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June 1995 Vol.19 No.6

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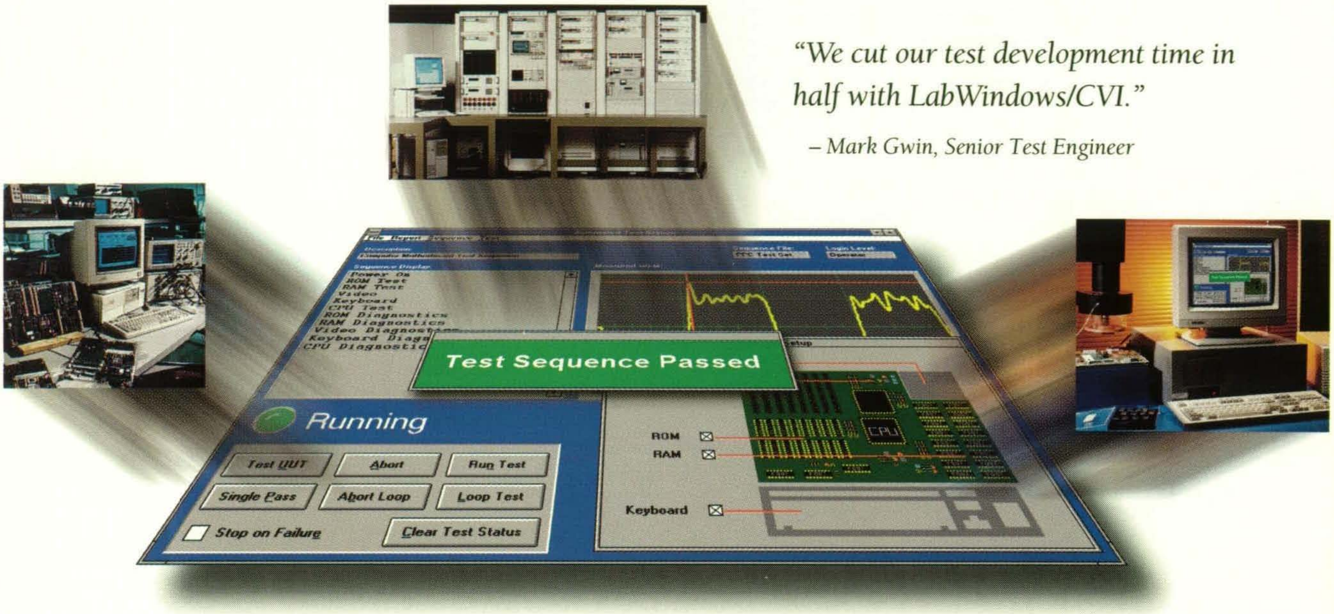

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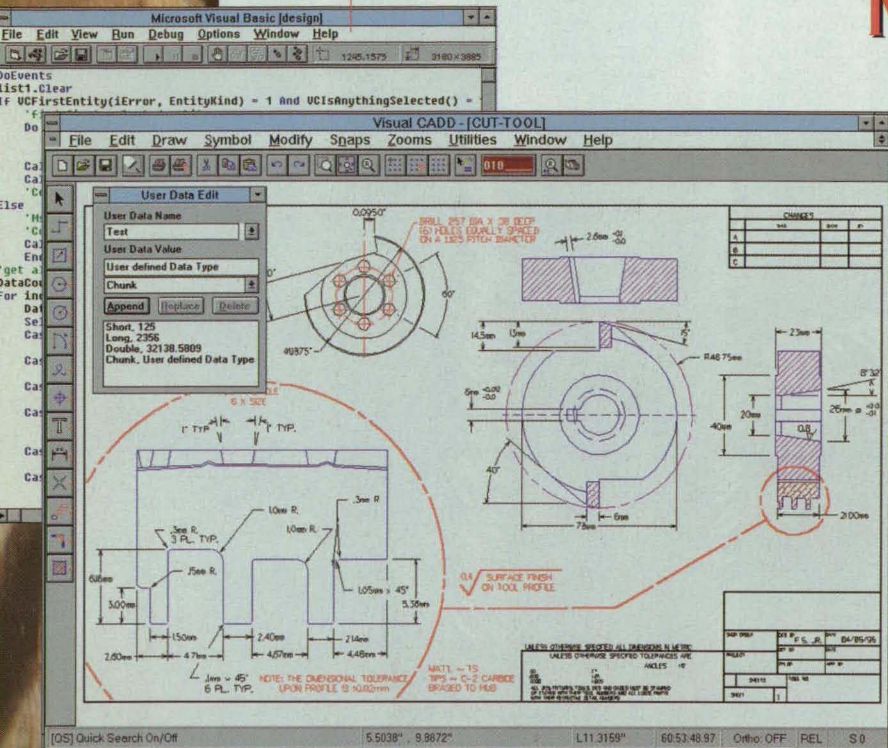

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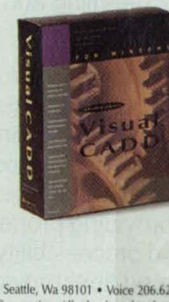

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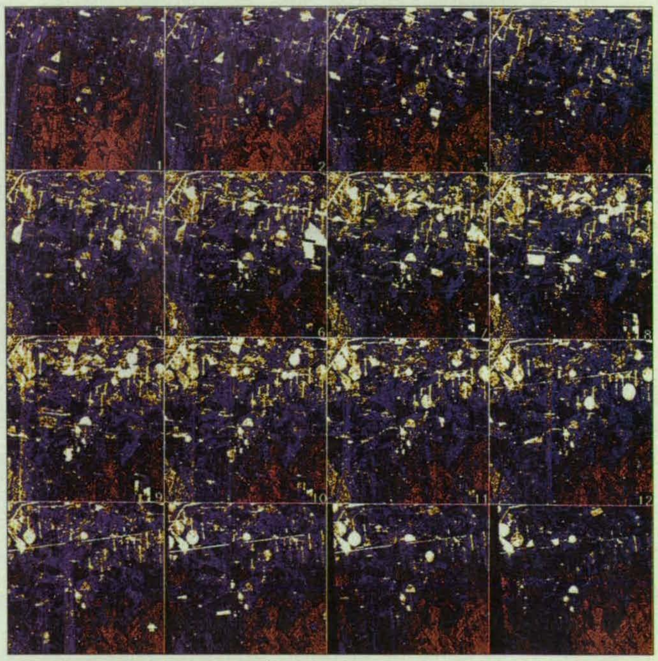

Frequency-channelized synthetic-aperture-radar (SAR) signal processing has been used to study variation in the radar-backscatter cross-section of agricultural fields as a function of direction angles. Maximum backscatter occurs when the radar beam is looking across furrows in a field—when the direction angle is 0°. Known as the Cardinal effect, this phenomenon was observed when the technique was applied to SAR data from agricultural fields in La Mancha, Spain. For more information on frequency-channelized SAR processing, turn to the tech brief on page 54.

Photo courtesy of Jet Propulsion Laboratory

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Contents *(continued)*

On the Cover:
Chrysler Corporation plans to introduce to the endurance road racing circuit in 1995 or 1996 the Patriot Mark II hybrid-powered race car. The Patriot incorporates a flywheel energy storage system that replaces the standard lead-acid battery and generates its own electricity. Combining a heat engine and an electric drive, the car can reach a top speed in excess of 200 mph. The Patriot also is a research project, allowing Chrysler to explore ways of producing low-emission, fuel-efficient, hybrid-powered passenger cars. ***Turn to Mission Accomplished on page 12.***

Photo courtesy of Chrysler Corporation

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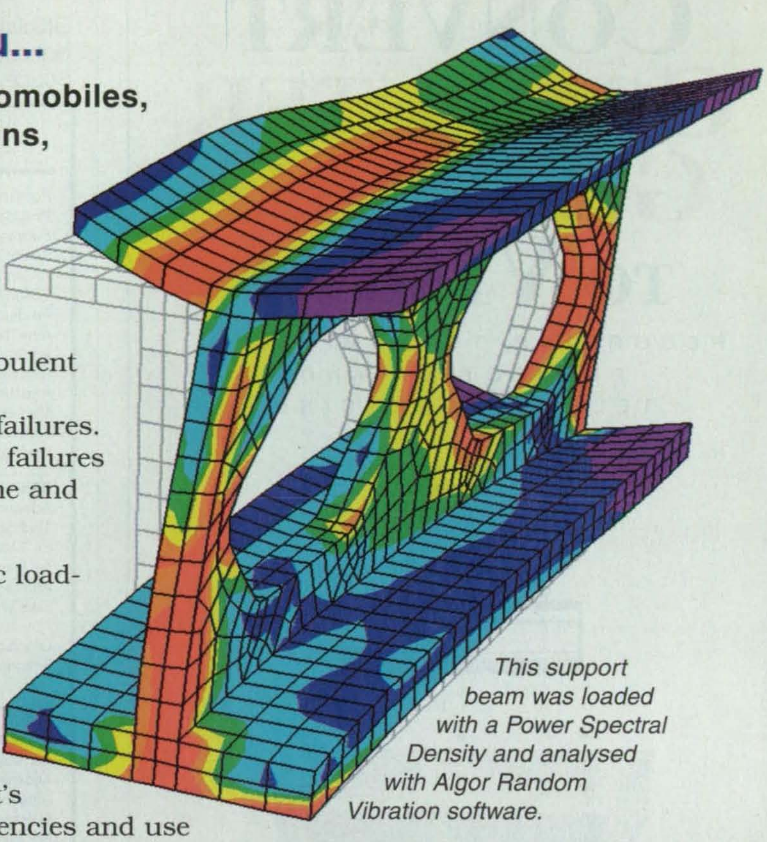

This support beam was loaded with a Power Spectral Density and analysed with Algor Random Vibration software.

