes

Vinyl groups exert a strong protective effect.

A report describes an experimental study of the chemical reactions of atomic oxygen in the ground state [O(^{3}P)] with polybutadienes and related polymers. Attention has been focused on such reactions because of the adverse effects of environmental atomic oxygen on polymeric materials in low orbits around the Earth. There is a need to study the mechanisms of the reactions of O(^{3}P) with a family of closely related polymers to identify the steps commencing with the initial attack by oxygen atoms and culminating in the degradation of the polymers.

The polymers selected for this study were cis- and trans-1,4-polybutadienes (CB and TB), atactic 1,2-polybutadiene (VB), polybutadienes of various 1,4/1,2 contents, trans polypentenamer (TP), cis- and trans-polyoctenamers (CO and TO), and ethylene/propylene rubber (EPM). Thin films of the polymers were cast on glass cover slips and on NaCl and KBr disks from solution in benzene. The films were exposed at room temperature to O(^{3}P) generated by a radio-frequency glow discharge in O_2. Transmission and ATR infrared spectra of the films on the salt disks were measured before and after exposure to O(^{3}P). The cover-slip specimens were weighed before and after exposure to determine the weight losses.

The spectra of the CB and TB films revealed extensive etching but no changes of microstructure within the films. This showed that the reactions were confined to the surface layers. The O(^{3}P) did not induce cis/trans isomerization in the remaining CB and TB. From the weight-loss measurements, the rates of etching of the elastomeric polybutadienes showed a strong tendency to decrease with increasing vinyl (or 1, 2) contents. The rates of etching of the polyalkenamers were found to increase with a decrease in —CH=CH— unsaturation.

To explain these findings, the authors cite the Cvetanović mechanism: O(^{3}P) is added to the double bond to form a transitory biradical adduct, which either rearranges to a vibrationally hot epoxide or carbonyl product or undergoes pressure-independent fragmentation. The hot products in turn are either collisionally deactivated to the corresponding stable compounds or undergo pressure-dependent fragmentation.

The protective effect of the vinyls in polybutadienes is explained partly by cross-linking initiated through abstraction of tertiary hydrogen atoms in the vinyl monomer units. The etch-rate data for the polyalkenamers as a function of unsaturation are attributed to a competition between addition of O(^{3}P) to the double bond and abstraction of hydrogen, which gives rise to fragmentation with high efficiency.

This work was done by Morton A. Golub, Narcinda R. Lerner, and Theodore Wydeven of **Ames Research Center**. *To obtain a copy of the report, "Reactions of Atomic Oxygen [O(^{3}P)] with Polybutadienes and Related Polymers," Circle 145 on the TSP Request Card.*
ARC-11851

Impact Damage in Carbon/Epoxy and Carbon/PEEK Composites

PEEK specimens showed less delamination than did epoxy specimens at a given impact energy.

A report describes the results of drop-weight impact testing (impact energies ranging from 0.80 J to 1.76 J) of specimens of carbon-fiber/epoxy and carbon-fiber/polyetheretherketone (PEEK) composite materials. Panels made of these materials can be assembled into lightweight, strong, stiff structures that are useful in automobiles, aircraft, sporting goods, and many other products. However, parts made of these composites are vulnerable to puncture-type impact damage. A better understanding of this damage can assist in the design of parts made of these materials and in the evaluation of the usability of a part that has been damaged by impact.

All of the specimens contained 69 weight percent fibers and were laminated in eight-ply bidirectional and unidirectional configurations. Each specimen was 30.5 cm long, 2.54 cm wide, and 1.02 mm thick.

Each specimen was clamped between two aluminum plates and struck, through holes in the plates, by an instrumented drop-weight impact tester. To obtain a puncture type of impact, the tup was of a smaller diameter (4.2 mm) than were those used in most previous studies, and the specimens were placed over a hole 10.3 mm in diameter. The impact energies were

varied by varying the drop heights from 7.6 to 15.2 cm for the bidirectional specimens and from 7.6 to 12.7 cm for the unidirectional specimens.

After impact, each specimen was cross-sectionally cut through the point of impact in a direction perpendicular to the outer fibers by use of a small diamond-wheel cutter. These cross sections were then observed and photographed at 12× magnification.

The bidirectional specimens showed little damage until the impact energy was 1.13 J. At this energy, delaminations were seen in the epoxy specimens. For a given impact energy, the PEEK specimens were less delaminated than were the epoxy specimens, and the unidirectional specimens were more damaged than were the bidirectional specimens. Of the unidirectional specimens, those made with PEEK proved to be more resistant to impact than were those made with epoxy: at every energy level, the PEEK matrices underwent much less cracking than did the epoxy matrices. In general, the impact damage sustained by unidirectional specimens is much more dependent on matrix shear toughness than is the damage sustained by bidirectional specimens because the unidirectional samples contain no cross fibers, which help prevent matrix shear failure during a puncture type of impact.

This work was done by A. T. Nettles and N. J. Magold of **Marshall Space Flight Center**. *Further information may be found in NASA TM-100391 [N90-21125], "Cross-Sectional Examination of the Damage Zone in Impacted Specimens of Carbon/Epoxy and Carbon/PEEK Composites."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18]. Refer to MFS-27245.

SiO_x Protective Coat for Polyimide Sheet

The surface film would protect the substrate from bombardment by atomic oxygen.

A report and a detailed appendix describe a protective coat of SiO_x (where x is 1.9–2.0) on Kapton H® polyimide sheet. The sheet is intended for use as the blanket substrate material of a flexible array of solar photovoltaic cells on the Space Station Freedom.

The continuous bombardment by atomic oxygen in low orbit around the Earth would rapidly oxidize an unprotected polyimide sheet. Previous experiments have shown that a coat of SiO_x is sufficiently impervious to atomic oxygen to forestall degradation and that it can withstand the chemical processing and most of the mechanical operations used to fabricate the solar array. However, because the SiO_x coat cannot withstand severe bending (as in forming the hinge joints at the edge of each solar panel), an aluminum foil coat would be used at the hinges.

The SiO_x coat is vacuum-sputtered onto the polyimide sheet. Such coatings have been durability-verified in space tests on STS-8 and the Long Duration Exposure Facility. For the solar-array blankets, the specification calls for a coating 1,000 ± 130 Å thick on a polyimide sheet 0.00100 ± 0.00020 in. (25.4 ± 5.1 μm) thick.

This work was done by Bruce Banks, James Sovey, and Michael Mirtich of **Lewis Research Center**. *To obtain a copy of the report, "New Technology Report — Interim Protective Coating Photovoltaic Array Environmental Protection (PAEP)" and the appendix, "Detail Specification for Atomic Oxygen Resistant Thin Film Coating on Polyimide Sheet Space Station/Platform Solar Array," Circle 134 on the TSP Request Card.*
LEW-14912

Computer Programs

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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.

Mechanics

Fatigue-Crack-Growth Computer Program

The propagation of a crack can be computed from any of several mathematical models.

Flaws and cracks in structures may grow under loads that induce fatigue and, upon reaching critical sizes, can cause the structures to fail. The growth of these flaws and cracks can occur at load levels well below the ultimate load-bearing capabilities of the structures. The Fatigue Crack Growth (NASA/FLAGRO) computer program was developed as an aid in predicting the growth of preexisting flaws and cracks in structural components of space systems. The earlier version of the program, FLAGRO4, was the primary software tool used by Rockwell International and the Shuttle subcontractors for fracture-control analysis of the Space Shuttle.

NASA/FLAGRO is an enhanced version of FLAGRO4 and incorporates state-of-the-art improvements in both fracture mechanics and computer technology. NASA/FLAGRO provides the fracture-mechanics analyst with a computerized method of evaluating the "safe-crack-growth-life" capabilities of structural components. NASA/FLAGRO could also be used to evaluate the tolerance to damage of a structure of given design.

The propagation of an existing crack is governed by the stress field in the vicinity of the tip of the crack. The stress-intensity factor is defined in terms of the relationship between the magnitude of the stress field and the size of the crack. The propagation of the crack becomes catastrophic when the local stress-intensity factor reaches the fracture toughness of the material.

NASA/FLAGRO implements a two-dimensional mathematical model that predicts the growth of a crack independently in two directions on the basis of the calculation of stress-intensity factors. The analyst can choose to use either a crack-growth-rate equation or a nonlinear interpolation routine based on tabular data. The growth-rate equation is a modified Forman equation that can be converted to a Paris or Walker equation by substituting different values into the exponent. This equation provides accuracy and versatility and can be fitted to data using standard least-squares methods. Numerical values of stress-intensity factors can be computed for making comparisons or verifying solutions. NASA/FLAGRO can check for failure of a part-through crack in the mode of a through crack when net ligament yielding occurs.

NASA/FLAGRO contains a number of special subroutines and files that provide enhanced capabilities and easy entry of data. These include solutions for cracks in specific cases, cyclic load spectra, sizes of initial flaws in nondestructive examination, interpolation in tables, and properties of materials. The files that contain data on the properties of materials are divided into two types: one defined by the user and one fixed. Data are entered and stored in the file defined by the user during execution of the program, while the fixed file contains data on the values of properties of many different materials that have already been encoded. Input prompted by displays on cathode-ray-tube terminals consists of in-

THE MATHWORKS INTRODUCES

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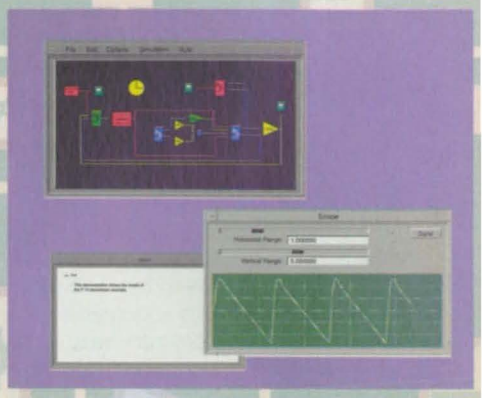

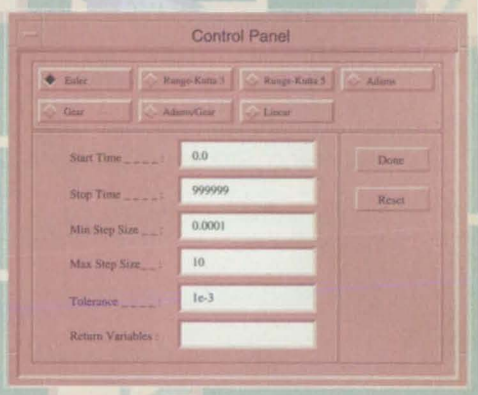

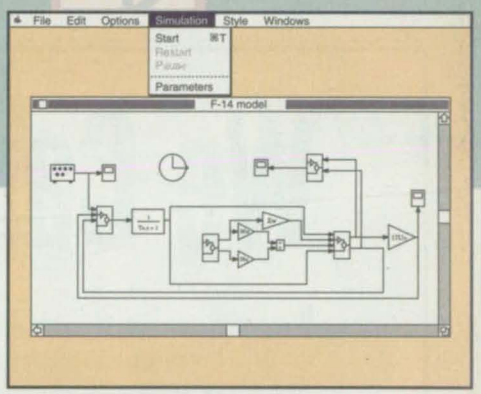

(Top) Use the Scope block to see the "real-time" response of this F-14 model during the simulation; (Center) Specify simulation parameters via dialog boxes or the MATLAB command line; (Bottom) SIMULAB takes full advantage of the X/Motif and Macintosh windowing systems.

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itial definition of the crack (the crack can be defined automatically), type of rate solution, type and geometry of flaw, properties of the material (if they are not in the built-in tables of data), load-spectrum data (if not included in the file of load spectra), and design-limit levels of stress. The output of NASA/FLAGRO includes an echo of the input with any error or warning messages, the final size of the crack, whether or not the critical size of the crack has been reached for the specified level of stress, and a profile that gives the history of the propagation of the crack.

NASA/FLAGRO is designed to be modular to facilitate revisions and operation on minicomputers. The program was implemented on a DEC VAX 11/780 computer with the VMS operating system. NASA/FLAGRO is written in FORTRAN 77 and requires a memory of 1.4 MB. The program was developed in 1986.

This program was written by Royce. G. Forman of **Johnson Space Center**, *V. Shivakumar of Lockheed Engineering & Science Co., and James C. Newman, Jr., of Langley Research Center. For further information, Circle 33 on the TSP Request Card.*

MSC-21669

Simulating Dynamics of the Gamma-Ray Observatory Satellite

GRODY helps the analyst perform and report on a simulation.

Analysts use a dynamics-simulator computer program to test the attitude-control system algorithms used by a satellite. The program must simulate the hardware, dynamics, and environment of the particular spacecraft and provide services that enable the analyst to conduct simulations. Researchers at Goddard's Flight Dynamics Division developed the GRODY computer program alongside the GROSS computer program (GSC-13147), which is a FORTRAN dynamics-simulator program that performs the same functions. GRODY was conceived for use in a case study to assess the feasibility and effectiveness of the Ada programming language for the development of flight-dynamics software. The researchers used popular object-oriented design techniques to link the design of the dynamics-simulator program with its function.

GRODY is designed for those familiar with the analysis of the attitudes of spacecraft. The program supports the planning of maneuvers as well as analytical testing and evaluation of the attitude-determination and -control system used on board the Gamma-Ray Observatory (GRO) satellite. GRODY simulates the computer and the control processor electronics aboard the GRO satellite. The analyst or other user sets up and controls the simulation. GRODY enables the analyst to check and update commands sent from the ground and the values of parameters, obtain displays of the status of the simulation, interrupt the simulation, analyze previous runs, and obtain printed output of simulation runs.

The video terminal can make sequences of commands visible, provide for full-screen display and modification of parameters by use of input fields, and assist in the verification of all input data. Input data available for modification include alignment and performance parameters for all attitude hardware, simulation-control parameters that determine the schedule, output, initial conditions, and on-board-computer commands of the simulation.

GRODY generates eight types of output: (1) a set of data on the results of the simulation, (2) a report on the analysis, (3) a report on the parameters, (4) a report on the simulation, (5) a display of the status, (6) plots, (7) diagnostic output (which helps the user trace any problems that have occurred during a simulation), and (8) a permanent log of all runs and errors. The analyst can send results in graphical or tabular form to a terminal,

disk, or hard-copy device and can choose to have any or all items plotted against time or against each other.

Goddard researchers developed GRODY on a VAX 8600 computer running version 4.0 of VMS. For nearly real-time performance, GRODY requires a VAX computer at least as powerful as a model 8600 running VMS 4.0 or a later version. To use GRODY, the VAX needs an Ada Compilation System (ACS), Code Management System (CMS), and a memory of 1,200 KB. GRODY is written mainly in Ada (99 percent) with the remainder in FORTRAN.

This program was written by M. Stark of **Goddard Space Flight Center**. *For further information, Circle 159 on the TSP Request Card.*
GSC-13293

Analyzing Large Reflector Antenna Structures

This finite-element-analysis program is flexible and easy to use.

The Iterative Design of Antenna Structures (IDEAS) computer program performs finite-element analysis and optimization of design, with special features for the analysis and design of microwave antennas and associated structural components. As the principal software tool for the analysis and design of structures at the Jet Propulsion Laboratory's Ground Antenna and Facilities Engineering section of NASA's Deep Space Network, IDEAS combines flexibility with ease of use.