Here's why:

Vibrations caused by road conditions, turbulent buffeting and other transportation-related disturbances are a major cause of product failures. In addition to critical safety concerns, such failures can lead to higher costs, increased downtime and reduced reliability.

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Standard loadings are usually available for these kinds of vibrations, because each has a characteristic "signature." For transportation-related applications of random vibration analysis, it is customary to develop vibration loading in a *Power Spectral Density* (PSD) for subsequent engineering analysis. A PSD is a curve of g^2/hertz versus frequency ("g" is gravitational constant). Random vibration analysis is the process by which these frequency-dependent loads are applied to your model to give you stresses and deflections.

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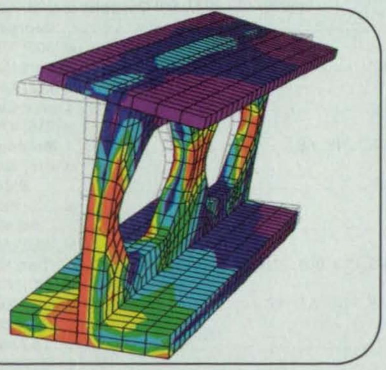

Here's when:

Analysis of the same beam, with vibration loads applied statically, shows an entirely different stress pattern.

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Mission Accomplished

The Chrysler Corporation is poised to stir up the endurance road racing circuit with the debut of a breakthrough entry that will sport more than just a sleek chassis. Following additional testing and evaluation, the auto maker plans to introduce the Patriot Mark II, an open-cockpit vehicle that can reach a top speed in excess of 200 mph via a hybrid power system that includes both a heat engine and an electric drive.

While Chrysler expects its hybrid-powered car to succeed on the track, the Patriot is first and foremost a research project, according to Francois Castaing, Chrysler's vice president of vehicle engineering. Even if the car fails, Castaing believes the Patriot racing experience will be a win/win situation since it will provide data for the Chrysler team to use in its attempt to meet the goals set by the Clinton Administration as part of the Partnership for a New Generation Vehicle (Super Car) program. The program participants, including Chrysler, General Motors, and Ford, are dedicated to building low-emission, fuel-efficient passenger cars, which may include a hybrid-powered vehicle. A hybrid car would have the benefits of environmental cleanliness and energy efficiency associated with electric cars, but would provide the power and range of conventional internal combustion cars.

Chrysler introduced the Patriot Mark I prototype in January 1994 at the North American International Auto Show as a "laboratory on wheels." After extensive evaluation, it was determined that the car's weight distribution and aerodynamics would not be competitive at high speeds. Chrysler engineers and designers, together with engineers at Reynard—the English developers of the car's body and chassis—altered the vehicle layout from a rear-engine to a mid-engine design, and created the second generation vehicle, the Patriot Mark II.

While standard electric cars typically are equipped with large lead-acid batteries that lose heat energy when they brake, hybrid-powered cars generate their own electricity without the need for a battery. Standard electric cars usually cannot travel more than 100 miles without recharging and have inadequate acceleration capability. The goal of hybrid cars is to run the internal combustion engine at a near-constant speed, allowing it to burn more efficiently.

The Patriot's unique design replaces the standard lead-acid battery with a carbon-composite, 125-pound flywheel energy storage (FES) system designed by SatCon Technology, a Cambridge, MA-based manufacturer of electromechanical products. The flywheel converts latent electric energy to rotational energy and stores it by spinning at up to 58,000 rpm in a near-perfect vacuum on almost frictionless bearings. The flywheel's carbon fiber has a tensile strength of 900,000 pounds per square inch, and acts as a buffer that allows the turbine to operate at a constant speed. Its latent energy is converted back to electricity and used when needed for maximum acceleration out of corners and down straightaways. When the car is not running at top speeds, the flywheel spins faster, storing the excess generated energy. In a hybrid-powered passenger car, the recaptured braking energy potentially could produce a 10 to 15 percent increase in fuel mileage.

Since the flywheel is responsible for the car's propulsion, the stress on the engine is reduced. Chrysler believes this technol-

ogy could produce smaller, more efficient engines in hybrid electric passenger cars, without sacrificing performance. The flywheel technology could replace batteries and serve as an energy storage system with no performance deterioration, even after thousands of recharges.

Mass-market electric vehicles historically have not been successful because they have lacked a battery that can generate the mileage equivalent of a tank of gasoline before requiring a recharge. A hybrid powertrain using flywheel technology could be a viable solution, provided the high costs involved can be reduced with sufficient production volume.

As a participant in NASA's Small Business Innovation Research (SBIR) program, SatCon began working with NASA in 1986 to research and develop flywheel technology. Information gleaned from 30 separate projects at NASA's Langley Research Center, Marshall Space Flight Center, Goddard Space Flight Center, Johnson Space Center, Lewis Research Center, and Ames Research Center from 1986 to 1994 combined to provide the technology behind the flywheel design. "We can't point to one specific project that was the basis for the car's flywheel," said Michael Turmelle, SatCon's vice president and CFO. "They [the projects] were all building blocks that led to the final design." NASA/SatCon programs dealing with micro-gyros, magnetic spindle bearings, induction motor flywheels, momentum wheels, EMA flywheels, and other related subjects all contributed to the technology base necessary to design and manufacture the Patriot's powertrain components.

In 1991, NASA started a more focused study of the flywheel as a potential battery power replacement for aerospace and commercial industries, beyond its automotive applications. SatCon supplies NASA with an Integrated Power and Attitude Control System (IPACS) that combines energy storage and spacecraft control functions in a single flywheel energy system.

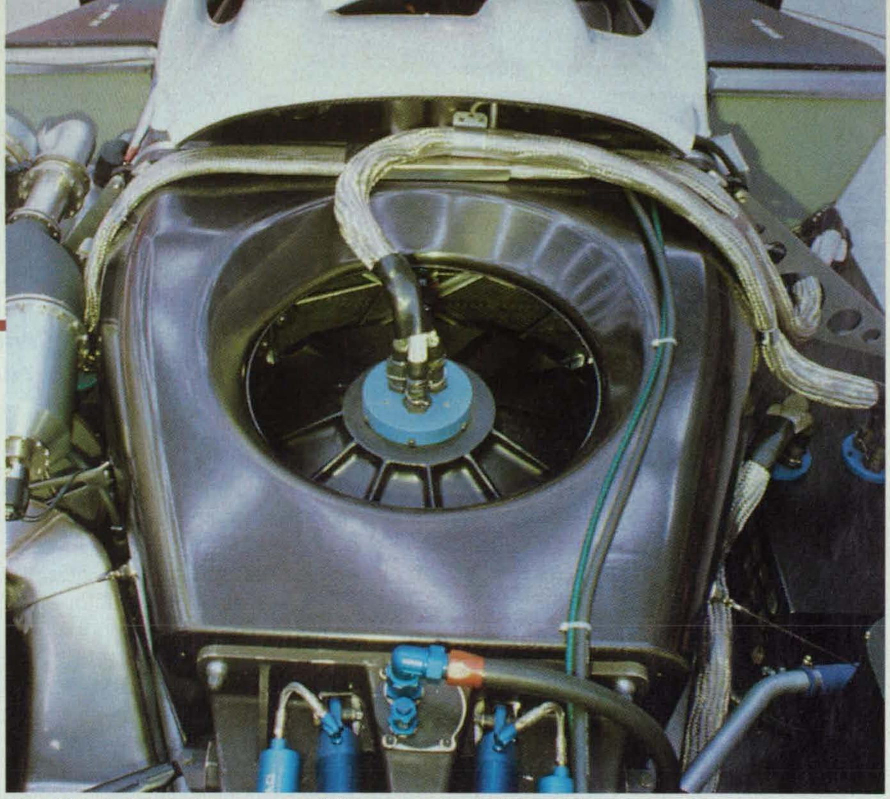
SatCon also provides the Patriot's drivetrain components: a turbo-alternator, traction motor, and an electronic power conversion unit. The Turbo Alternator Unit (TAU) integrates a gas turbine and a high-frequency AC induction alternator on the same shaft. The TAU burns compressed natural gas to spin twin turbo alternators that run at different speeds—one at 60,000 rpm and one at close to 100,000 rpm. The turbo alternators, similar to those used to provide power to jet airplanes parked at the terminal, produce electricity equivalent to 500 horsepower in a volume slightly larger than a shoebox. The generated electric power not used by the drive motor to power the car is stored in the flywheel. The electric drive motor draws power from both the alternators and the flywheel to reach a top speed of more than 200 mph. The car's electrical system controls about 800 volts, and the capacity of the Patriot's power controller approaches levels of wattage typically found in a 300-home neighborhood substation.