The relatively small bending stiffnesses of the members of large, steerable reflector antennas makes it appropriate to use pin-jointed (three translational degrees of freedom per joint) mathematical models to represent the responses of these antennas to static and dynamic loads. This facilitates the formulation of the IDEAS redesign algorithm, which has only one design variable per element of the structure.

The preparation of input data decks is simplified by the use of NAMELIST inputs to promote clarity of data input for problem-defining parameters and to promote selection, by the user, of execution and design options and output requests. Reasonable default values are provided for most of these parameters. The formulation of the mathematical model of the structure uses many attractive and familiar features of the NASTRAN program (in many cases, bulk-data cards in the IDEAS and NASTRAN formats are interchangeable). Such features as automation of the simulation of a full symmetric structure based on reflective-symmetry analysis of only half the structure make IDEAS a handy and efficient software tool

for analysis, with many features unavailable in any other finite-element-analysis program.

The design variables are either areas of rods or thicknesses of plates. The design objective is to minimize the total weight of the structure, subject to a variety of simultaneous displacement/compliance constraints, or, as an alternative, to constrain the weight of the structure to a specified value while maximizing a natural vibrational frequency or minimizing a compliance.

A primary feature is to perform root-mean-square-best-fitting path-length-error and boresight-pointing-error analyses for the Cassegrain microwave antenna structure loaded by gravity, wind, or other environmental effects. Rigging angles computed automatically or chosen by the user can be accounted for in these analyses, and the path-length and pointing errors can be selected for automatic conversion to design constraints for optimization. In addition, the conventional types of displacement constraints, or functions thereof, can also be chosen as constraints.

A stress-ratio algorithm can be invoked within the optimization as a side constraint to choose the size of each member of the structure so that, when under specified loads, the member is not subjected to tension or buckling stresses greater than those allowable. Tables of properties of commercially available structural shapes can be supplied by the user for the selection of discrete member sizes and for establishing the radii of gyration in computations of allowable buckling stresses.

Calculations of the total weight of the structure can be broken down according to material. The center of gravity, the weight balance, the static first and second moments about the center of mass (or optionally about a grid point specified by the user), and lumped structural weights at grid points can also be calculated. In addition to standard analysis outputs for gravitational, thermal, and external applied loads, there are other outputs for calculations of linear combinations of specific node displacements, (e.g., to represent motions of rigid attachments), application of required counterweight loading, natural-vibrational-frequency eigenvalues and eigenvectors with modal reactions and modal forces, and evaluations of effective modal masses.

The IDEAS program is written in ATHENA FORTRAN and ASSEMBLER for the EXEC 8 operating system of the UNIVAC 1000-series computer. The program was developed in 1988.

This program was written by Roy Levy and Douglas M. Strain of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 144 on the TSP Request Card.*

NPO-17783

Mechanics

Hardware, Techniques, and Processes

Books and Reports

Computer Programs

Composite Struts Would Damp Vibrations

A design concept takes advantage of the anisotropy of fiber/matrix laminates.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new design of composite-material (fiber/matrix laminate) struts would increase the damping of longitudinal vibrations without decreasing longitudinal stiffness or increasing weight significantly. A composite strut of the proposed type is expected to be stronger than is an aluminum strut of the same weight and stiffness. Computer simulations of the dynamic behaviors of representative designs show that damping factors of 10 to 30 percent should be achievable.

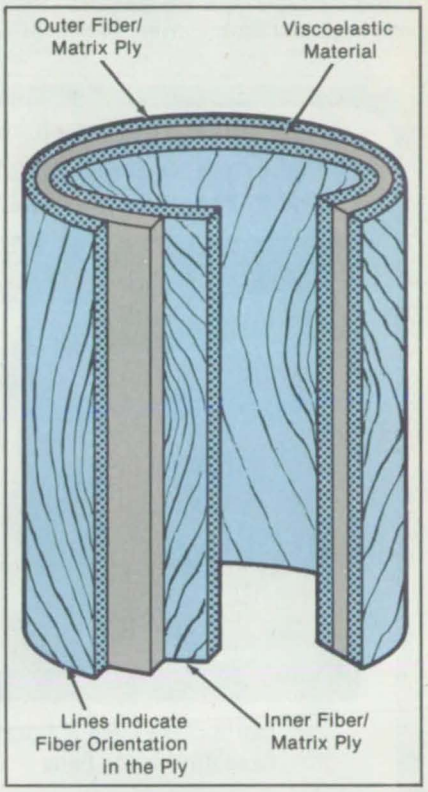
According to one simple design, a strut would include a cylindrical layer of viscoelastic material between an inner cylindrical composite layer in which the fibers are laid out in a chevron pattern and a similar outer layer with the opposing chevron pattern (see figure). In a more elaborate version, there could be several different layers, some with unidirectional and some with chevron patterns; there could be more than one viscoelastic layer; and/or the viscoelastic layer(s) could also be reinforced with fibers. Typical orientations of fibers in the chevron patterns would be of the order of ±15° with respect to the cylindrical axis.

The principle of operation is based on the anisotropic mechanical properties of the matrix/fiber layers. At any given location along the axis of the strut, a longitudinal (axial) tension or compression load would cause the inner chevron ply to twist about the axis in one direction and the outer, opposing-chevron ply to twist in the other direction. The opposing twists would give rise to a shear stress across the viscoelastic layer. Although such interlaminar shear stress is disadvantageous in many other structural applications, in this application it would be turned to advantage in that the stresses and energies of longitudinal vibrations would be channeled into the viscoelastic layer, where they would be dissipated. Because the twisting/damping would occur all along the length of the strut, the overall amount of damping would increase with length — a distinct advantage over struts of conventional design, in which damping does not increase appreciably with length.

The chevron-pattern layers could be made in several different ways. Even now, fabric layers preimpregnated with epoxy resins (prepregs) are sometimes distorted unintentionally into chevron patterns because of misalignment of equipment during impregnation processes, and it should be relatively easy to exploit this phenomenon. Alternatively, prepregs containing unidirectional fibers could be heated and stretched into the chevron configurations. In yet another approach, almost any hot-melt filament winder could produce a chevron pattern if the epoxy resin were tacky enough.

This work was done by Benjamin P. Dolgin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 87 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 18]. Refer to NPO-17914.



Plies With Opposing Chevron Patterns of fibers would convert longitudinal vibrational stresses into shear stresses in an intermediate viscoelastic layer, which would dissipate the vibrational energy.

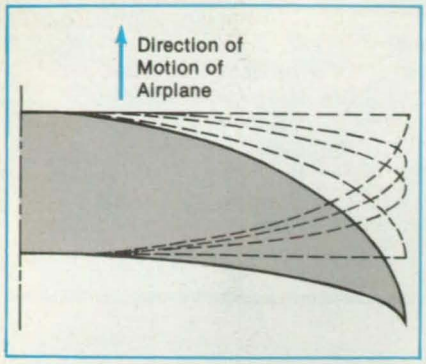
Crescent Wing Planforms Reduce Lift-Dependent Drag

Optimization of wing designs takes a tip from nature.

Langley Research Center, Hampton, Virginia

A new understanding of optimization of the design of a wing to minimize induced drag has been developed by use of computational methods that account properly for the nonlinear effects of the deflected wake, the nonplanar shape of the wing, and the vortex rollup. According to classical linear aerodynamic theory, an elliptically loaded wing has the minimum induced drag. The results of a new nonlinear analysis, however, indicate that even lower levels of induced drag are possible with crescent wings (see figure).

The new work includes computations and experimental evaluations of wings with sheared tips and crescent planforms. The sheared tip is a highly swept and highly tapered surface located in the same plane as that of the inboard wing panel to which it is attached. The crescent planforms are lunate shapes like some found in nature, similar to certain bird wings and fish fins. Theoretical and experimental analyses of these shapes reveal superior aerodynamic efficiency (lower induced drag) and improved high-angle-of-attack characteristics when compared to classical elliptical wing planforms.



Wings That Have Crescent Shapes like these generate less induced drag than do wings that have conventional tips.

A sheared tip installed on a straight wing is a first approximation of a crescent planform, in that the lifting line is curved in the plane of the chord of the wing. Wind-tunnel tests were made, and the results compared to nonlinear theoretical predictions. The induced drag was found to be reduced significantly below that of conventional wingtips.

This work was done by Bruce J. Holmes of **Langley Research Center**, *Paul M. H. W. Vijgen of High Technology Corp., and C. P. vanDam of the University of California, Davis. For further information, Circle 38 on the TSP Request Card.*
LAR-14015

Mode-II-Fracture Specimen and Holder

A simple design facilitates testing.

Lewis Research Center, Cleveland, Ohio

A test specimen and loading frame have been developed for the fatigue and fracture testing of materials under mode-II (sliding-mode) loading. Mode-II data are required for some analyses of failures in structural materials, bearing materials, ceramics, and the like.

The fracture of a nonbrittle material subjected to mode-II loading proceeds col-

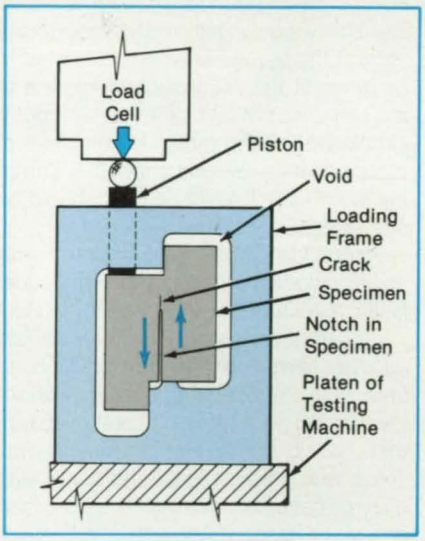


Figure 1. The **Specimen/Loading Frame Assembly** is placed in a compression-testing machine. Loads directed oppositely along the centerline cause a self-similar crack to propagate.

Figure 2. The **Photoelastic Pattern** of this specimen shows symmetry about the notch centerline, indicating pure mode-II loading.

linearly with a starter notch, as half of the specimen "slides" past the other half. Important features of this new specimen are that a nearly pure mode-II condition exists at the test zone; that the single-ended notch provides a singular location for the analyses of data; that the load is applied in a straightforward mode-II direction, eliminating the need for a calculation based on angular loading; and that the simple design of the specimen permits fabrication by grinding only.

The use of the loading frame enables consistently accurate alignment of specimens before insertion of the specimen/frame assemblies into the compression-testing machine. This makes the design attractive for testing in hostile environments in which access to the machine or furnace may be limited. An additional feature of the design of the specimen/frame assembly is that it could, with little or no modification, be placed horizontally into an impact testing machine and be subjected to loading at high speeds.

The specimen and loading frame are illustrated in Figure 1. The photograph (see Figure 2) indicates the good alignment of the mode-II forces at the tip of the notch in a photoelastic specimen. The predominance of the mode-II forces has also been verified by the boundary-integral-equation method.

This work was done by Robert J. Buzzard, Louis Ghosn, and George Succop of **Lewis Research Center**. *No further documentation is available.*
LEW-14964

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.

Measurements of Boundary Layers on a Compressor Blade

Experiments and analysis of data are described.

A two-volume report describes an experimental study of the flow of air around a double-circular-arc turbine blade in a cascade of such blades. The measurements were made in a wind-tunnel test section at an angle of incidence of 5° and a chord Reynolds number of 500,000. The study provides a well-documented, somewhat-complicated flow field that can be used to develop or test future computer codes for the simulation of such viscous-flow fields.

The first volume discusses the experimental techniques and presents the experimental results in graphical form. The flow in the boundary layer and near the wake was measured by a single-component laser-Doppler velocimeter: in particular, data were obtained at 11 locations on the pressure surface of the blade, 11 locations on the suction surface, and 3 locations in the wake. Additional measurements of turbulence were taken by calibrated hot-wire probes in the boundary layer and by uncalibrated hot films mounted on the surface. Measurements by probes at the inlet and outlet and measurements of static pressures on the blade supplement the data on the boundary layer.

The first volume also discusses several interesting features of the flow that emerge from the analysis of the experimental data. The boundary-layer measurements on the pressure surface indicate a transition region over at least 40 percent of the chord of the blade. A small, bubblelike separation region near the leading edge of the suction surface causes an immediate transition from laminar to turbulent flow. The non-equilibrium turbulent boundary layers separate again near the trailing edge of the suction surface. The similarity (in the mathematical sense of proportionalities and other relatively simple transformations of flow quantities and geometries) of the outer region of turbulent boundary layers ceases in the separated region. Also, similarity does not hold in the near-wake region, which includes negative mean velocities because of the separation near the trailing edge of the suction surface.

The second volume begins with a detailed description of the procedures for the analysis of the experimental data. Topics include statistical and curve-fitting techniques, boundary-layer integral parameters, similarity solutions for laminar boundary layers, wall-wake velocity profiles and skin-friction coefficients of turbulent boundary layers, and a similarity relation for wakes.

This volume presents the raw data in tables to make them directly accessible for computational comparison with other experimental or numerically simulated data. Processed data that result from the various analyses are also presented in tables. A computer tape that contains the data is available to other researchers.

This work was done by Steve Deutsch and William Z. Zierke of Pennsylvania State University for **Lewis Research Center**. *Further information may be found in NASA CR-179491 and CR-179492 [N87-13441 and N87-13442], "The Measurement of Boundary Layers on a Compressor Blade in Cascade at High Positive Incidence*

Angle [Volume I (Experimental Techniques and Results) and Volume II (Data Report)]."

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.

LEW-14748

Analysis of Turbulence in a Simple Shear Flow

Reynolds stresses and time-average velocity are found via the principle of stabilization.

A report presents an analysis of turbulence in a simple shear flow. In the mathematical model used in this study, the turbulence is considered to arise from the growth of small fluctuations in an initially unstable plane Poiseuille flow. Invoking the principle of stabilization, the fluctuations in velocity, and, therefore, the Reynolds stresses, are considered to grow until a new stable state is approached. This principle enables one to find the Reynolds stresses and the mean velocity of the turbulent flow that arises from the initial plane Poiseuille flow.

The initial flow is taken to be along the x direction, which is parallel to the two bounding planes and perpendicular to the y direction. There is assumed to be no flow or variation along the third perpendicular (z) direction. A disturbance in the flow is assumed to be represented by a stream function characterized by a temporal frequency and a spatial frequency along the x direction. The shearing Reynolds stress is assumed to be given by a function that resembles the stream function in its general form and is characterized by the same spatial and temporal frequencies.

The Reynolds equations (a specialized form of the Navier–Stokes equations of flow) are put in a form in which the fluctuations in velocity are treated as small perturbations of the initial flow. The stream function and the expression for the Reynolds stress are inserted in the Reynolds equations, which are then partially solved to eliminate the pressure and to obtain a generalized Orr–Sommerfeld equation in dimensionless form. The right side of the Orr–Sommerfeld equation contains a factor in the expression for the Reynolds stress, and part of the problem is to determine this factor.

The Reynolds number R is assumed to have a value R^* slightly greater than the critical Reynolds number R_{cr} above which the flow becomes unstable. It is noted that at zero Reynolds stress, the eigenvalues of the Orr–Sommerfeld equation would have positive imaginary parts (indicating growth of perturbations) at $R = R^* > R_{cr}$, and that these imaginary parts would vanish at $R = R_{cr}$. Then by the principle of stabilization, the Reynolds-stress factor must be selected in such a way that at $R = R_{cr}$, this factor converts the generalized Orr–Sommerfeld equation to the Orr–Sommerfeld equation for the initial, unperturbed stream function. These observations lead to a linearized equation for the "feedback" between the Reynolds stresses and the mean flow, in the form of a second-order differential equation in y for the relationship between the dimensionless Reynolds-stress and the dimensionless stream function.