Cryogenics Experts Inc. (CEXI) of Los Angeles which, previously worked with NASA to design space shuttle ground support fueling systems, is providing the Patriot's fuel pump, fuel tank, and vaporizer. Liquid natural gas (LNG) will be kept on the race course in a cold storage tank at -159°C. The LNG is then pumped into the car's 123.3-liter-capacity fuel tank at approximately the same speed as regular gasoline. An on-board fuel pump pressurizes the LNG, which is then vaporized and fed into the turbine.

Chrysler currently is working with the Marshall Space Flight Center's Technology Transfer Office to identify possible space shuttle-based insulation materials which could be integrated into the Patriot's fuel system. One candidate is the Sprayed-On Foam Insulation (SOFI) material used on the shuttle's external tank. Samples and data of various high-temperature insulation materials currently used in the shuttle program have been provided to Chrysler for review. The MSFC Materials and Processes Laboratory potentially will apply these materials to Chrysler's engineering prototypes, if Chrysler determines these materials provide a good solution to their immediate needs.

Chrysler's first application of natural gas as a clean-air fuel was in 1992, when its natural-gas-fueled, full-size van was certified by the California Air Resources Board as a low-emission vehicle (LEV). In February 1994, Chrysler's CNG minivan was certified as the first ultra-low-emission vehicle (ULEV).

The state of California has mandated that by the 1998 model year, two percent of all vehicles sold in the state must be zero-emission vehicles. Hybrid-powered cars such as the Patriot, because they are not zero-emission vehicles, cannot meet the new laws. But that hasn't put the brakes on the company's research into cleaner, more fuel-efficient vehicles. Through the Patriot project, Chrysler hopes to show that these cars also can be powerful, good-looking, and fun to drive.



(Above) *The Patriot's flywheel energy storage (FES) system consists of a high-speed flywheel, a motor/generator, a bearing support system, and a containment/vacuum housing. When the car is not running at top speeds, the FES system stores excess generated energy and converts it back to electricity, which is used when needed for maximum acceleration.*
(Opposite page) *A non-running prototype of Chrysler's hybrid-powered Patriot Mark II race car was first introduced at the North American International Auto Show in Detroit in January 1994. Designed to produce low emissions and provide fuel efficiency, the mid-engine car is expected to make its road racing debut in 1995 or 1996.*

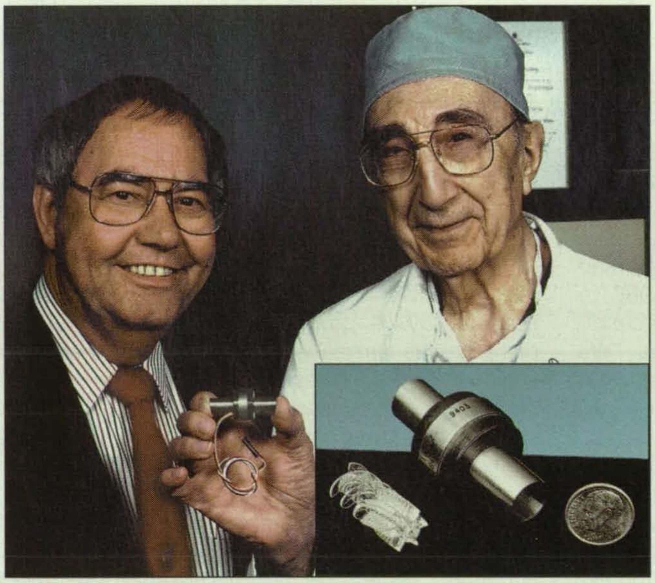
Johnson Space Center

The Johnson Space Flight Center covers 1,620 acres of former cattle ranchland on the Texas coast.

Famous for relaying such historical proclamations as "Houston, Tranquility Base here. The Eagle has landed" from the 1969 Apollo 11 moon mission, the Lyndon B. Johnson Space Center, Houston, TX possesses a large research and development support matrix that makes less splashy but no less valuable contributions to society. As the center for manned spaceflight control, Johnson performs life sciences research focused on maintaining the human body as well as plant life in space, which has led to an array of spinoffs from heart pumps to bioreactors. Computer software developed for complex astronaut training tasks also has found use in Earthbound activities.

From its conception in 1961, when it was called the Manned Spacecraft Center, JSC has been responsible for monitoring and controlling manned space missions after liftoff. The center officially opened in 1963 on a 1620-acre cattle pasture donated by Rice University, and in 1965 the Mission Control Center (MCC) took over manned operations from Cape Canaveral, beginning with Gemini 4. Renamed in February 1973 after the late US president, Johnson in the 1980s took on the immense task of training all US astronauts--pilots, mission specialists, and payload specialists--for the space shuttles, building simulators, and controlling each mission from the ground. Now more than 100 astronauts rank among the 3200 federal employees and 14,000 contractor personnel working at or near the center.

JSC's research supporting space exploration spans the gamut--propulsion, structures, energy generation, storage and transmission, human factors engineering, aerospace medicine, sensors, communications, computers, and materials. Indicative of the creative juices flowing at Johnson, its researchers have won NASA's Invention of the Year Award for the last three years.



JSC engineer David Saucier and Dr. Michael DeBakey, two developers of the Left Ventricular Heart Assist Pump, display the device.

Technology transfer at JSC involves moving concepts and products from the government into the private sector either by licensing technology or through cooperative development projects. The Technology Transfer and Commercialization (TTC) Office, "seeks out promising technologies that can form the basis for new and improved products, manufacturing processes, and services," according to Bob Dotts, assistant director at the TTC Office. "It also promotes some technologies that are new and perhaps risky, that might not be developed in time to compete in rapidly changing world markets without partnerships with industry and government."

Services available through the office include technology licensing, information on JSC technologies and facilities, assistance in forming cooperative research and development agreements, and technical problem-solving assistance. Licenses for JSC patents are individually negotiated with a prospective licensee, with each license specifically addressing its duration, product commercialization, royalties, and periodic reporting. To assist in the development and commercialization of certain innovations, Johnson may supply licensees technical support from its scientists and engineers. There are also commercialization opportunities for some technologies not protected by patents.

The TTC Office accepts problem statements--one- to two-page descriptions of companies' needs. The office canvases Johnson's technical divisions for a relevant technology. If the office cannot locate a potential solution, it forwards the problem statement to the Mid-Continent Technology Transfer Center, which canvases the other NASA field centers as well as other federal labs and assists the client if the technology is found.

The office continually assesses the commercial potential of Johnson's evolving technologies. Contract clauses require contractors to report new technologies--ideas, prototypes, products--that emerge from contracted activities, and these are inventoried and categorized according to perceived commercial potential. Johnson does this categorization in cooperation with its external partners, and the technologies with the highest commercial potential are studied for patentability or publication in NASA Tech Briefs.

JSC's external partners include IC^2, a technology incubator at the University of Texas in Austin; the Mid-Continent Technology Transfer Center at Texas A&M University in College Station, TX; and the Research Triangle Institute in North Carolina. While Johnson provides access to the technologies, the commercialization centers help industries identify and incorporate these technologies into processes and products. The centers also assess markets for the best way to focus federal commercialization efforts.

Johnson has produced many technologies that have found utility beyond the center. Armed with NASA turbopump technology and capabilities in computational fluid dynamics analysis, JSC researchers teamed up with Baylor College of Medicine specialists, to devise the Left Ventricular Heart Assist Pump. This small turbine pump helps the heart circulate blood throughout the body, keeping a patient with a diseased heart alive until the organ recovers or is replaced by a transplant. As it can be used either as a temporary or permanent device, it can also allow patients who are not transplant candidates or whose hearts may not recover, the chance to live a nomal life; without such a pump, many heart-diseased patients would be bedridden.