The validity of this approach is based on the fact that, as determined in a previous study, Reynolds-stress disturbances grow much faster than mean-motion disturbances do. Hence, one can assume that the Reynolds stresses are large enough to stabilize the mean flow, which is still sufficiently close to its original unperturbed state. But the Reynolds stresses that are substituted into the Reynolds equations change the mean velocity profile, and consequently, the conditions of instability. These new conditions, in turn, change the Reynolds stresses, and so forth. By performing the computations iteratively in sufficiently small steps, one can obtain acceptable accuracy.

This work was done by Michail A. Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analysis of Turbulence in Shear Flows Using Stabilization Principle," Circle 131 on the TSP Request Card.*

NPO-17374

Conjugate Gradient Algorithms for Manipulator Simulation

The applicability of conjugate-gradient algorithms for robot manipulator dynamic simulation is discussed.

A report discusses the applicability of conjugate-gradient algorithms to computation of the forward dynamics of robotic manipulators. The forward-dynamics problem can be stated as follows: given the vector of the positions ($\mathbf{Q}$) and velocities ($\dot{\mathbf{Q}}$) of the joints of manipulator and the vector of forces and torques (τ) applied to the joints, find the vector of the accelerations ($\ddot{\mathbf{Q}}$) of the joints. The integration of $\ddot{\mathbf{Q}}$ leads to new values for $\dot{\mathbf{Q}}$ and $\mathbf{Q}$. The process is then repeated for the τ at the next time step. Rapid computation of the forward dynamics — preferably faster than real time — is essential to teleoperation and other advanced robotic applications. The research on conjugate-gradient algorithms described in this report is part of a con-

tinuing effort to find algorithms that meet the requirements for increased computational efficiency and speed.

The conjugate-gradient method is among the methods used most widely for the iterative solution of systems of linear equations. In this report, the classical conjugate-gradient (CCG) algorithm is applied to the forward-dynamics problem, and the redundancy in the resulting equations is analyzed. This leads to an improved CCG algorithm that reduces the cost of computing each iteration by eliminating the redundancy in the extrinsic equations via a better choice of coordinate frame for the projection of the intrinsic equations. Once the cost of each iteration has been reduced in this way, the efficiency of computation can be increased further by reducing the number of iterations via a preconditioning algorithm.

Next, a preconditioned-conjugate-gradient (PCG) algorithm is derived. In this algorithm, a positive-definite diagonal matrix, the elements of which are the diagonal elements of the inertia matrix, is used as a preconditioner. An efficient subalgorithm for the computation of these elements is also developed.

The report notes that even with these improvements, the CCG and PCG algorithms may not offer enough computational efficiency for faster-than-real-time simulations. The reason is that they are serial algorithms, the computational efficiency of which is inherently limited. Further increases in efficiency and speed would require the exploitation of parallelism. The authors find that the PCG algorithm is suitable for modification into a parallel form. The results of a preliminary investigation of a parallel version of the PCG algorithm and, in particular, of the effect of preconditioning on its convergence are presented.

This work was done by Amir Fijany and Robert E. Scheid of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report "Efficient Conjugate Gradient Algorithms for Computation of the Manipulator Forward Dynamics," Circle 35 on the TSP Request Card.*
NPO-17929

Calculating Viscous/ Inviscid Interactions

Some experiences in the numerical simulation of compressible flow are described.

A report describes some experiences in the numerical simulation of compressible, viscous flows by finite-difference approximations of the Navier–Stokes equations. The focus is upon the viscous/inviscid-interaction approach, in which the flow is mathematically modeled with interacting zones, within each of which a different model of viscous or inviscid flow applies. Impractically large amounts of computer memory and computing time are often required for the solution of the full Navier–Stokes equations over an entire flow field with a grid fine enough to resolve all the high gradients. The viscous/inviscid-interaction approach can reduce the task of computation by taking advantage of simpler models and coarser grids in some of the zones.

The report contains two parts. Part I begins with a discussion of the use of boundary-layer equations to study separated flows. Issues include marching boundary-layer equations through separation points and boundary-layer algorithms based on integral, finite-difference, and finite-element methods. A steady two-dimensional formulation and an unsteady three-dimensional formulation of the boundary-layer problem are presented. The results of two three-dimensional simulations are presented and compared with experimental data.

Part II reviews three methods based on the viscous/inviscid-interaction approach. The first method involves a conventional full-potential/boundary-layer transpiration boundary-condition matching procedure. To obtain the desired converged and compatible viscous and inviscid flow-field solutions, the viscous/inviscid iteration scheme must allow each computed flow to be influenced by the other, yet remain stable and computationally efficient even when this interaction is strong. In this method, one obtains an approximation to the inviscid flow, extracts some information (e.g., pressure) from the inviscid flow to feed the viscous algorithm, extracts information from the viscous algorithm, and inserts it into another estimate of the inviscid flow. This cycle is continued until the inviscid and viscous solutions are converged and compatible. The interface schemes for the transfer of information between the inviscid and viscous algorithms are critical and still a subject of active research. Two-dimensional examples of the more "classical" interfaces are discussed.

The second method involves a vector-potential/boundary-layer (vorticity)-interaction scheme. The vorticity of the viscous flow is embedded in the inviscid flow through a field-forcing term. The outer "inviscid" algorithm is tightly coupled to the viscous flow over the entire viscous-flow domain. If necessary, the inviscid flow can convect vorticity downstream (i.e., as in a wake). To date, this approach has been applied to separated, but fairly simple, flows. However, it is straightforward to include the effect of normal pressure gradients in this scheme, and free shear layers are tracked automatically. Hence, some of the deficiencies of the "classical" effective-displacement-thickness interaction have been avoided.

The third method involves a fortified Navier–Stokes scheme, which represents the next step toward complete generality. In this case, a general global algorithm is "fortified" (i.e., the accuracy and/or convergence rate are improved) in any region where a less-complete, but more-efficient, numerical formulation can be used. For example, the boundary-layer equations can be used to resolve thin shear layers. It has been shown that this approach can significantly improve the efficiency of the overall algorithm.

This work was done by W. R. Van Dalsem, J. L. Steger, and K. V. Rao of **Ames Research Center**. *Further information may be found in NASA TM-100015 [N87-12466], "Some Experiences with the Viscous-Inviscid Interaction Approach."*

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-12115

Computational Fluid Dynamics in Aerospace

Progress in methods, solutions, and computer technology is reviewed.

A report reviews recent progress in computational fluid dynamics (CFD) at NASA Ames Research Center. It addresses the state of the art in terms of methods, examples of solutions, and computer technology.

The text begins with a discussion of the general trends. As it notes, the long-range goal of CFD is to develop computer programs that can accurately simulate the viscous flows about aerospace vehicles and their components in flight within a reasonable time (e.g., 15 min). A simulation should depict the detailed fluid physics; the stability, control, and performance of the vehicle; and the thermal and aerodynamic loads in a time frame suitable for use in design.

The aerospace research community is undergoing a cultural change as CFD becomes an increasingly-capable, recognized design technique and as CFD merges with experimental aerodynamics in a continuing process of mutual validation and advancement. As new technological capabilities thus evolve, they are expected to contribute to the achievement of the following ambitious goals set by the Aeronautical Policy Review Committee established by the Office of Science and Technology Policy:

- To build toward the emergence of a new generation of fuel-efficient, affordable subsonic transport aircraft around the turn of the century;
- To develop the technology for aircraft capable of sustained supersonic cruising for efficiency in long-distance travel; and
- To perform research toward a vehicle that can routinely cruise and maneuver into and out of the atmosphere and can take off and land on conventional runways.

The report goes on to discuss the methods of CFD. Topics include the following:

- The importance of resolution (i.e., the sizes of finite-difference computational grids) in the solution of the governing Navier-Stokes equations for turbulent flows;
- The synergistic development of improved algorithms and multiprocessor (e.g., parallel-processing) computers;
- Postprocessing techniques for the visualization of the computed flow fields; and
- The need for coordinated, modular organization of computer programs as such programs become increasingly complicated, requiring structured coding practices and organized efforts.

The authors provide examples of CFD solutions of aerospace and fluid-physics problems to illustrate recent progress. The aerospace solutions include rotor/stator velocity vectors from a three-dimensional Navier-Stokes code for turbomachinery, pressure distributions from a simulation of aeroelasticity of a wing surface-pressure contours on a four-bladed helicopter rotor in forward flight, and particle traces about several aerospace vehicles. The fluid-physics solutions include particle traces around a cylinder capped at the front end by a hemisphere, total-pressure contour plots and particle traces over a double delta wing, a horseshoe-shaped vortex, and contours of vorticity in a boundary-layer flow.

The review of computer technology covers supercomputers, scientific work stations, local supercomputing networks, and remote access to supercomputers. Capabilities and costs are discussed, along with trends in designs and uses of equipment and programs. The authors note the existence of both the requirements and the technology for a worldwide revolution in high-speed communication of data and that consequently future researchers in CFD will have access to the best supercomputing capabilities anywhere from their desk-top computers.

This work was done by Paul Kutler, Joseph L. Steger, and F. R. Bailey of **Ames Research Center**. *Further information may be found in AIAA paper 87A-42083, "Status of Computational Fluid Dynamics in the United States."*

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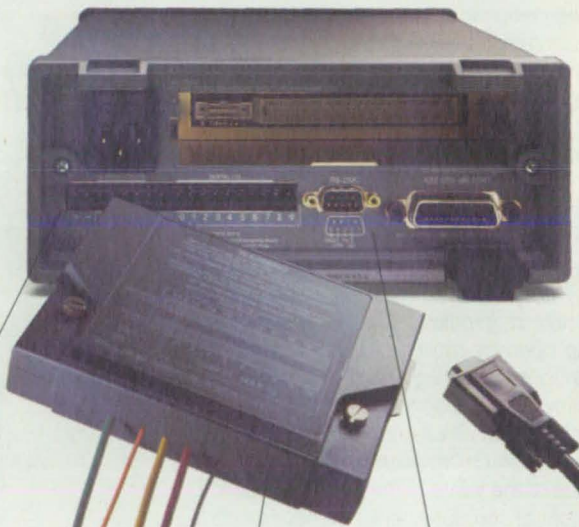

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Compact Force-Reflecting Hand Controller

A novel design keeps joints mechanically independent.

NASA's Jet Propulsion Laboratory, Pasadena, California

A force-reflecting hand controller for a remote manipulator offers two times the work volume of any of its predecessors. It can be folded into a volume half that of its immediate predecessor for storage. It is the first six-degree-of-freedom, cable-driven controller designed with six revolute joints; it contains no prismatic joints. Like its predecessor, the unit offers the advantages of low friction, low inertia, and no backlash. Intended for use in telerobotic experiments during space flight, the controller could be modified for such terrestrial applications as construction and the handling of dangerous (e.g., hot, poisonous, radioactive, or infectious) materials.

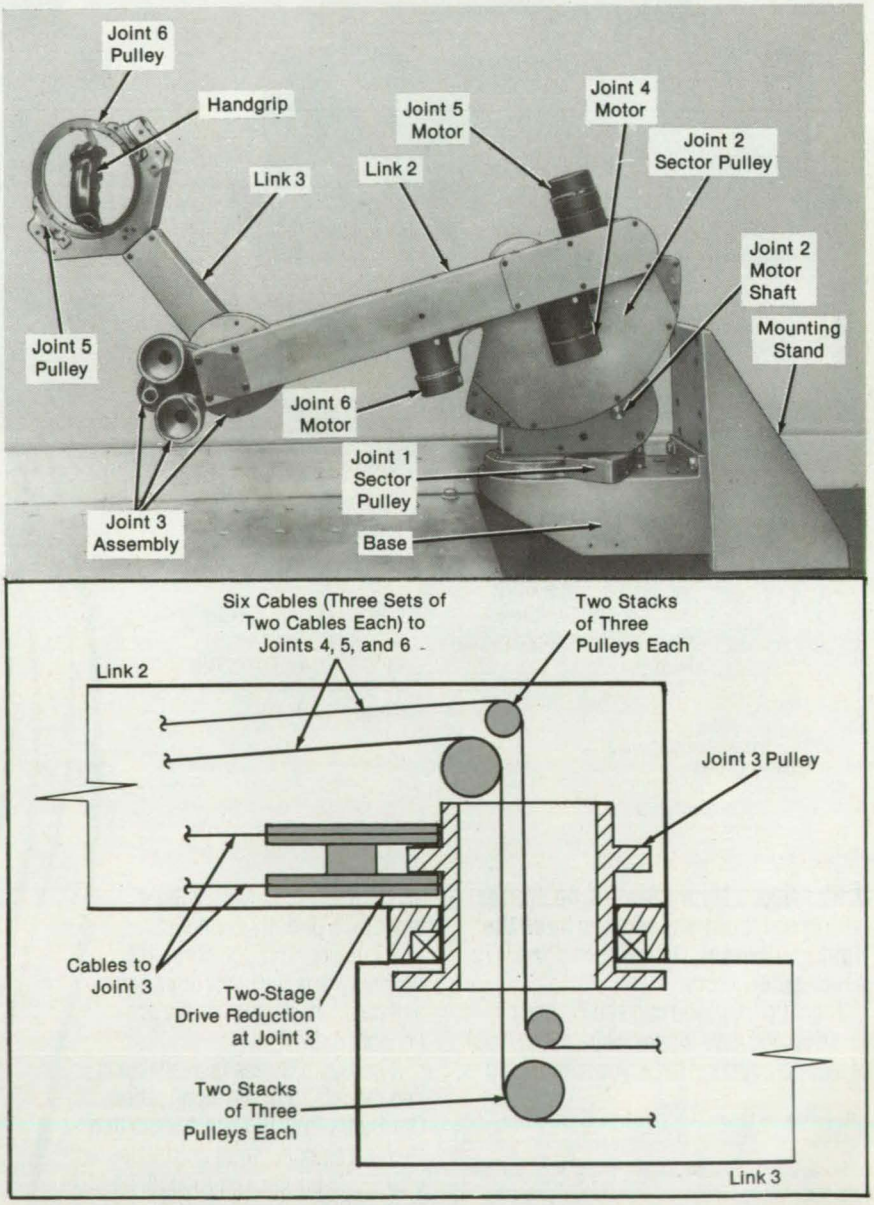
The operator views a video display of the remote manipulator and its environment. The operator moves the handgrip on the controller, actuating a system of cables and pulleys connected to brushless dc motors equipped with shaft-angle encoders. The encoders send information on the angular positions of the joints in the hand controller to a control computer, which generates commands for the corresponding joints of the remote manipulator. The manipulator responds by following the commanded trajectory. Information on forces, torques, and the positions of joints in the remote manipulator are processed through the control computer and fed back through the cables and motors of the hand controller to the operator's hand.

The unit includes three links and six joints. A novel routing scheme allows actuator cables to pass through intermediate joints along the kinematic chain without affecting or being affected by the operations of those joints. The cables run inside the links, which are beams of hollow square cross section and thus are strong and rigid.