Johnson's need to train astronauts and space-station flight controlers resulted in the 1994 NASA Invention of the Year Award for the General-Purpose Architecture for Intelligent Computer-Aided Training (NASA Tech Briefs, Vol. 19, No. 4, April 1995). The system substitutes a computer teacher for a human on complex training tasks, adapting to the trainee's learning ability or skill level. JSC distributes the software directly and has arranged for private companies to distribute some derivative versions.

Johnson's life science research into growing plants in outer space led to a synthetic growth medium that requires only water for growth, which has been licensed to two private companies for general marketing. A rotating bioreactor cell-culture apparatus that produces cell types that would not otherwise grow outside the body has also been licensed for commercial development.

A Johnson facility in New Mexico, the White Sands Test Facility, has been reaching out to industry in designing, testing, and operating safer oxygen systems. White Sands has expertise in advanced materials testing for oxygen and propellant exposure environments, including materials ignition and combustion. Oxygen system manufacturers often have difficulty accessing hazard analysis and test data for their equipment, so White Sands made its facilities available to industry. Users gain relatively inexpensive access to the testing complex--and White Sands in turn often benefits. White Sands conducted hazardous tests for Wendell Hull & Associates, Las Cruces, NM, for example, and the company now serves as a liaison for White Sands, arranging contract testing and finding ways to cut the time--in some cases, down to as little as two weeks--for obtaining and setting up data. Companies such as General Electric Aircraft Engines, Evendale, OH, and Exxon Research and Engineering Company, Florham Park, NJ, have economically obtained combustion test data from White Sands.

Crew members preparing to service the Hubble Space Telescope used virtual reality in training. Research into training techniques at Johnson has led to innovations such as the General-Purpose Architecture for Intelligent Computer-Aided Training.

For further information, contact Johnson Space Center, Technology Transfer & Commercialization Office, Mail Code HA 2101 NASA Road 1, Houston TX 77058-3969; Tel: (713) 483-3809; Fax: (713) 244-8452;E-mail: commercialization @jsc.nasa.gov. □

For More Information Write In No. 418

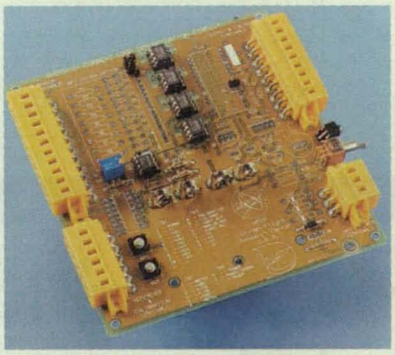
PATENTS

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Method of Encouraging Attention by Correlating Video Game Difficulty With Attention Level

(US Patent No. 5,377,100)
Inventors: **Alan T. Pope** and **Edward H. Bogart**, Langley Research Center

The invention uses biofeedback to alter the difficulty of an electronic video game according to the player's attention level. An adjuster increases or decreases the speed or evasiveness of the depicted object with variations in electrical activity in the brain. The aim is to in-crease the player's attention span and overcome the effects of conditions such as attention deficit disorder.
For More Information Write In No. 740



Constant Current Loop Impedance Measuring System That Is Immune to The Effects of Parasitic Impedances

(US Patent No. 5,371,469)
Inventor: **Karl F. Anderson**, Ames Research Center

In measuring characteristics of an environment, the commonly used Wheatstone bridge system often has parasitic resistances from connecting wires, components, and environmental conditions, interfering with the system's variable resistor and causing inaccurate measurements. Anderson's invention is unaffected by such resistances while providing an output that varies linearly with the variation in the measured characteristic.
For More Information Write In No. 741

Jet Mixer Noise Suppressor Using Acoustic Feedback

(US Patent No. 5,392,597)
Inventor: **Edward J. Rice**, Lewis Research Center

The invention improves on jet mixer noise suppression by introducing feedback from acoustic waves received from the downstream side of the nozzle, allowing thorough mixing in significantly shorter distances so the mixing-produced noise is more amenable to reduction by acoustic treatment. This design means a smaller, lighter, and less expensive mixer.
For More Information Write In No. 742

Radiation Sensitive Area Detection Device and Method

(US Patent No. 5,399,877)
Inventors: **Daniel C. Carter, Diana L. Hecht,** and **William K. Witherow**, Marshall Space Flight Center

Radiation sensitive area detector systems are limited by small active areas, low spatial resolutions, high levels of spatial distortion, non-uniform response, and the inability to capture near real-time imagery. Devices using barium fluorohalide films have background noise and limited pixel shapes. The device of Carter et al. brings the illumination source closer to the film and accomplishes injection and detection of the ion excitation and fluoresced illumination along the same optical path to maximize light transmission and ensure high spatial scanner resolution.
For More Information Write In No. 743

Monolithic In-Based III-V Compound Semiconductor Focal Plane Array Cell With Single Stage CCD Output

(US Patent No. 5,386,128)
Inventors: **Eric R. Fossum, Thomas J. Cunningham, Timothy N. Krabach,** and **Craig O. Staller**, Jet Propulsion Laboratory

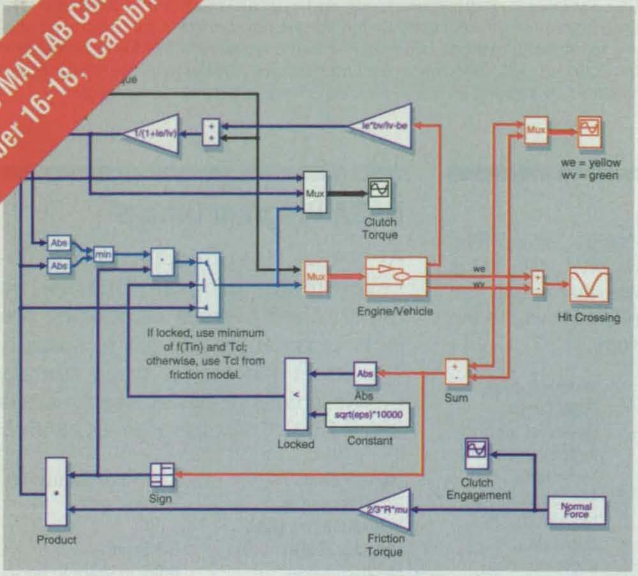
InGaAs detectors can operate at high temperatures and detect short-wavelength infrared and visible light, and this invention allows fabrication of a truly monolithic short-wavelength focal plane array with high detectivity. An InGaAs infrared focal plane array is more manufacturable than previous arrays because the growth techniques for III-V compound semiconductors are more advanced and lead to higher processing yields.
For More Information Write In No. 744

Quality Monitor and Monitoring Technique Employing Optically Stimulated Electron Emission

(US Patent No. 5,393,980)
Inventors: **William T. Yost, Christoper S. Welch, Edmond J. Joe,** and **Bill B. Hefner**, Langley Research Center

Techniques for monitoring manufacturing-process contaminants often require bulky machinery and operational expertise. With one commercially available newer technique, optically simulated electron emission (OSEE), indications of contamination may remain after recleaning .Yost et al. altered the OSEE monitor design to increase stability, reproducibility, definition, and sensitivity of results, decrease ambiguity, and extend the range of substrates measured.
For More Information Write In No. 745

1995 MATLAB Conference
October 16-18, Cambridge, MA



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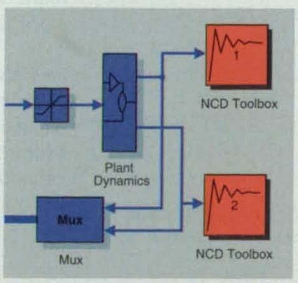

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC). We encourage all businesses with technical needs to contact the appropriate organizations for more information. For those who have access to the Internet, general information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions regarding how to acquire the free Mosaic software can be obtained by sending an e-mail request to: innovation@oact.hq.nasa.gov.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Syed Shariq
(415) 604-0753
syed_shariq@qmgate.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3119
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc-mail.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
William Spuck
(818) 354-2240
william_h_spuck@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@profs.jsc.-nasa.gov

Kennedy Space Center
Selected technological strengths: Emissions and Contamination Monitoring; Sensors; Corrosion Protection; Bio-Sciences.
Bill Sheehan
(407) 867-2544
billsheehan@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Charlie Blankenship
(804) 864-6005
c.p.blankenship@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Walter Kim
(216) 433-3742
wskim@lims01.lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Harry Craft
(800) USA-NASA
susan.van.ark@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Lon Miller
(601) 688-1632
lmiller@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium.