Joint 3 (see figure) is critical and can be used to illustrate the principle of operation. Pairs of stacked pulleys on opposing sides of this joint direct cables to joints 4, 5, and 6 along the axis of rotation of this joint. These pulleys do not make contact with joint 3 and remain mechanically decoupled from it. When joint 3 rotates, it is not necessary to counterrotate the motors for joints 4, 5, and 6 to keep the same relative positions. Because link 2 is offset from link 3 at joint 3, the arm can be folded compactly for storage. There is no net kinematic offset of the controller, however, and control computations are therefore simpler and faster.

This work was done by Edward R. Snow, Douglas A. McAffee, and William T. Townsend of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 153 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 18]. Refer to NPO-17851.



The **Hand Controller** offers six degrees of freedom, although additional degrees of freedom can be accommodated by stringing more cables through joint 3. Because the cables to joints beyond joint 3 pass in pairs symmetrically disposed about the axis of joint 3 without making contact with joint 3, all joints beyond joint 3 are mechanically independent of joint 3.

Modifications of Hydrostatic-Bearing Computer Program

Design time and effort are reduced.

Marshall Space Flight Center, Alabama

Several modifications have been made to enhance the utility of HBEAR, a computer program for the analysis and design of hydrostatic bearings. These modifications make the program applicable to more realistic cases and reduce the time and effort necessary to arrive at a suitable design.

One modification is the inclusion of a subroutine that calculates the maximum and minimum allowable depths of the recesses from the following equations: For the maximum allowable depth of the recesses,

$$\frac{\text{Volume of Orifice} + \text{Volume of Recess}}{\text{Volume of Film}} \leq 1.0.$$

For the minimum allowable depth of the recesses,

$$\frac{12\,\mu Q}{\pi^2 n G \bar{P}_R (P_s - P_a)(h_r + c)^3}\left[\frac{2(B_p + L_p)}{d_o} - \pi\right] \leq 0.1$$

where G is a correction for the effects of turbulence, μ is the dynamic viscosity, Q is the volumetric flow rate, n is the number of recesses, P_s is the supply pressure, P_a is ambient pressure, h_r is the depth of a recess, c is the radial clearance, B_p is the circumferential length of a recess, L_p is the axial length of a recess, and d_o is the diameter of the orifice. $\bar{P}_R$ is the recess pressure ratio and is defined as:

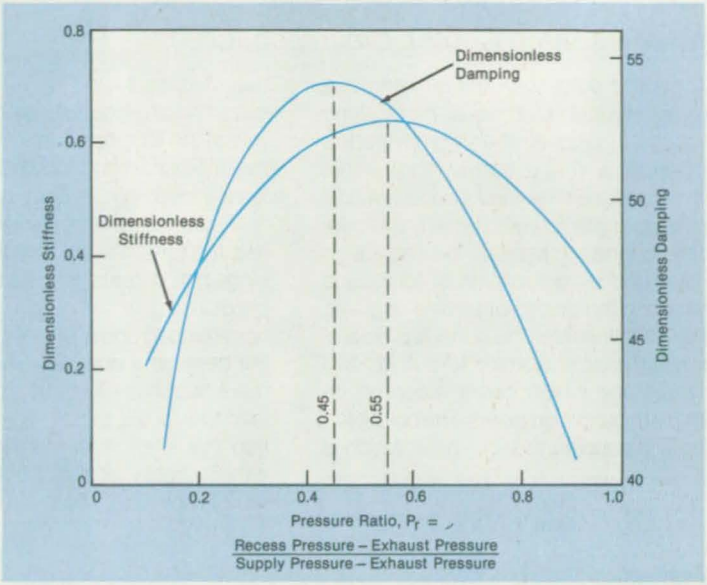
$$\bar{P}_R = \frac{P_R - P_a}{P_s \quad P_a}$$

where $\bar{P}_R$ is the pressure in the recess. The depth of the recesses should be kept between these two limits to avoid flow instabilities that could adversely affect the stability of the bearing.

Another modification is to add the capability to represent the cross section of the hole in the housing as an ellipse. This feature is intended to give a more realistic representation of thermal and mechanical distortions.

Other modifications of the program greatly reduce the design time and effort by automating the calculation procedure. One of these modifications is to incorporate the calculation of the computational grid on which the design problem is solved. The other is to cause the program to iterate on the area of the orifice to optimize the bearing with respect to its rotordynamic characteristics. This feature alone reduces the design effort by a factor of approximately 3.

The dimensions of the recess and pad and the ratio of the area of the recess to that of the pad are easily varied and optimized. These quantities can be modified to design for the required performance characteristics. The performance can be expressed in terms of a ratio between two drops in pressure, as shown in the figure. The program uses a search technique to iterate on the size of the orifice to obtain the required pressure ratio.



The Performance of a Bearing is quantified, in this case, in terms of the nondimensionalized forms of the stiffness and damping. At a pressure ratio of about one-half, the stiffness and damping are both optimum. The size of the orifice can be modified easily so that the pressure ratio is about 0.5.

This work was done by Robert I. Hibbs, Jr., and Robert F. Beatty of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

MFS-29638

Torque-Splitting Gear Drive

Torque is transmitted equally along two paths and recombined.

Lewis Research Center, Cleveland, Ohio

A geared drive train transmits torque from an input shaft in equal parts along two paths in parallel, then combines the torques in a single output shaft. This scheme reduces the load on the teeth of the meshing gears while furnishing redundancy to protect against failures. Such splitting and recombination of torques is common in the design of turbine engines.

Figure 1 illustrates the general problem. A driving gear transmits torque to two second-stage pinion gears mounted on shafts with bull pinion gears. The bull pinion gears are coupled to a bull gear, which is mounted on the output shaft of the drive train. This arrangement is unforgiving of errors in the lengths of arc over which gears mesh. Such errors lead to disproportionate torque loads on the bull pinions.

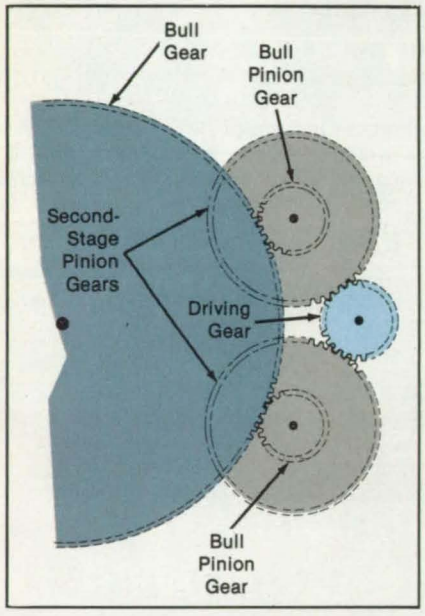


Figure 1. This **Load-Sharing Scheme** functions as intended only when all gears are perfectly sized, shaped, and aligned. The slightest deviation in machining tolerance can cause one pinion to transmit the entire torque load while the other essentially freewheels.

Figure 2 illustrates a scheme that equalizes the torque transmitted to the second-stage pinion gears. In this scheme, the simple driving gear of Figure 1 is replaced by a right-handed and a left-handed helical driving gear on a common shaft. Rolling-element bearings allow this shaft to move axially to a small extent. Torque is coupled into this shaft from the motor or turbine either directly or through a spline and a flexible coupling, which also allow for small axial motion.

When one of the two second-stage pinion gears is more heavily loaded by its helical driving gear than is the other of the two second-stage pinion gears, the inequality in the load exerts a net axial force on the common shaft. This force moves the shaft axially by a slight amount until the load is equalized and the net axial force vanishes. The free axial range of the common shaft allows it to move continually to maintain equal loading of both second-stage pinions.

This work was done by J. Kish of United Technologies for the Army Propulsion Directorate at **Lewis Research Center**. *For further information, Circle 3 on the TSP Request Card.* *LEW-14908*

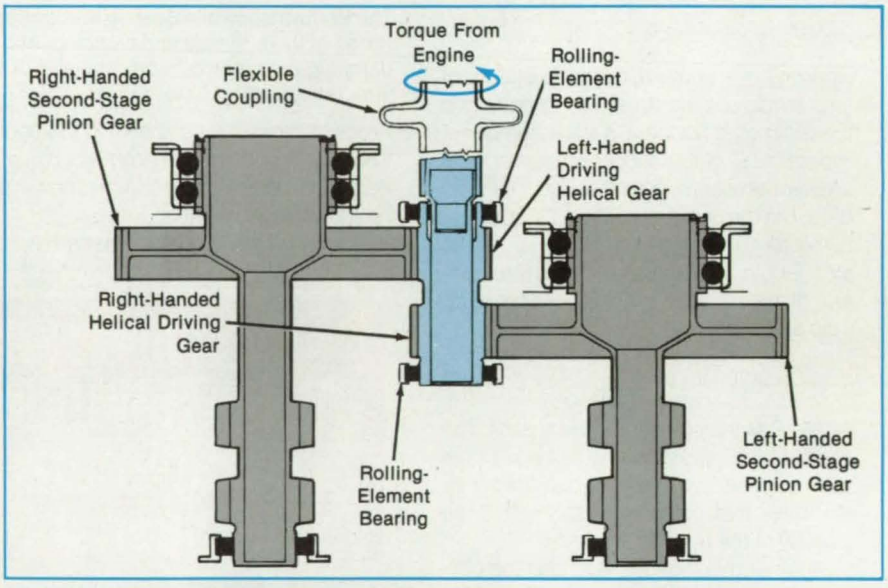


Figure 2. This **Torque-Splitting Drive** provides for the transmission of equal torques from the engine to the two second-stage pinion gears.

"Bearingless" Bull Gear

Weight could be reduced substantially.

Lewis Research Center, Cleveland, Ohio

A concept for mounting a bull gear would eliminate the need for the heavy bull-gear shaft and its supporting bearings that would otherwise be required to react large loads. The "bearingless" mounting concept is intended primarily for application in a helicopter in which a bull gear on the shaft that turns the rotor combines driving torques from three or more engines. For a representative bull gear of 48-in. (1.22-m) diameter, the new mounting scheme could reduce the weight of the helicopter by as much as 590 lb (268 kg).

The driving torque would be coupled to the bull gear from the three engines by three pairs of pinion gears in a torque-splitting driving scheme, possibly like the one described in the preceding article (see Figure 1). The bull gear and the pinion gears would have herringbone teeth, so that the gears would couple only torques and lateral loads, but not axial loads, to each other. Supporting rings would be mounted at the midplanes of the bull and pinion gears; that is, between the halves of the herringbone tooth patterns (see Figure 2). The outer surfaces of these rings would be smooth and would have diameters equal to the pitch diameters of the gears to which they would be attached.

When the driving torque loads of the engines were equal, each pair of pinion gears would exert the same lateral (that is, radial) force on the bull gear, and the bull gear would, therefore, remain centered. The driving forces on the bull gear would be reacted through the teeth and into the bearings of the pinion gears. Because of deflections caused by normal gear-tooth separating loads and out-of-mesh mounting tolerances, the support rings would be separated by slight gaps and, therefore,

would not bear any load under this normal operating condition.

If one engine were to fail, its pinion gears would turn freely and cease to exert the normal gear-tooth separating load. This would cause the bull and the freewheeling pinion gears to deflect slightly toward each other, closing the gap between the supporting rings. The lateral load would then be reacted through the touching supporting rings and, as before, into the bearings of the affected pinion gears.

This work was done by J. Kish and G. Webb of United Technologies for the Army Propulsion Directorate at **Lewis Research Center**. *For further information, Circle 37 on the TSP Request Card.*
LEW-14911

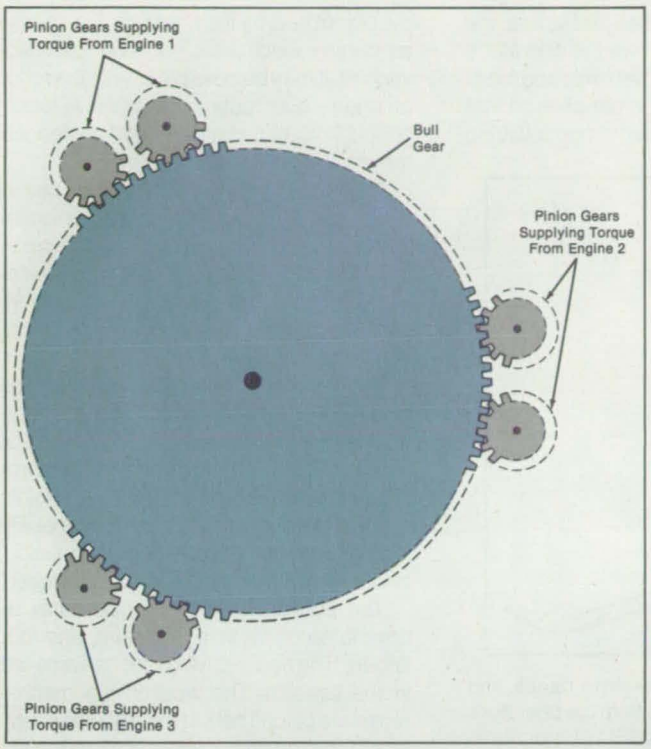


Figure 1. Three **Pairs of Pinion Gears** would supply torque to the bull gear. The pinion gears would also provide lateral support, eliminating the need for the bull-gear shaft and its bearing.

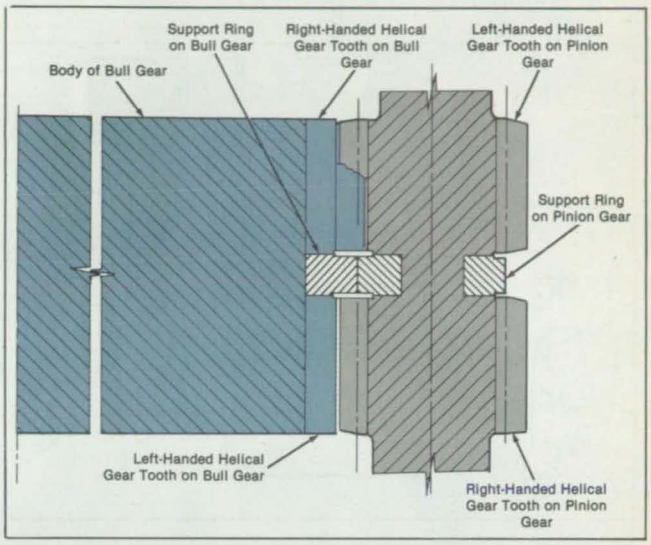


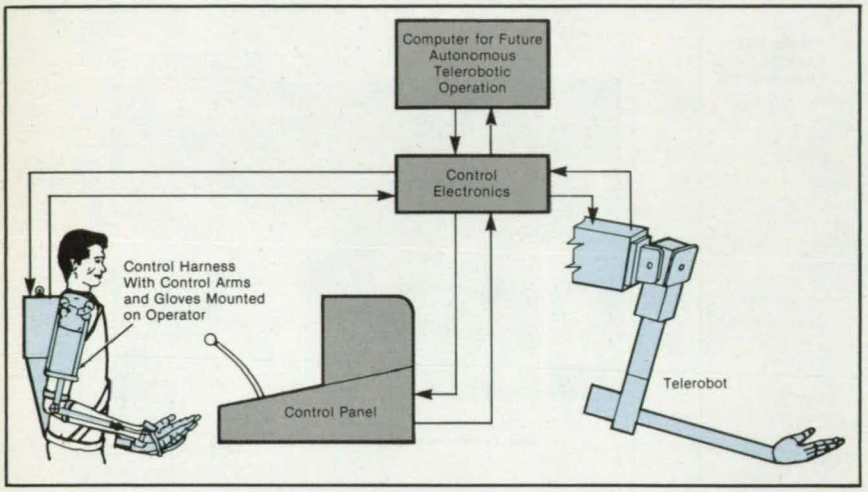
Figure 2. **Supporting Rings** with outer surfaces that meet at the pitch circles would react lateral loads.