Lee Rivers
National Technology Transfer Center
(800) 678-6882

Robert Stark
Far-West Technology Transfer Center
University of Southern California
(800) 472-6785 or
(213) 743-6132

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
(800) 472-6785 or
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(800) 472-6785 or
(904) 462-3913

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(800) 472-6785 or
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(800) 472-6785 or
(412) 648-7000

Chris Coburn
Great Lakes Industrial Technology Center
Battelle Memorial Institute
(800) 472-6785 or
(216) 734-0094

Easy Access To The FLC: Call (206) 683-1005 for the name of the Federal Laboratory Consortium Regional Coordinator in your area. The Regional Coordinator, working with the FLC Locator, can help you locate a specific laboratory to respond to your needs.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Gene Pawlik
Small Business Innovation Research Program (SBIR)
(202) 358-4661
gpawlik@oact.hq.nasa.gov

Robert Norwood
Office of Space Access and Technology (Code X)
(202) 358-2320
rnorwood@oact.hq.nasa.gov

Philip Hodge
Office of Space Flight (Code M)
(202) 358-1417
phodge@osfms1.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Bert Hansen
Office of Microgravity Science Applications (Code U)
(202) 358-1958
bhansen@gm.olmsa.hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Stephen Gomes
American Technology Initiative
Menlo Park, CA
(415) 325-5353

Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1200

John Gee
Ames Technology Commercialization Center
Sunnyvale, CA
(408) 734-4700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.
For software developed with NASA funding, contact **NASA's Computer Software Management and Information Center (COSMIC)** at (706) 542-3265, fax (706) 542-4807.
If you have a questions...**NASA's Center for AeroSpace Information** can answer questions about NASA's Commercial Technology Network and its services and documents. Use the Feedback Card in this issue or call (410) 859-5300, ext. 245.

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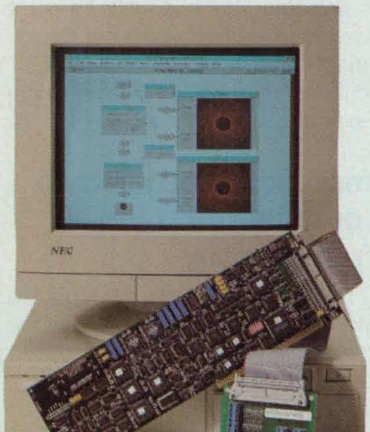

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For More Information Write In No. 530

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 Commercial Technology Office of the sponsoring NASA center (see page 20).

Compressor Has No Moving Macroscopic Parts

This compressor uses beds of magnetic particles that are alternately energized and deenergized to create a compressive motion. The unit is relatively easy to fabricate because it needs no precisely fitting moving parts. It also needs no lubricant fluid and can be operated continuously without on/off cycling. (See page 76.)

Beam-Steering Subsystem for Laser Communication

This system would involve a fast beam-steering subsystem that would stabilize only the angle between the transmitting and receiving beams, instead of stabilizing both the transmitting and receiving lines of sight individually as in the older designs. (See page 32.)

Small Magnetometer

A small, light-weight, low-power magnetometer measures three-dimensional magnetic fields. It uses three cores and associated coils spaced 22 mm apart. (See page 46.)

Improved Capacitive Liquid-Level Probe

An improved probe measures the level of dielectric fluid in a tank. The probe is insensitive to temperature-induced and other spurious capacitive effects that could otherwise distort the readings. (See page 40.)

Improved Piezoelectric Loudspeakers and Transducers

These devices feature the light weight and energy efficiency of piezoelectric transducers and mechanical coupling efficiency approaching that of much heavier, less energy-efficient electromagnetic loudspeakers. (See page 42.)

Enhanced Boiling-Metal Cooling of Vanes Exposed to Hot Gases

Automatic self-powered jet pumps are proposed to enhance boiling-liquid-metal cooling of vanes exposed to hot gases. Originally intended for operation in supersonic flows of hot gases in rocket engines, the concept may be applicable to vanes and blades in high-performance turbine engines. (See page 54.)

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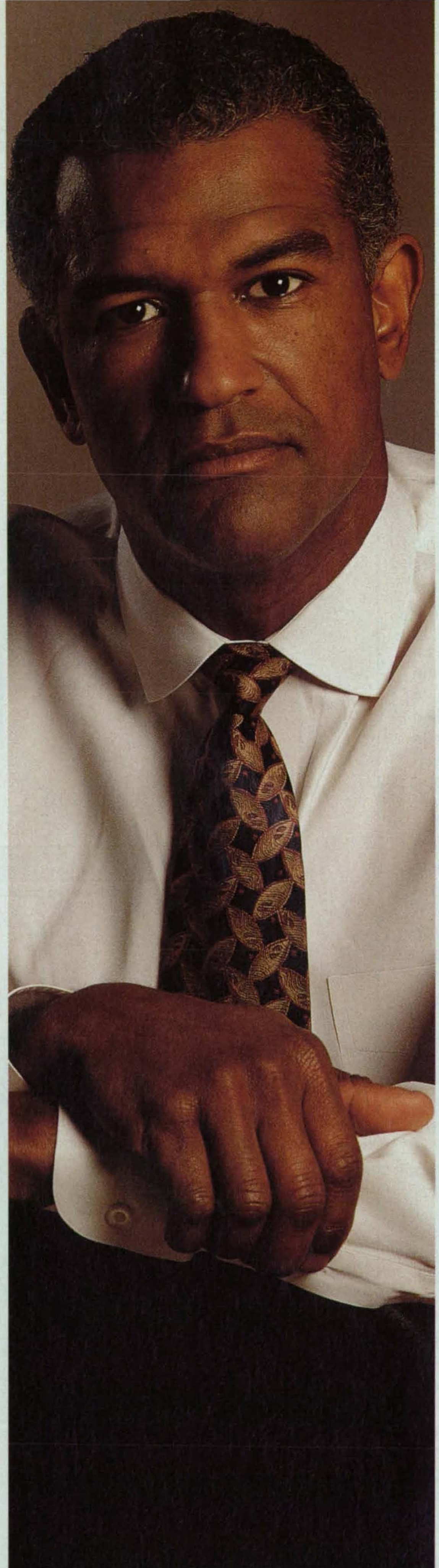

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*The Power Macintosh 6100/66 DOS Compatible, and other Power Macintosh models using SoftWindows from Insignia Solutions, run MS-DOS 6.2 and Windows 3.1. †For proof, ask for the 1995 Ingram study comparing Power Mac computers to Pentium-processor-based computers running Windows. All Apple products are designed to be accessible to individuals with disability.

Two Optical-Beam-Forming Concepts for Array Antennas

Novel combinations of optical and electronic techniques would result in compact, lightweight beam-steering antennas.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two optical-beam-forming concepts have been selected for development of phased-array antennas. Potential applications of these concepts include steered-beam or quasi-optical microwave antennas in communication and radar systems, remote control of antennas in general, and photonic communication. These concepts involve the use of novel combinations of optical and electronic techniques to distribute a radio-frequency signal to or from the antenna elements in an array: the phase and amplitude of the radio-frequency signal traveling to or from each element would be controlled in such a way as to cause the array as a whole to transmit or receive the signal in the desired spatial pattern, which could be steered, narrowed, broadened, or otherwise varied. The components needed to implement the optical-beam-forming concepts would weigh less and occupy less space than do the coaxial-cable and waveguide phasing signal-distribution components of older phased-array antennas.

Figure 1 illustrates transmitting and receiving configurations according to one concept. A laser would generate unmodulated beams at frequencies f_1 which would be separated by a beam splitter. One beam would be modulated by the information signal to be transmitted. An assembly of advanced electronically controlled spatial light modulators would holographically shuffle the other beam, forming it into the required spatial pattern. A lens would then form the beam into a Fourier transform of this pattern onto a plane containing the input apertures of optical fibers leading to the various antenna elements: the Fourier-transform pattern would correspond to the required distribution of complex amplitude across the antenna aperture.