Anthropomorphic Remote Manipulator

A telerobot has arms, hands, and fingers similar to those of a human.

NASA's Jet Propulsion Laboratory, Pasadena, California

A two-armed telerobot now undergoing development can manipulate objects with dexterity approaching that of a human. It is designed to be remotely operated by a human. The human operator wears a harness with exoskeletonlike sleeves and gloves; the remote manipulator follows the operator's arm, hand, and finger movements and feeds back position and force information so that the operator has a sense of manipulating the object held by the telerobot. Eventually, as control electronics become more advanced, it may be possible to give the robot autonomy over routine manipulative tasks, although human control will still be needed for unstructured activities.



From a Distance, an operator controls a telerobot via a harness with dual arms, hands, and fingers similar to those on the telerobot. Optical fibers carry control signals from the operator's harness to the telerobot and feedback signals in the opposite direction.

The robot is being developed for use in outer space. It is well suited for such terrestrial uses as handling materials and maintaining equipment in hazardous environments where mechanical dexterity and nearly instantaneous feedback of sensory information are needed.

The dexterity of the robot arms is unprecedented. Each arm has seven degrees of freedom and both hands have 16 degrees of freedom. Like a human arm, the robot arm is compliant; it loosens or stiffens its joints in response to external forces. This capability is essential for cooperative dual arm manipulations and humanlike grappling techniques.

The robot arm includes an upper arm, elbow, forearm, wrist, hand, palm, and four fingers. The finger-driving mechanisms are in the forearm. The wrist-driving mechanisms are placed behind the elbow to counterbalance the arm. Cables actuate the fingers. Servo-adjustable springs in the joint drives provide the compliance.

One of the fingers is thumblike, and the three other fingers are as in a human hand, providing a stable grip. A fifth finger, like the little finger of a human hand, was omitted because it would increase weight and bulk but add little dexterity.

Position, force, and compliance sensors are built into the arm. Because of the exact kinematic correspondence between the telerobot and the control arm mounted on the operator's arm, no time-consuming coordinate computations are needed. The resulting fast control rate assures high fidelity between the operator and robot.

The operator can view the robot directly through a window or by a video display. The operator will not always have an unobstructed view of the robot hands in relation to the manipulated object, however: fingers may be obscured by the body of the robot or by the object itself, or the video camera may be at a bad angle. Generally, after a hand has been visually guided to the vicinity of the object, the operator relies more on touch. The operator adjusts the tightness of the grasp by adjusting his own grasping strength in the glove in response to feedback information from the finger sensors.

This work was done by Bruno M. Jau of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 27 on the TSP Request Card.* *NPO-17975*

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Circle Reader Action No. 546

Fabrication Technology

Hardware, Techniques, and Processes

Books and Reports

Fabrication of Ceramic Mats

A slurry of ceramic powder, binder, and solvent would be extruded through a spinneret.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process to make mats of fine zirconia filaments has been proposed. Zirconia ceramic is supplied as a powder, but a still finer powder is needed for making the porous zirconia membranes to be used in the electrolytic dissociation of air to obtain oxygen. Mats of fine zirconia fibers would be easier to ball-mill than is the commercially available zirconia powder.

In the proposed technique, ceramic filaments would be extruded from a slurry. The slurry would consist of zirconia ceramic powder suspended in a liquid vehicle of binder and solvent. The filaments would be formed by forcing the slurry through a spinneret (see figure), the nozzles of which would be lined with sapphire to protect against erosion. After being partially dried by air jets, the filaments would fall onto a moving belt, forming a loose mat. Finally, the mat would be compressed to the desired thickness and sintered.

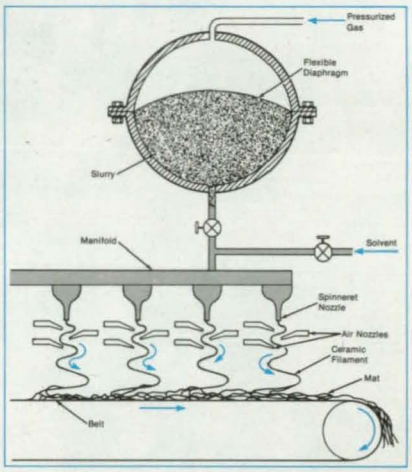
The fiber-extruding apparatus would prevent contact between air and the slurry prior to extrusion. Air could dry the surface of the slurry enough to form a skin, which might clog the fine holes in the spinneret. Before the slurry is pumped into the tank, the tank would be evacuated to remove air. A flexible diaphragm would separate the slurry from the gas used to pressurize the tank during extrusion. Valves would enable the flushing of the system with solvent to remove residual slurry prior to shutdown.

This work was done by Earl R. Collins, Jr. of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 95 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

Refer to NPO-17210, volume and number of this NASA Tech Briefs *issue, and the page number.*



Ceramic Mats would be formed by sintering mats of partially dried filaments extruded from a slurry of ceramic powder, binder, and solvent.

Magnetic Deflection of Welding Electron Beam

The beam is redirected so that it strikes the workpiece at an effective angle.

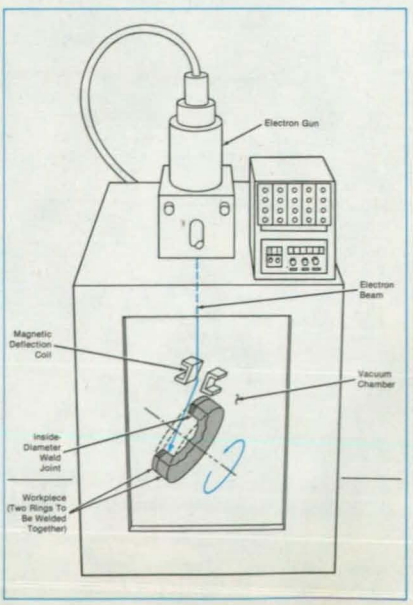
Marshall Space Flight Center, Alabama

Electron-beam welds inside small metal parts can be produced with the aid of a magnetic deflector. Until now, internal welding by electron beams has been limited to parts that have inside diameters large enough to accommodate an electron gun and/or that can be positioned and oriented so that the weld joint is accessible to the electron gun.

In the example shown in the figure, a magnetic coil diverts an electron beam in a vacuum chamber so that it strikes an internal circumferential joint nearly perpendicularly. As the parts are rotated, the beam scans the joint and welds it.

The weld joint can be positioned to where heavy microfissure concentration can be removed when subsequent machining is required, thus increasing the likelihood of removing any weld defects located in the face side of the electron-beam weld.

This work was done by R. Michael Malinzak and Gary N. Booth of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 89 on the TSP Request Card.*
MFS-29659



The **Vacuum Chamber for Electron-Beam Welding** houses a magnetic deflection coil and a rotating workpiece. The coil bends the electron beam so that it impinges on the weld joint at nearly a right angle.

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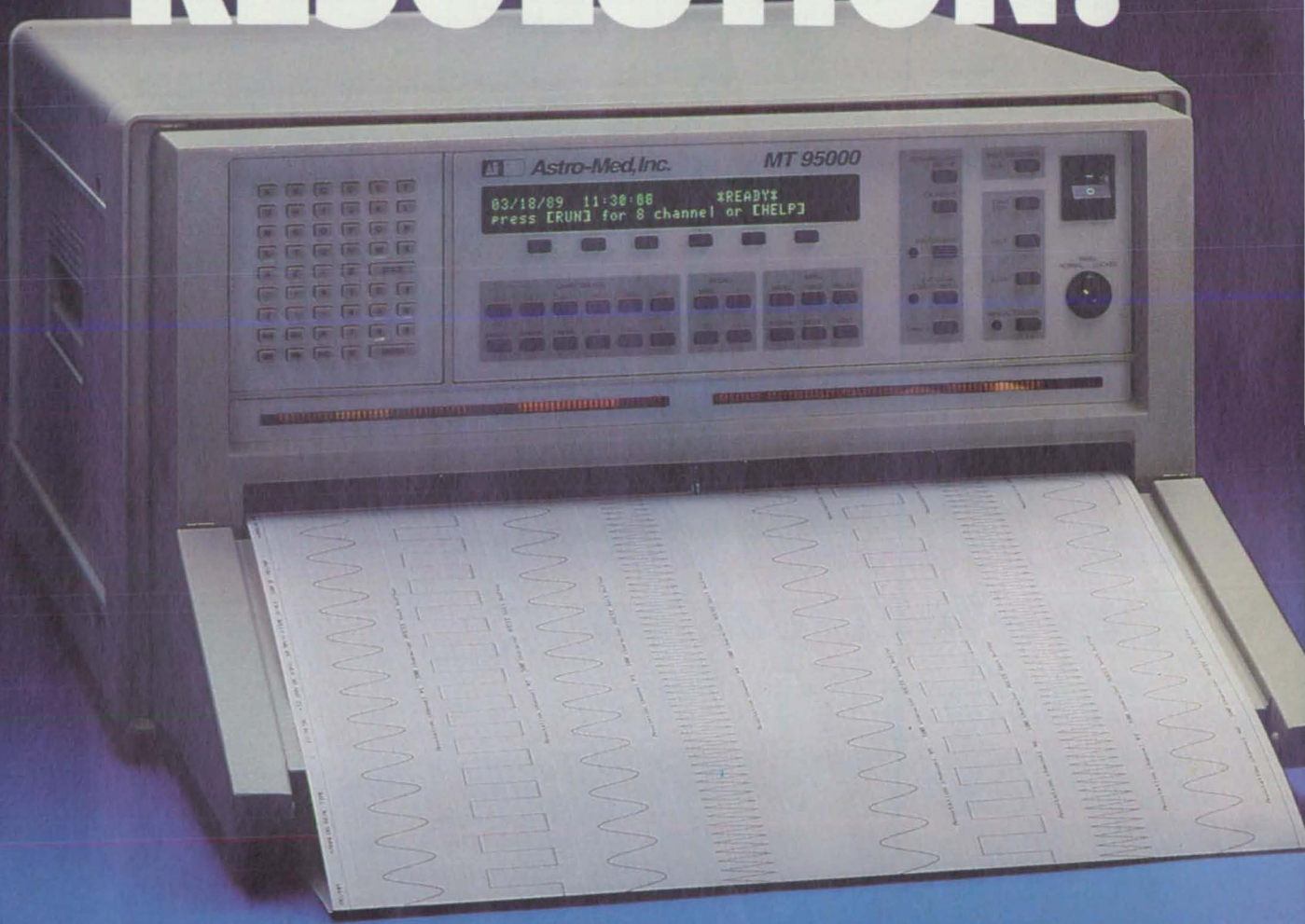

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Circle Reader Action No. 405

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.

Ion Processes Modify Tribological Properties of Surfaces

Treatments reduce friction and increase resistance to wear.

A NASA technical memorandum reviews the state of the art of the use of ion-assisted treatments to coat and otherwise modify surfaces of materials to reduce friction and increase resistance to wear. The focus is upon the treatment of materials destined for use in sliding, rolling, rotating, and/or oscillating contact under such severe environmental conditions as variable temperature, ionizing radiation, vacuum, and oxidizing or corrosive atmospheres at high temperatures. Because conventional oils and greases decompose and/or evaporate under such conditions, the materials in contact must be provided with adherent, solid lubricating coats that have optimized chemical and structural properties at the surfaces, independent of the properties of the bulk materials.

The ion-assisted treatments discussed in the report include the following:

- Ion-assisted deposition (sputtering, ion plating, and plasma-enhanced deposition);
- Ion-beam techniques (ion-beam implantation, ion-beam mixing, and ion-beam-enhanced deposition); and
- Plasma thermochemical processes (ion nitriding, ion carburizing, ion boriding, and ion oxidation).

The ion-assisted deposition techniques are primarily coating processes, while the ion-beam techniques and thermochemical processes usually form no discrete coats but do modify the surfaces of the bulk materials.

The report discusses the general principles of solid-film lubrication. This is followed by discussion of solid lubricants for spacecraft mechanisms, including layer lattice compounds, soft metals, and double-layered coats consisting of films of MoS_2 and/or WS_2 sputtered onto hard underlayers of BN, Cr_3Si_2, TiB_2, TiN, and/or B_4C on stainless-steel substrates. The next topic is lubricants for space power and aeropropulsion systems, including ductile inorganic compounds, self-lubricating composite coats, and lubricious ceramics modified by metal ions. Among the most notable self-lubricating composite coats is one called "PS200," which consists of a metal-bonded chromium carbide matrix in which Mg and CaF_2/BaF_2 eutectic are dispersed.

These lubricating films are described in terms of the interrelationships between structures, properties, and performances as measured by reductions in friction and resistances to wear. The characteristics of principal interest in this regard include adhesion, cohesion, nucleation, growth of microstructure, density, and thickness. Also discussed are the most recent advances in the use of the ion-beam surface-modifying techniques, with emphasis on the development of lubricious ceramic surfaces for use at high temperatures.

This work was done by Talivaldis Spalvins of **Lewis Research Center**. *Further information may be found in NASA TM-101304 [N88-28176], "Status and Directions of Modified Tribological Surfaces by Ion Processes."*

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.
LEW-14865

Mathematics and Information Sciences

Three-Dimensional Moire Pattern

The pattern apparent to the observer can indicate the observer's position.

Lyndon B. Johnson Space Center, Houston, Texas

The use of moire patterns to determine positions has been extended to three dimensions. Previously, moire patterns have been used to determine positions only along lines or in planes. By use of a suitable three-dimensional moire pattern, an observer can determine the position of the center of perspective, thereby also receiving an indication of depth even without a stereoscopic view.

The three-dimensional moire concept requires two moire templates or grids (see figure), which do not necessarily have to be flat. The grids are separated from each other. The template on the side closer to the observer contains alternating black and transparent areas. The template farther from the observer contains alternating black and white areas.

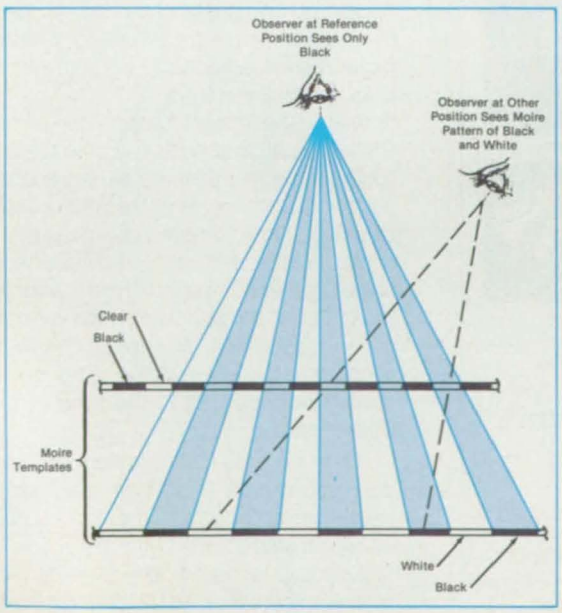
The pattern on the farther template is generated mathematically or photographically from the pattern on the nearer template. From a center of perspective at a reference location, portions of the farther template are visible through the transparent areas of the nearer template: These are the portions that are made black.