The temporally modulated f_2 beam would be collimated and expanded, then directed (along with the f_1 beam) onto the fiber-optic input plane by use of another frequency-selective sur-

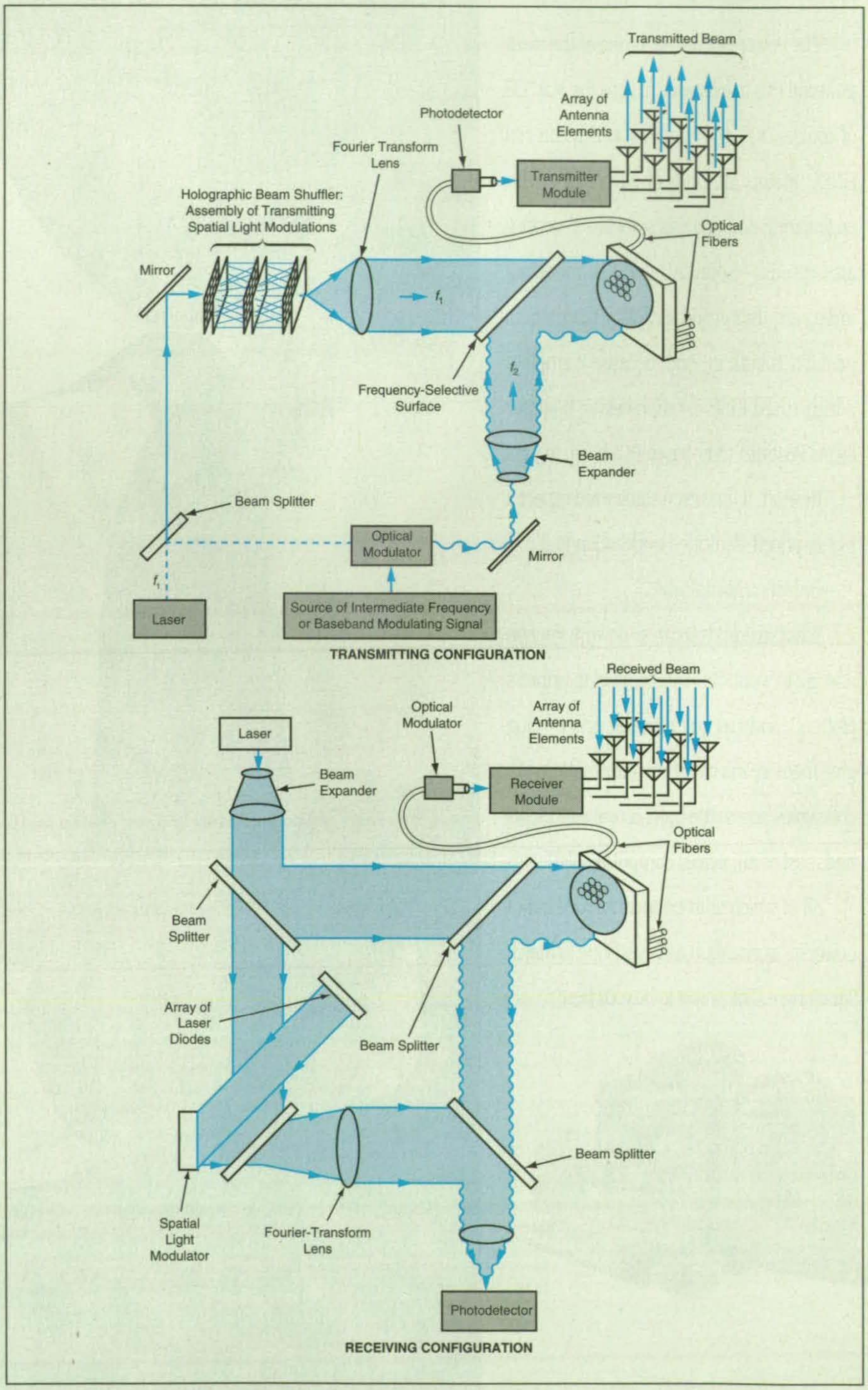

Figure 1. **Optical Beam Forming** would be used to shape and aim the transmitted or received radio beam.

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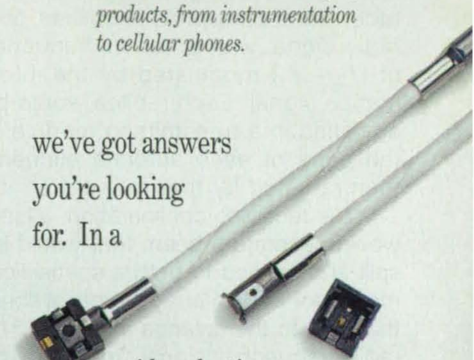


face. At the output end of each optical fiber, the f_1 and f_2 signals would be heterodyned in optical detectors, yielding controlled-amplitude, controlled-phase replicas of a radio signal with a carrier frequency of $|f_2 - f_1|$ modulated by the information signal. Each replica would be amplified in a transmitting module at the base of each antenna element, then radiated by that element.

In the receiving configuration, a laser would generate a beam that would be split and applied to both a spatial light modulator and an array of optical fibers that lead to the antenna elements. The radio-frequency signal received by each antenna element would be used to modulate the light reflected back along the optical fiber, while the conjugate of the desired antenna-aperture distribution of complex amplitude would be applied via the spatial light modulator. The two beams would be recombined and focused on a photodetector, where heterodyne action would yield the combined replicas of the radio-frequency signal received by the various antenna elements. With some modifications, the transmitting and receiving configurations could be incorporated into a single system.

Figure 2 illustrates an alternative transmitting configuration. In this case, the f_1 beam would be shaped by a single spatial light modulator, f_1 would equal f_2, and the entire radio-frequency signal (carrier plus information) would be applied as modulation to the f_2 beam. As before, the f_1 and f_2 beams would be combined and sent to the antenna elements via optical fibers. The output end of each optical fiber would be located at a photodiode array integrated into a bow-tie antenna element. Heterodyne action in the photodiodes would reconstruct the radio-frequency signal, which would be radiated by the antenna element. The integrated array of photodiodes and antenna elements is denoted a "traveling-wave photodetector" (TWPD).

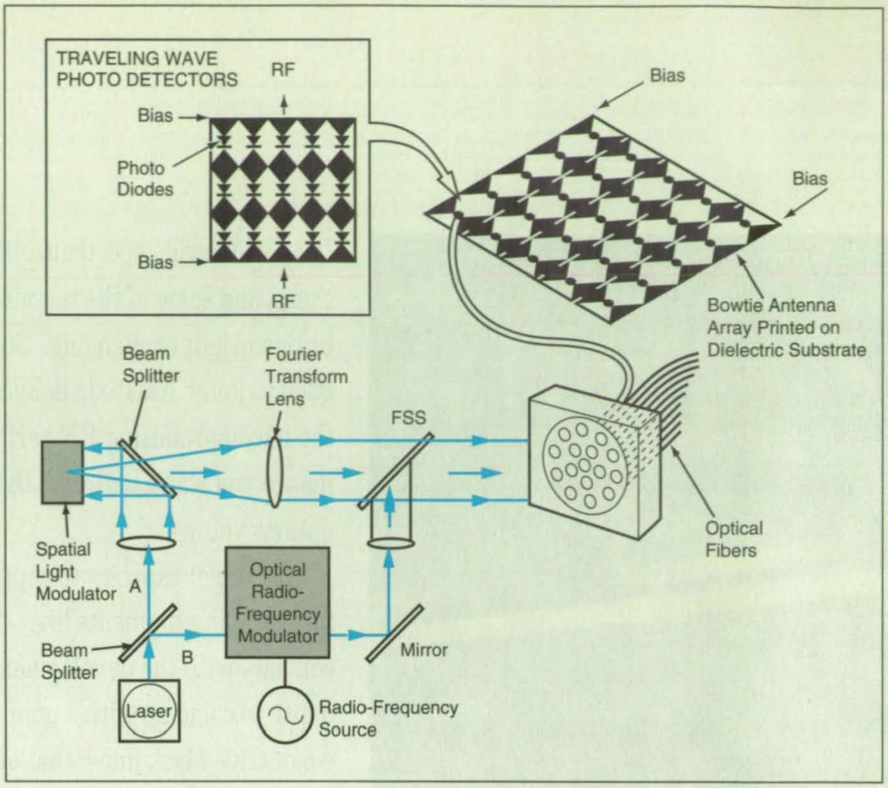


Figure 2. **Traveling-Wave Photodetectors** would convert optically formed and divided beams into radio signals.

In another version of this concept (not shown), the temporally modulated optical signal would be applied to the TWPD via an optical-beam power divider (OBPD), which might or might not perform spatial modulation as in Figure 1 or Figure 2. In this case, the OBPD would provide the antenna-aperture amplitude distribution only; the phase distribution would be shaped in two dimensions (for two-dimensional beam steering) by use of two integrated electro-optical grid-array phase shifters.

This work was done by Te-Kao Wu and C. W. Chandler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 295*** *on the TSP Request Card.*
NPO-18969

Interface Provides Standard-Bus Communication

A microprocessor-controlled interface incorporates service-request and direct-memory-access features.