An observer looking at the templates from the reference position sees only black. When the center of perspective is changed to any other position, the observer sees the pattern of the transparent, black, and white areas visible from that position. The patterns on the templates can be chosen so that the moire pattern seen from every distinct position is unique. Thus, the position of the observer or observing device can be determined by interpreting the moire pattern in terms of the corresponding position.

The three-dimensional moire concept could be used in rangefinding applications in which precision is not required. It could be used to gauge the location of a mobile robot in an environment hostile to humans. A robot equipped with a video camera and suitable data-processing equipment that could "read" the moire pattern would be able to measure its own position.

This work was done by Richard D. Juday of **Johnson Space Center**. *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, Johnson Space Center [see page 25]. Refer to MSC-21416.



Separated Moire Templates are covered by patterns that complement each other when viewed by an observer at the reference position.

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.

QR Factorization in the Partial-Realization Problem

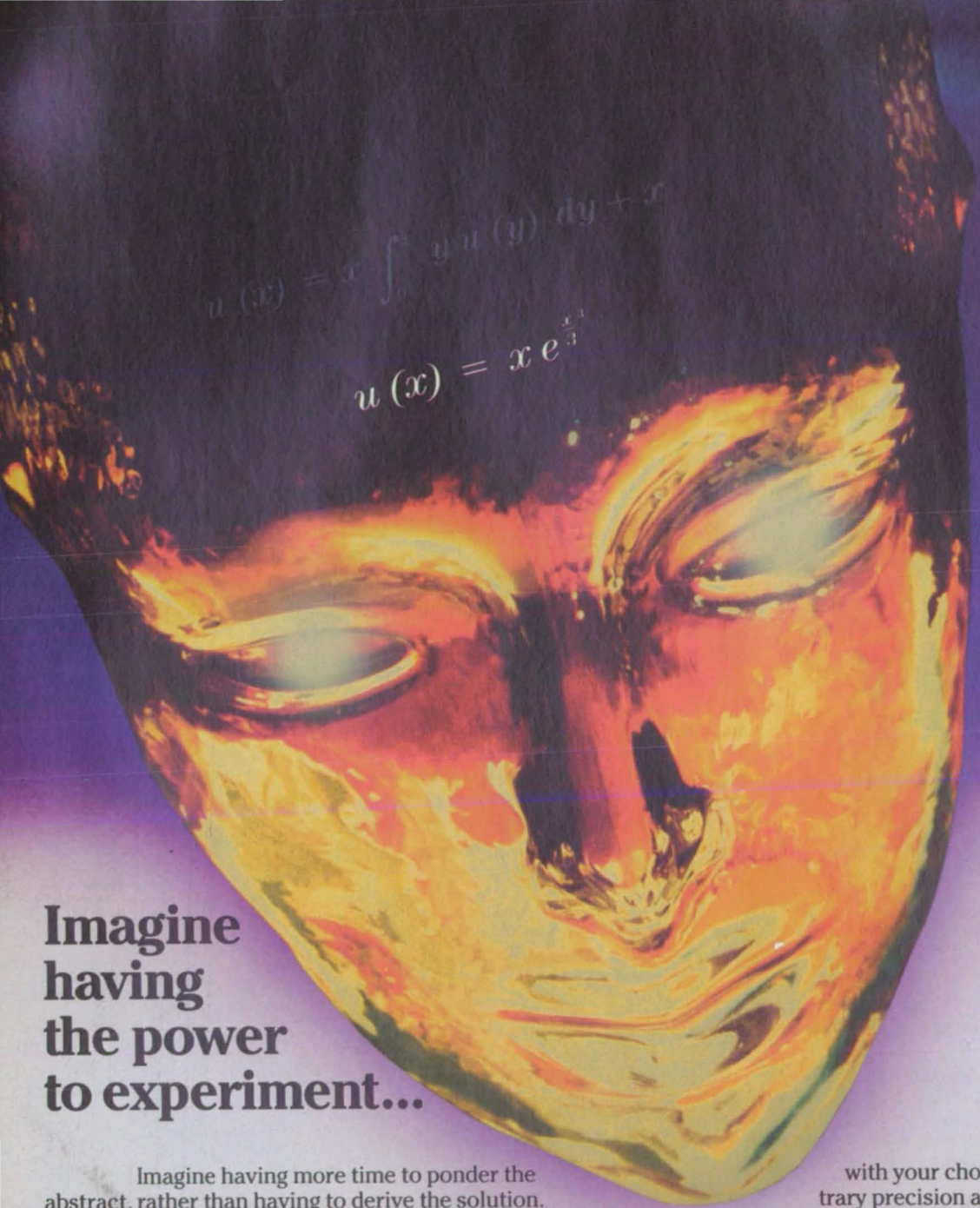
QR factorization is superior to other methods of factorization.

A report discusses the use of QR factorization in solving the partial-realization problem. The subject matter is relevant to the characterization of a system, the details of which are hidden (a "black box"), on the basis of the relationship between its inputs and outputs. When the realization process is successful, the system is shown to be linear with a known number of degrees of freedom and representable by a mathematical model that provides a basis for the prediction of outputs and the design of controllers.

The discussion applies to a single-input, single-output system for which the impulse response is specified by the vector of outputs recorded at equal intervals of time. The realization problem is to determine the constant-coefficient matrices in a linear mathematical model of the system that would have the same impulse response as that of the real system. The partial-realization problem is to obtain lower-rank matrices that approximate the response.

The numerical process of realization depends on factorization of the Hankel matrix, which is formed from the output vectors. The author shows that the QR factorization, a well-known process used to obtain approximate solutions to overdetermined linear problems, is superior to other factorization methods suggested previously for use in the solution of the realization problem. The straightforward use of the QR factorization results in a new realization scheme that possess all of the computational advantages of Rissanen's realization scheme. These advantages are computational efficiency, recursiveness, use of limited computer memory, and the realization of a system triplet having a condensed structure. Moreover, this new scheme is robust when the order of the system corresponds to the rank of the Hankel matrix.

When the order of the system does not correspond to the rank of the Hankel matrix, an approximate realization could be determined via the QR factorization. In this second scheme, the given Hankel matrix is approximated by a low-rank non-



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Hankel matrix. Furthermore, it is demonstrated that column pivoting might be incorporated in this second scheme. The main conclusion of this research is that the QR factorization, with or without column pivoting, might replace the single-value decomposition as a computational technique in solving partial-realization problems.

This work was done by M. H. Verhaegen of **Ames Research Center**. *To obtain a copy of the report, "The Use of QR Factorization in the Partial Realization Problem," Circle 11 on the TSP Request Card.*
ARC-12284

Conditional Probability and the Sparse Distributed Memory

The contents are a Monte Carlo approximation to a multidimensional conditional-probability integral.

A report presents a conditional-probability interpretation of Kanerva's sparse distributed memory (SDM). The SDM is a conceptual digital electronic memory in which addresses are chosen sparsely in a space of many dimensions and the content of the memory at each address is a positive or negative integer that is written (incremented or decremented) or read according to special rules. The SDM was shown in a previous study to be related to the Hopfield associative memory (a type of electronic neural network), which, in turn, was shown in another previous study to be interpretable in terms of Bayesian (conditional-probability) statistics. Thus, it seemed natural to inquire into the relationship between the SDM and conditional probabilities, and the results of the inquiry constitute the subject matter of this report.

The conditional probabilities enter via the probability distributions that specify uncertainties in training pairs of input and output vectors and the relationships between these distributions and the special rules for writing and reading the contents of the SDM. It is shown that the contents of the SDM constitute a Monte Carlo approximation to a multidimensional conditional-probability integral — that is, a finite sum of the multidimensional integrand evaluated at randomly chosen points. The SDM produces acceptable responses, provided that it has been trained with enough data to provide good estimates of the joint probabilities and there are enough Monte Carlo samples to obtain a sufficiently close approximation to the integral.

The analysis makes clear that to construct, by use of a training set of examples of inputs and outputs, an analog device that can thereafter transform other inputs into outputs acceptably close to the correct outputs by use of the SDM, care must be taken to match the data in the training set to the data-processing resources. In particular, ambiguities in amplitude space can arise here similarly to the way aliasing can corrupt samples of analog signals in the time and space domains when the sampling densities are too low. Finally, the report points out that generalizations of the SDM may lead to better understanding of biological neural networks. One conjecture is that the synapses, in at least some situations, might be viewed as performing random Monte Carlo samples of some complex joint probability distribution and that biological networks might do computations based on probability-density functions rather than only mean values.

This work was done by Charles H. Anderson of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Conditional Probability Interpretation of Kanerva's Sparse Distributed Memory," Circle 2 on the TSP Request Card.*
NPO-17902

Life Sciences

Books and Reports

101 Microgravity Experiments on Animals
101 Human Error in Complex Systems
102 More Life-Science Experiments for Spacelab

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.

Microgravity Experiments on Animals

Laboratory equipment will be evaluated, and physiological experiments will be performed.

A paper describes experiments on animal subjects that have been planned for the Spacelab Life Sciences 1 mission scheduled for launch in mid-1990. The mission represents the first step in establishing technology for maintaining and manipulating rodents, nonhuman primates, amphibians, and plants during space flight without jeopardizing the crew's environment. The knowledge gained in the orbiting animal-holding facilities and general purpose workstation will be used in subsequent Spacelab missions and in the Space Station.

In addition to providing data on the effectiveness of techniques and equipment, the experiments focus on the effects of microgravity on cardiopulmonary, cardiovascular, and musculoskeletal systems; on the regulation of the volume of blood and the production of red blood cells; and on calcium metabolism and gravity receptors. The major experiments are the following:

- The Particulate Containment Demonstration Test is designed to show that the research animal-holding facility and the rodent cages within it, the general-purpose workstation, and the general-purpose transfer unit (to transfer animals between the holding facility and the workstation) retain particulates generated within them during the experiments in flight.
- The Integrated Rodent Experiments yield data for the comparison of animals housed in the research animal-holding facility with those housed in another type of animal-containing unit, the animal enclosure module, in which the animals are observed and photographed but not otherwise subjected to experimentation. A total of nine rodents are kept in these two units, and they are to be examined before and after the mission to determine a variety of physiological parameters. In later missions, crewmembers will remove animals from the holding facility for examinations during flight.
- The Jellyfish Experiment is an investigation of the role of microgravity in the development and function of gravity receptors, formation or demineralization of the receptors, and swimming and pulsing behavior.
- The small-mass-measuring experiment checks the stability of a new version of an instrument for measuring small masses in space. The instrument is essential for measuring the masses of rodents and specimens of tissue on future missions.

This work was done by B. P. Dalton, H. Leon, and R. Hogan of **Ames Research Center** *and B. Clarke and D. Tollinger of MATSCO. To obtain a copy of the report, "Spacelab Life Sciences 1: The Stepping Stones," Circle 59 on the TSP Request Card. ARC-12343*

Human Error in Complex Systems

Experiments seek to find causes.

A report presents the results of research aimed at understanding the causes of human error in such complex systems as aircraft, nuclear powerplants, and chemical processing plants. The research considered both slips (errors of action) and mistakes (errors of intention), and the influence of the workload on them.

Two experiments were conducted. In experiment 1, human subjects operated PLANT, a computer simulation of a generic dynamic production process. A PLANT operator's task is to supervise the flow of fluid among nine tanks interconnected by pumps, valves, and pipes to make an unspecified product. The operator may open and close valves, adjust system input and output, check flows between tanks, and order repairs of PLANT components by typing commands on a keyboard.

The maximization of production is the primary goal. However, as in real systems, the operator must deal with such physical limitations as the capacities of tanks and the reliabilities of components. Therefore, the operator also must be concerned with such secondary goals as maintenance of stability and compensation for failures. The subjects' error patterns and amounts of production were recorded under a variety of processing conditions.

In experiment 2, the subjects again used PLANT, but with different control strategies.

The subjects were questioned in depth as they watched instant replays of their behavior in controlling the system. The question sessions were intended to gain understanding of the factors that prompted subjects to perceive increases of their effort and of the influences of these perceptions on subsequent behavior. In addition, the subjects were told that they would receive production bonuses.

The researchers obtained a complex pattern of results — one that was not consistent with predictions. Briefly, production was higher in experiment 2 and errors were fewer. Moreover, subjects felt that they had to make less effort in experiment 2.

Generally, the results indicated that:

- Humans respond to conditions in which errors might be expected by attempting to reduce the incidence of errors; and
- Adaptation to conditions is a potent influence on human behavior in discretionary situations.

This work was done by Nancy M. Morris and William B. Rouse of Search Technology, Inc., for **Ames Research Center**. *Further information may be found in NASA CR-177484 [N89-18008], "Human Operator Response to Error-Likely Situations in Complex Engineering Systems."*

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-12424

More Life-Science Experiments for Spacelab

Research is planned on cardiovascular, vestibular, metabolic, and thermal responses of animals in weightlessness.

A report describes experiments to be done as part of the Spacelab Life Sciences 2 mission (SLS-2), scheduled for mid-1992. SLS-2 will be carried aloft by the Space Shuttle in the microgravity laboratory facilities of the attached Spacelab module. The experiments are expected to shed light on the effects of prolonged weightlessness on humans.

One set of experiments will be carried out with rodents as subjects to study the following effects of weightlessness and the return to normal gravitation on Earth:

- Changes in the cardiovascular system;
- Changes in the production of red blood cells;
- Changes in the volume of blood;
- Changes in bones and the absorption and excretion of calcium; and
- Deleterious changes in gravity receptors in the inner ear.

Primates (squirrel monkeys) will be the subjects of two experiments designed to study the effects of weightlessness and the return to gravity on the following:

- Balances among fluids and electrolytes; and
- Temperatures, eating, drinking, and heart rates.

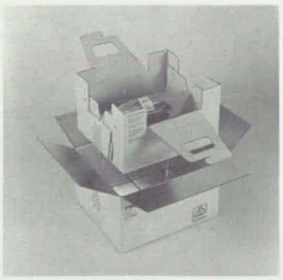
The paper describes the objectives and methods of each experiment. The paper also describes the principal equipment to be used in the experiments. Two rodent-holding facilities will house 24 animals each. A primate-holding facility will house four squirrel monkeys and enable researchers to take blood and urine samples — an opportunity not previously available on Spacelab missions. A general-purpose workstation will provide an enclosed, laminar-airflow workbench for conducting some of the more complex steps in the rodent experiments. A small-mass-measuring instrument will determine the masses of specimens in microgravity.

This work was done by P. D. Savage, Jr., B. Dalton, R. Hogan, and H. Leon of **Ames Research Center**. *To obtain a copy of the report, "Spacelab Life Sciences-2 ARC Payload — An Overview," Circle 6 on the TSP Request Card. ARC-12316*

New on the Market

A new **gas analyzer** from Aritron Instruments, Pittsburgh, PA, uses sound to measure indoor air contamination. It can be adjusted for sensitivity to a particular gas, such as carbon dioxide, carbon monoxide, Freon, nitrogen dioxide, sulfur dioxide, ozone, formaldehyde, or radon. The analyzer offers measuring ranges from ppb to percentage of total room air.
Circle Reader Action Number 786.