Langley Research Center, Hampton, Virginia

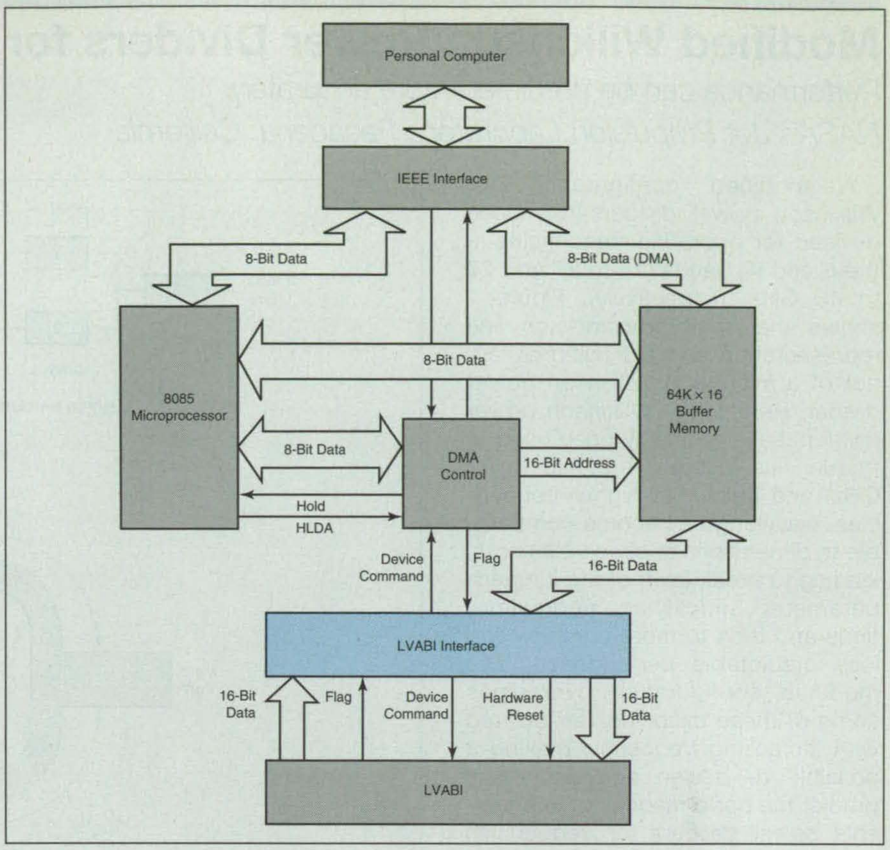
The IEEE-488/LVABI interface is a circuit card that enables digital communication between (1) a system called the "laser auto-covariance buffer interface" (LVABI) and (2) a compatible personal computer via (3) a general-purpose interface bus (GPIB) that conforms to the Institute for Electrical and Electronics Engineers (IEEE) Standard 488, which is an industry standard for digital communications. Thus, the IEEE-488/LVABI interface serves as a second interface that enables the first interface to exploit the advantages of the GPIB, via utility software written specifically for the GPIB. The advantages of the GPIB include compatibility with multitasking and support of communication among multiple computers. GPIB utility software includes language-interfacing libraries and drivers that can ease integration of the IEEE-488/LVABI interface with software developed previously by the user.

The figure shows the relationships among the major functional blocks of a data-communication and -processing system that includes the IEEE-488/LVABI interface, which makes the complete GPIB protocol available to the LVABI. This protocol includes service-request (SRQ) and direct-memory-access (DMA) features for rapid transfers of data. The IEEE-488/LVABI interface contains and is controlled by a microprocessor that is, in turn, controlled by an internal firmware driver that screens all incoming commands before passing them to the LVABI.

The SRQ capability enables the LVABI to signal the personal computer after a data-acquisition cycle. This enables the computer to continue processing instead of polling the LVABI to determine whether the cycle has ended. A DMA control circuit coordinates transfer of data between the LVABI and the computer through a 64K-by-16-bit buffer memory. The IEEE-488/LVABI interface provides DMA transfers in either direction. The transfer includes a conversion from 16 bits parallel to 8 bits parallel when reading from the LVABI.

The basic concept of the IEEE-488/LVABI interface could also be applied in designing interfaces for circuits other than the LVABI for unidirectional or bidirectional handling of parallel data up to 16 bits wide. Adaptations to other circuits would necessitate modifications of the firmware of the IEEE-488/LVABI interface.

This work was done by William G. Culliton of **Langley Research Center**. *For further information,* ***write in 2*** *on the TSP Request Card.* *LAR-15111*



The **IEEE-488/LVABI Interface** enables the LVABI interface to communicate with the personal computer via the GPIB.

Modified Wilkinson Power Dividers for K and K_a Bands

Performance can be predicted more accurately.

NASA's Jet Propulsion Laboratory, Pasadena, California

A modified configuration for Wilkinson power dividers has been devised for operating frequencies in the K and K_a bands (18 to 27 and 27 to 40 GHz, respectively). Figure 1 shows the basic transmission line representation and a traditional layout of a microstrip Wilkinson power divider. Heretofore, Wilkinson power dividers have ordinarily been used at frequencies in the X-band (8 to 12 GHz) and below. At higher frequencies, wavelengths become comparable to dimensions of circuit elements, leading to breakdown of the lumped-parameter simplifying approximations and thus to more complex and less predictable performance. The modified configuration overcomes some of these difficulties associated with increasing frequency, making it possible to design and accurately predict the performances of unequal-split power dividers for frequencies above X-band.

In the idealized Wilkinson power divider, the desired power-split ratio with equal phase is achieved by use of two input branches with electrical lengths of 90° and with their impedances Z_1 and Z_2 chosen to obtain the desired power-split ratio. The lumped resistor, R, provides the required isolation between the output ports. Two output branches, also with electrical lengths of 90°, serve as quarter-wave output transformers; their impedances Z_3 and Z_4 are chosen to match the outputs of the divider to the output port impedance Z_0.

Figure 2 shows a Wilkinson power divider with the modified configuration. The dimensions were chosen for an operating frequency of 30.5 GHz, an output power-split ratio of 2:1, and input and output transmission-line impedance of 50 Ω. This device was fabricated on a 0.381-mm-thick substrate of dielectric constant 3.25 metallized with copper to a thickness of 17.78 µm. In a test at the design frequency, the measured return losses at all three ports exceeded 20 dB, and the isolation between the output ports exceeded 17 dB. A power combiner containing 13 dividers of this type (in which the roles of input and output ports are reversed) was also fabricated to provide equal transmission and equal

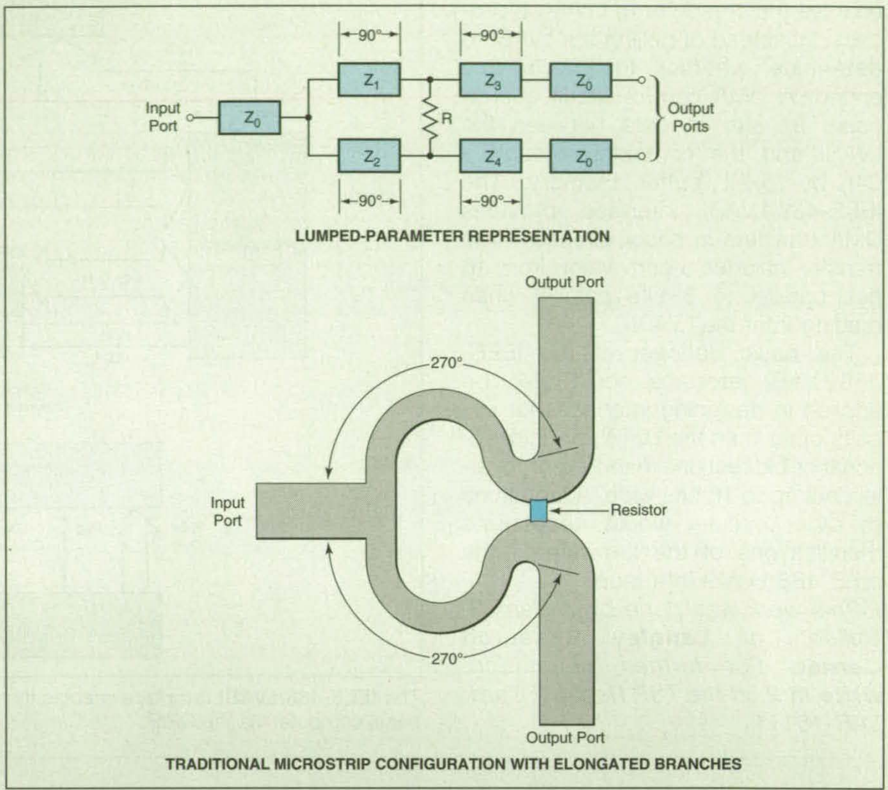


Figure 1. The **Basic Wilkinson Power Divider** provides for matching of input and for two matched, equal-phase outputs with unequal power split and isolation between output ports. Note that in the traditional microstrip configuration, the electrical lengths of the branches are 270° instead of 90°: this is because the 90° segments would be impractically short. The effects of the 270° lengths are equivalent.