The CRADELAIR™ suspension pack, a **protective packaging system** which "floats" fragile products, is available from ADE Inc., Chicago, IL. CRADELAIR guards against shock, vibration, moisture, dirt, and electrostatic damage, while eliminating the need for bulky packaging such as cushioning wraps and loose-fills.
Circle Reader Action Number 780.



Elmo Manufacturing Corp., New Hyde Park, NY, has introduced a **CCD camera** with .08 Lux low light capability and 500 lines horizontal resolution. The model SE-360 camera offers seven shutter speeds to 1/4000 sec. and is available in three power configurations: 12 v dc, 24 v ac, and 120 v ac. It measures 2.56" x 2.56" x 4.98", weighs 1.66 pounds, and costs $646.
Circle Reader Action Number 788.

A high-intensity **black light lamp** offered by Spectronics Corp., Westbury, NY, produces higher UV intensity than conventional 100 watt lamps and has a visible emission under two footcandles to comply with military and aerospace specifications. The Spectroline® model SB-100 features heat-resistant wiring and an encapsulated transformer to reduce shock hazard. Its lightweight lamphead has a detachable pistol grip for handheld use.
Circle Reader Action Number 784.

Kaye Instruments Inc., Bedford, MA, has introduced an intelligent **RTD probe** that transmits temperature data to a computer in °C, °F, or Kelvin. Accurate to 0.01° C, the probe communicates directly with any RS-232C port. Menu-driven functions include display of temperature trends, password-protected probe configuration, probe recalibration, and access to BASIC for user-developed programs.
Circle Reader Action Number 778.

Planar Systems Inc., Beaverton, OR, has introduced a 10 inch (diagonal) **electroluminescent display** with 16 gray scale levels. The model EL7768MS flat panel display is timing- and pin-compatible with the feature connector on IBM XT/AT style VGA boards and uses standard TTL video signals. It offers high contrast and definition, video timing response, and wide angle readability.
Circle Reader Action Number 782.

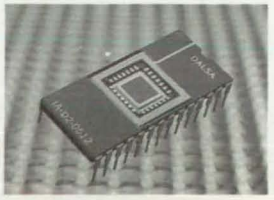
New on the Market

A new **continuous-tone thermal printer** from Alden Electronics Inc., Westboro, MA, provides images 10.1" wide by any length up to 150', with 256 tone shades and a resolution of 203 dots per inch. Images are created on a choice of thermal fiber, plastic, or transparent plastic paper. A high-speed black/white mode is used to print line art or images from computer-aided design systems.
Circle Reader Action Number 794.

The Sno Gun™ dry ice snow **cleaning system** from Va-Tran Systems Inc., Chula Vista, CA, presents an alternative to CFC-based cleaning agents. In a nontoxic cleaning process using CO_2, submicron particles and fingerprints are removed without leaving residue or scratching delicate surfaces. The handheld, nonconductive system allows electrical and electronic components to be safely cleaned while energized.
Circle Reader Action Number 798.

EAR Specialty Composites, Indianapolis, IN, has introduced the ISO-LOSS® LS **high-density foam**, a urethane foam offering low compression set, high strength, and dimensional stability for OEM applications such as gaskets, low-load isolators, and shock-protective padding. The foam offers consistent performance from -40° to +93° C and withstands intermittent exposure as high as 121° C. It is impermeable when compressed up to 50 percent.
Circle Reader Action Number 792.

Dalsa Inc., Ontario, Canada, has developed an **image sensor** with a full frame transfer architecture providing output data rates of 16 MHz. The sensor features a 10 µm square pixel and 512 x 512 square imaging area; a dynamic range greater than 2000:1; and a 60 frames per second frame rate.
Circle Reader Action Number 800.



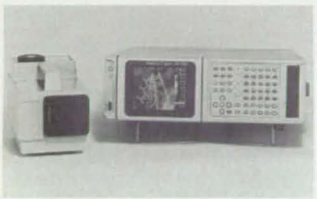
Ramtron Corp., Colorado Springs, CO, has developed a **ferroelectric DRAM** which combines the read/write capability and endurance of DRAMs with the nonvolatility, or ability to retain data without power, of magnetic memory. The FMx 1208 FRAM® is fabricated using a 3.0-micron silicon gate CMOS technology and integrated ferroelectric storage cells. It operates from a single +5 volt power supply and is TTL/CMOS compatible at all inputs and outputs.
Circle Reader Action Number 764.

Data Translation, Marlboro, MA, has announced GLOBAL LAB™ *Image*, an **image processing and analysis software package** for PC-based scientific and engineering applications. It offers automatic object counting and measurement, frequency analysis, and spectrum editing. Priced at $2495, the software features a Microsoft Windows 3.0 environment which allows data to be exchanged between GLOBAL LAB *Image* and other programs for analysis or report generation.
Circle Reader Action Number 790.

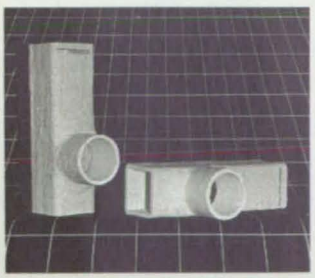
Contemporary Cybernetics Group, Newport News, VA, has introduced an 8 mm **tape backup system** with fast file search capability. The CY-8200-SX stores over 10 Gb on a single tape at up to 60 Mb per minute and can search 1 Gb of data in 17 seconds. Also available is the CY-8500 8 mm **tape drive**, which stores up to 25 Gb on a single tape with transfer rates up to 90 Mb per minute.
Circle Reader Action Number 796.

New on the Market

Mikron Instrument Co., Wyckoff, NJ, has introduced the TH1100 series Thermo Tracer, a highly-accurate **thermal imaging system** for temperature measurement, recording, and analysis. The system features a built-in LCD and a floppy diskette for data storage and retrieval. It offers an accuracy of 0.5 percent of full range through automatic calibration and correction for ambient temperature and reflection. Sensitivity can be selected from 0.1° to 70° C depending on target temperature and distribution.
Circle Reader Action Number 768.



New **pre-molded refractory parts** from Zircar Products Inc., Florida, NY, feature 100 pounds per cubic foot density, high strength and abrasion resistance, and can be used in environments up to 1450° C. Formed from a ceramic fiber reinforced-alumina based composite, the parts can be flat, cylindrical, or virtually any other simple or complex shape. Applications include corrosive hot gas ducting, molten metal holding and transport, induction coil liners, and high-temperature gasketing.
Circle Reader Action Number 766.



SketchMate, a **desktop plotter** that converts into a sign-making machine, is available from Roland Digital Group, Irvine, CA. Priced at $695, the device supports IBM PCs and compatibles and operates with a variety of HPGL-compatible software programs. For plotting applications, SketchMate supports eight pens in a choice of 32 colors on bond or tracing paper, overhead presentation sheets, or matte film.
Circle Reader Action Number 776.

Sarcos Inc., Salt Lake City, UT, has introduced a **ten-degree-of-freedom manipulator**, including a three-degree-of-freedom end effector designed to handle tools and other objects with high dexterity and a high-mobility wrist which allows the arm to position objects in a human-like manner. The arm can perform man-equivalent tasks using either autonomous or teleoperated control. Force transducers located at all joints allow the system to be run with active compliance.
Circle Reader Action Number 772.

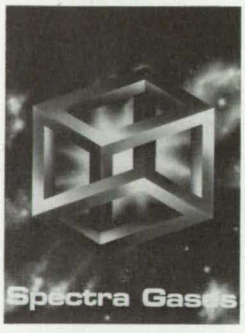
The Satellite **induction heating workstation** from Ameritherm Inc., Scottsville, NY, has a capability of 2.5 to 25 kW output for handheld or robotic use. Powered by an all-solid-state induction heating system, the portable unit excites carbon fibers or conductive adhesives, causing rapid localized cures in PEEK or adhesive bondlines. It can be used "in situ" to eliminate certain autoclave operations.
Circle Reader Action Number 774.

Lab Partner Plus™, a **handheld laboratory computer** offered by Calculated Solutions Inc., Greenville, SC, performs difficult calculations such as mixtures involving radioactive materials, as well as routine computations of weights, volumes, and concentrations. Data is shown on a 16-character liquid crystal display. The manufacturer offers an optional printer that works in tandem with Lab Partner Plus.
Circle Reader Action Number 770.

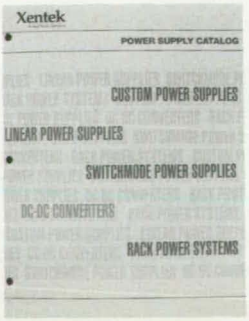
New Literature

Miniflow Systems Inc., Portsmouth, NH, has issued a brochure introducing its **bearingless flowmeter** for automotive, aerospace, and industrial test stand applications. Able to accurately measure flow from 8 ml to 8 gallons per minute, the flowmeter is free of friction effects common to conventional turbines and provides true kinematic performance. It is immune to shock and cannot be overranged.
Circle Reader Action Number 726.

A free catalog featuring **specialty gases** is available from Spectra Gases Inc., Irvington, NJ. It contains specifications for pure gases, gas mixtures, excimer gas premixtures, excimer gas handling systems, and related equipment. New products include halogen scrubber systems, isotopic gases, and an oil-free vacuum pump.
Circle Reader Action Number 728.

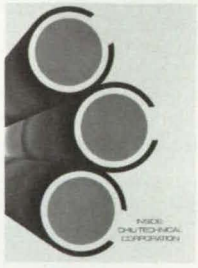


Standard and custom **power supplies** are the subject of a new four-color catalog from Xentek Inc., Vista, CA. The free catalog features switchmode and linear power supplies, including the world's smallest quad-output switchmode power supply, and PC board-mounted dc-dc converters. It also describes Xentek's vertically-integrated design and manufacturing facilities with advanced CAD/CAM systems, screen rooms for RFI/EMI testing and certification, and automated printed circuit assembly.
Circle Reader Action Number 720.



More than 5000 standard **wires and multiconductor cables** are highlighted in a new catalog from National Wire and Cable Corp., Los Angeles, CA. It includes military and commercial wires, instrumentation cables, computer cables, digital seismic data cables, biomedical instrumentation cables, and molded cable assemblies.
Circle Reader Action Number 718.

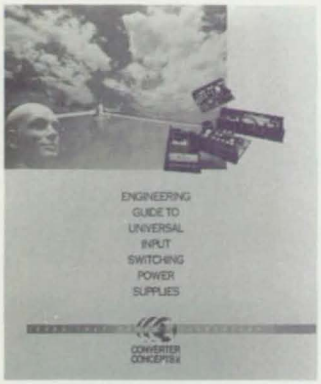
A 200-page databook published by Scientific Technologies Inc., Hayward, CA, covers **infrared sensing products**, including safety light curtains, scanners, sensors, data communication products, temperature controllers, and power monitoring equipment. Each product section is preceded by an explanation of industry terms and an update on product developments.
Circle Reader Action Number 724.



Fiber optic illuminating products are featured in a brochure from Chiu Technical Corp., Kings Park, NY. It describes quartz halogen light sources, high-pressure xenon and mercury arc power supplies, adjustable ring lights, darkfield/brightfield examination bases, and locking microscope bases.
Circle Reader Action Number 716.

A new catalog of **pressure transducers/transmitters, load cells,** and **display/control instruments** is available from DCT Instruments, Columbus, OH. Featured are pressure transducers with 10 mv/v output for ranges from 15 to 100 psi, and transducers/transmitters with DIN 43650 connectors.
Circle Reader Action Number 722.

New Literature

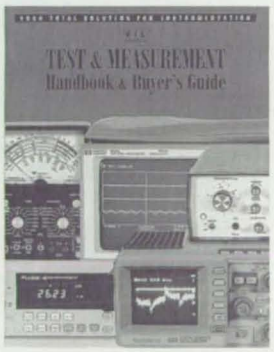


Converter Concepts Inc., Pardeeville, WI, is offering a catalog of its **universal input power supplies**. The catalog includes product information and specifications for the VF, VI, VM, VT/VX, WI, CP, VL, and XT power supplies, and contains tips on selecting the correct power supply for a given application.
Circle Reader Action Number 702.

Advanced Motion Applications, a technical booklet from Galil Motion Control Inc., Sunnyvale, CA, offers solutions to common **motion problems** such as cut-to-length, pick-and-place, engraving, position and tension control, winding machines, flying shears, contouring, and S-curve profiling. The free booklet provides an overview of motion control functions and programming.
Circle Reader Action Number 712.

A full-color brochure from Thin Film Technology Inc., Buellton, CA, highlights the company's **vacuum coating and substrate patterning services**. Sputtering and E-beam evaporation techniques are discussed, as well as pattern generation with resolution to .0001 inch. Chamber sizes up to 8 ft in diameter by 14 ft long can accommodate up to 200 sq ft of substrate area in one pumpdown.
Circle Reader Action Number 704.

More than 6500 **UNIX-based products and services** from 1500 vendors are compiled in a new directory published by UniForum, Santa Clara, CA. The two-volume directory covers software, hardware, and services. Listings are organized by category and cross-referenced by vendor, product, service vendor, and key word. X/Open's software directory is also included, listing products conforming to the XPG2, XPG3, and POSIX specifications.
Circle Reader Action Number 714.



More than 2500 electronic **test and measurement instruments** from over 100 manufacturers are featured in a new handbook and buyer's guide from EIL Instruments Inc., Sparks, MD. The free publication has sections on multimeters, recorders, printers, data/telecommunications testers, power supplies, function generators, frequency counters, and logic testers. Application data and feature comparisons are included.
Circle Reader Action Number 708.

The 1991 Video Optics Guide, published by DO Industries Inc., Rochester, NY, details stock **video optical products** and accessories, including the Zoom 6000 video microscope for inspection and quality control, Zoom 7000 and 7000E macro lenses, Dyotar high-depth-of-field lenses, fixed focal length lenses, manual and motorized zoom lenses, and fiber optic lighting equipment.
Circle Reader Action Number 710.

High-pressure valves and system components are described in a free catalog from Haskel Inc., Burbank, CA. Featured products include air- and oil-piloted directional control and release valves, regulating relief valves, pneumopulse cycle controllers, air pilot switches, stainless steel check valves, and high-pressure gas storage cylinders. The 24-page catalog contains selection charts and application notes.
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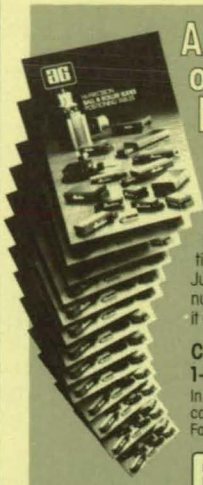

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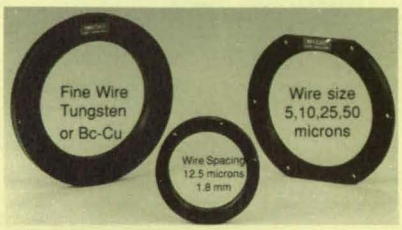

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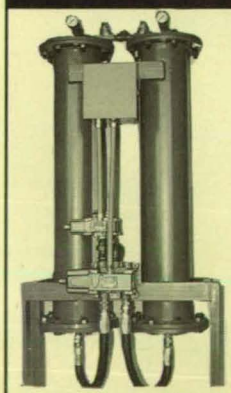

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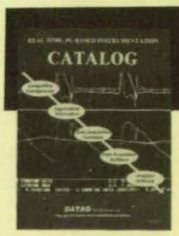

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Subject Index

Cont. from pg. 15

THE AWARD WINNERS

Unisys Corporation

Unisys Space Systems Division, headquartered in Houston, TX, supplies ground-based software for the space shuttle program as a subcontractor to Rockwell Space Operations Company. Unisys is responsible for more than 18 million lines of computer code in 15 programming languages. Its software products are applied in all aspects of shuttle operations, including flight design and mission planning, flight simulations for crew and flight controller training, pre- and post-flight verification of shuttle software, and real-time command, control, and communications in the Johnson Mission Control Center.

Unisys also provides software and systems engineering for space station Freedom under subcontract to Rockwell, and performs software engineering, testing, analysis, and systems support for space station control center development as part of a contract team headed by Loral.
Contact: Dr. David Weisman, (713) 282-4355.

United Technologies Corporation

United Technologies' USBI designs, acquires, assembles, tests, and refurbishes the non-motor segments of the space shuttle's solid rocket boosters (SRBs). USBI supplies the aft skirt, located at the base of the booster, which provides attach points to the mobile launch platform and support to the shuttle on the launch pad for all load conditions prior to lift-off; the external tank (ET) attach ring strut assembly, which allows for expansion and contraction of the SRB and ET; and the forward assembly, comprised of an expendable nose cap, the frustum, and the forward skirt.

Once the SRBs have been disassembled after launch and recovery, each major reusable structure begins refurbishment with a high-pressure water blast, or hydrolasing wash, that removes the thick thermal protection insulation. A 30-foot-tall gantry robot developed by NASA and USBI applies the water, which is pumped at 17,500 psi or 28.5 gallons per minute and stabilized by precise nozzle angles that break down the insulation without removing the underlying paint.

The robot removes the thermal coating in an estimated four percent of the time needed to complete the job manually. Stripping the frustum section, for example, previously required four to six hours manually. With the automated process, the same operation now takes 12 minutes.
Contact: Andrea Shea-King, (407) 867-7906.

Westinghouse Electric Corporation

Westinghouse has supplied space systems to the US government since the 1960s with equipment such as the Gemini Rendezvous Radar, the Apollo 11 lunar television camera, SEASAT and other space-based radars, a materials processing furnace used in the Apollo and Skylab programs, and power control modules and the master timing unit for the space shuttle fleet.

The company provides operations support to Goddard Space Flight Center and is developing infrared and visible sensor technologies for next-generation Earth observation and meteorological satellites.
Contact: T.A. Kurcz, (301) 765-7244.

For information on attending the 1991 Technology Transfer Awards Dinner, see page 43.

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NASA's INNOVATORS

The internationally-acclaimed research of NASA scientist **Dr. M. Patrick McCormick** has sharpened the world's focus on ozone loss as a major threat to the planet's health. Using satellite-borne sensors, McCormick discovered a key atmospheric agent contributing to the "hole" in the polar ozone curtain that protects the Earth from the sun's dangerous ultraviolet rays. His finding represents a giant step forward in understanding global ozone depletion.

McCormick, head of the Langley Center's Aerosol Research Branch, discovered the existence of polar stratospheric clouds (PSCs), high-altitude clouds made of ice crystals and nitric acid which form over Antarctica in the winter. This previously unknown phenomenon is now recognized as a pivotal catalyst in the chemical reactions that are destroying the ozone layer. "Without PSCs, I am convinced you would not have an ozone hole," McCormick said.

The role of PSCs in ozone depletion is linked to the presence in the atmosphere of chlorofluorocarbons, man-made chemicals widely used as refrigerants and cleaning solvents. When these chemicals break down, they release chlorine gas which attacks the ozone. And chlorine has a voracious appetite — one atom can destroy hundreds of thousands of ozone molecules.

Normally, the chlorine is "locked" in stable compounds. But when PSCs are present, the compounds react on the cloud surfaces, freeing chlorine to attack ozone until the Antarctic temperatures warm in the summer and the clouds dissipate. Moreover, as PSCs condense, they remove nitrogen gas that protects the ozone layer, adding to its vulnerability.

Photos courtesy Langley Research Center

Dr. McCormick (inset) discovered unique high-altitude clouds that play a pivotal role in ozone depletion.

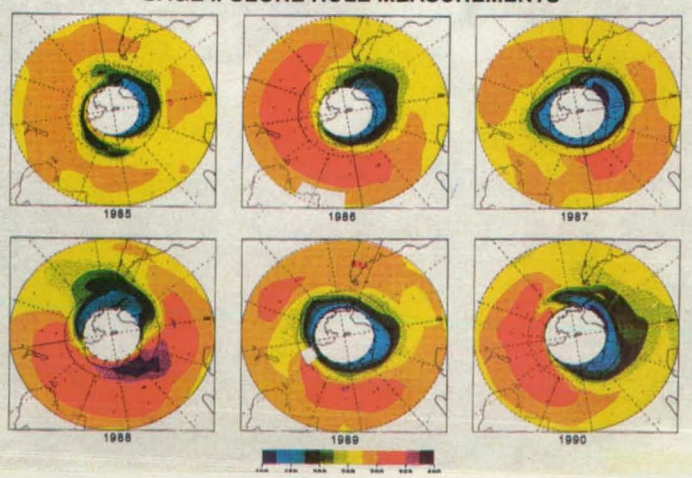
The satellite instruments McCormick developed use a solar occultation technique, which involves measuring sunlight as it passes through the Earth's atmosphere. By analyzing the wavelengths of the light, McCormick can determine what types of gases and particles are present in the atmosphere. This study of the stratosphere from satellites began with the Stratospheric Aerosol Measurement (SAM) experiment flown on the 1975 Apollo-Soyuz mission. The effort continued with devices aboard the Nimbus 7 spacecraft in 1978, the Application Explorer Mission spacecraft from 1979 to 1981, and the second Stratospheric Aerosol and Gas Experiment (SAGE II) aboard the Earth Radiation Budget satellite, still operating today after its launch from the shuttle in 1984.

The Langley scientist first identified PSCs when his SAM and SAGE experiments revealed there were extensive clouds in the coldest parts of the polar stratosphere. This finding was later confirmed by laser detection from aircraft missions led by McCormick, who is now working on a 1993 shuttle experiment that will employ space-based lasers to further probe the atmosphere.

In January, McCormick received the American Meteorological Society's prestigious Jule G. Charney Award, given in recognition of outstanding achievement in the atmospheric or hydrologic sciences. He previously earned the NASA Exceptional Scientific Achievement Medal, and his work on defining the role of trace gases and aerosols at flight altitudes was recognized by a U.S. senate resolution.

A NASA employee since 1967, McCormick currently serves on the NASA/World Meteorological Organization's Ozone Assessment Panel. He said studies show that the ozone hole in 1990 was severe for the third time in four years. The hole will continue to be a problem, he predicted, and he has called for the rapid development of safe alternatives to chlorofluorocarbons. ❑

SAGE II OZONE HOLE MEASUREMENTS



Satellite data revealed that the 1990 Antarctic ozone hole matched the record 1987 ozone depletion in depth, duration, and area.

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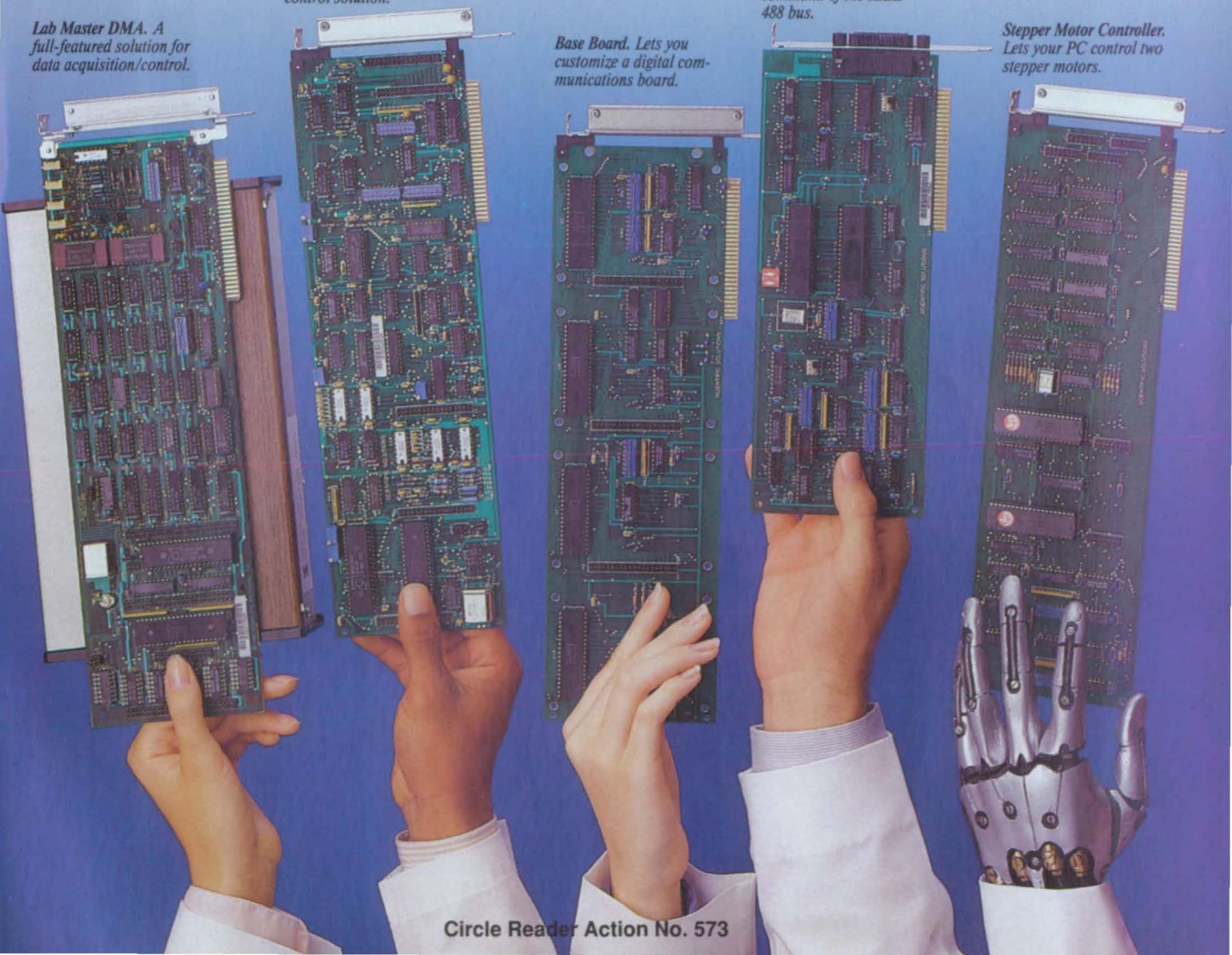

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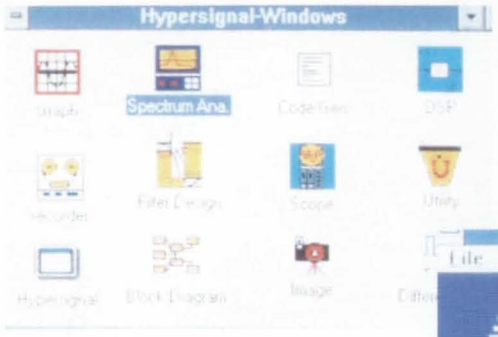

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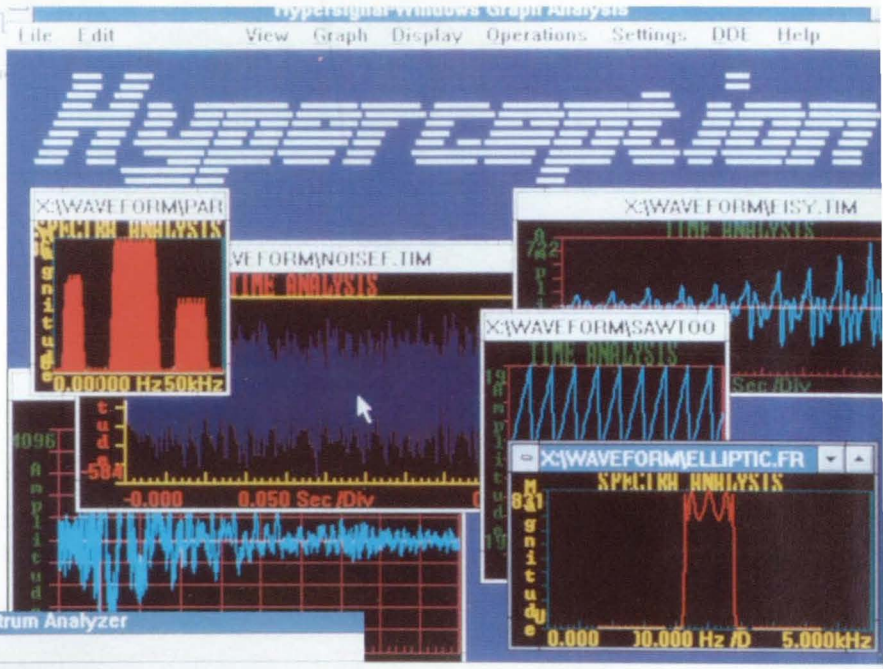
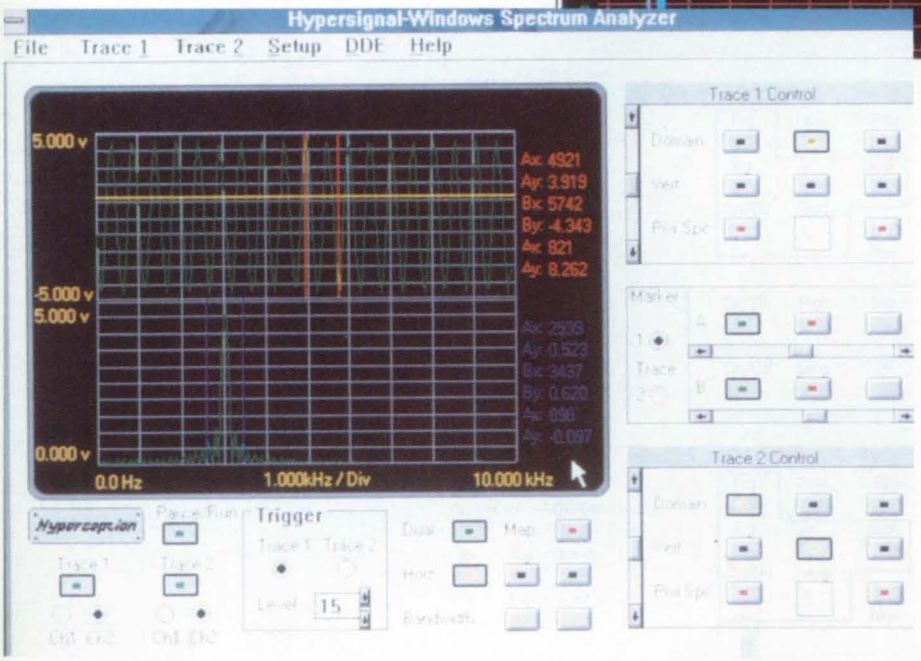


REAL-TIME SPECTRUM ANALYZER TO 10 MHZ



For a few more words, including catalog and demo disks, contact

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