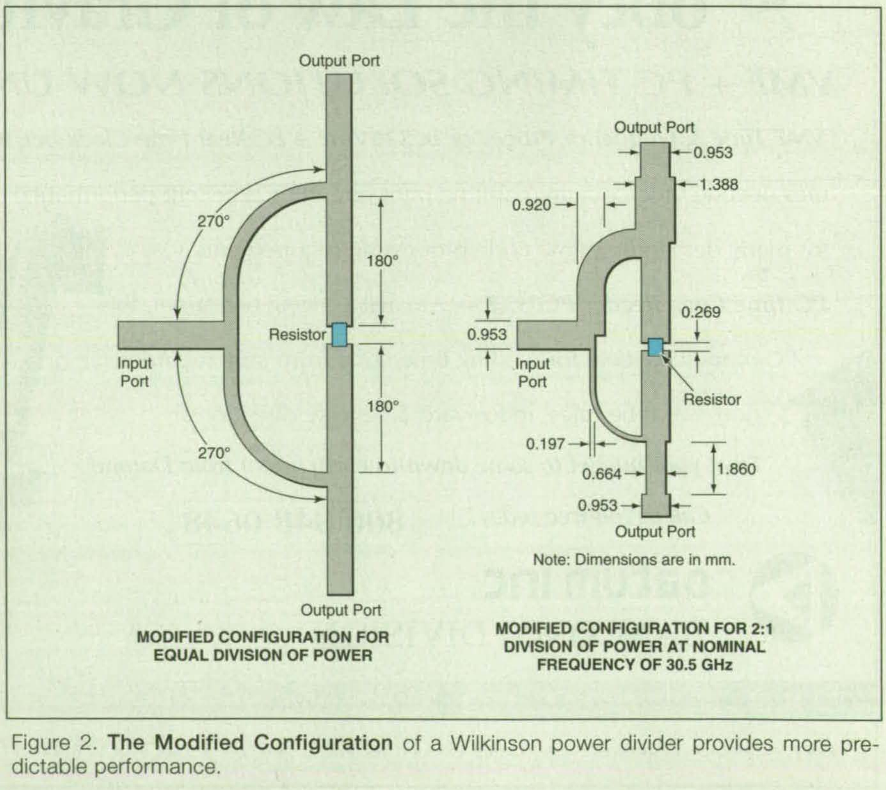


Figure 2. **The Modified Configuration** of a Wilkinson power divider provides more predictable performance.

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Tera One • Yorktown, Virginia 23693 • **Fax** (804) 833-9300 insertion phase from 14 ports to 1 port at frequencies around 20 GHz. The only major disadvantage of the modified configuration is relatively high insertion losses, with typical values ranging from about 1 to about 1.6 dB at each port, the exact value depending on the specific design.

This work was done by Dimitrios Antsos of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 85*** *on the TSP Request Card.*
NPO-19383

Beam-Steering Subsystem for Laser Communication

A simplified design concept calls for fewer optical and mechanical components.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed free-space laser communication system would contain fewer optical and mechanical components than are called for in typical conventional designs based on decade-old technology. The system would involve a novel fast beam-steering subsystem that would stabilize only the angle between the transmitting and receiving beams instead of stabilizing both the transmitting and receiving lines of sight individually as in the older designs.

Each station in the system would include a telescope plus associated optical and mechanical components mounted on a platform. External sensing-and-control equipment would initially turn the platform to aim the telescope approximately toward a beacon laser at the remote station with which communication was to be established. The focal plane of the telescope would contain a charge-coupled-device (CCD) imaging array large enough to provide a field of view wide enough to capture the image of the beacon in the presence of initial aiming error. The pixel resolution of the CCD array would be chosen to be fine enough so that the error in angular position derived from the image on the array would be less than the maximum aiming error allowed during steady operation.

The laser beam transmitted to the remote station would be reflected from a fast-response, two-axis steering mirror on the telescope platform and sent out through the telescope. A beam splitter would reflect a small fraction of the power of the transmitted beam onto the CCD array (see Figure 1). The angular positions of the remote station and the transmitted beam relative to the optical axis of the telescope and relative to each other would be computed from the centroids of the beacon and transmitted-beam images.

If the two stations were moving relative to each other, then it would be necessary to aim the transmitted beam toward the predicted angular position of the remote station corresponding to the predicted time of arrival of the transmitted signal at the remote station. The angle between this predicted angular position and the present line of sight is called the "point-ahead" angle. A microprocessor would compare the actual angle between the received and transmitted laser beams with the point-ahead angle; the difference between these angles would constitute an error (feedback) control signal that would be used to keep the transmitted beam aimed at the point-ahead angle.

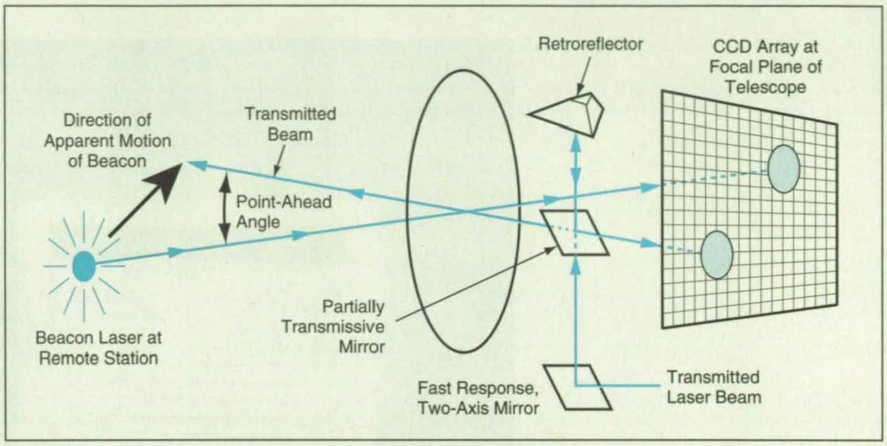


Figure 1. **Received and Transmitted Beams of Light** would both be imaged onto a CCD array at the focal plane. The relative angular positions of these beams would be computed from the centroids of their images.

The beam-steering control loop would be nested (see Figure 2). Part of the feedback control signal would be processed through a compensation filter and fed to the fast-response steering mirror to compensate for small, rapid angular disturbances. Part of the feedback control signal would be processed through a low-pass filter and fed to a gimbal actuator that would turn the platform to compensate for larger, slower angular disturbances, keeping the telescope aimed approximately toward the beacon and keeping the fast-response steering

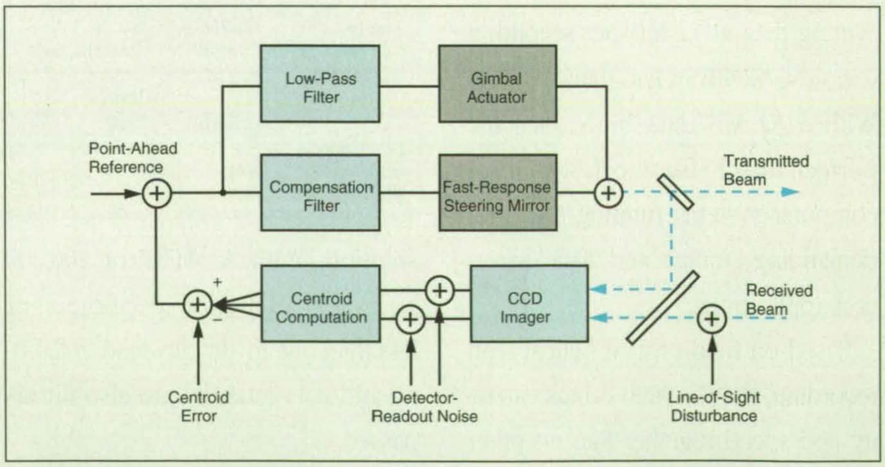


Figure 2. The **Beam-Steering Control Loop** would keep the telescope aimed approximately along the received beam and would precisely maintain the desired point-ahead angle between the transmitted and received beams.

mirror near the middle of its dynamic range. Overall, the beam-steering control subsystem would maintain the direction of the transmitted beam within the allowable error even if the jitter of the platform were several times as large as this error.

This work was done by James R. Lesh, Chien-Chung Chen, and Homayoon Ansari of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 14*** *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 20]. Refer to NPO-19069.

Joint Synchronization of Viterbi and Reed-Solomon Decoders

Synchronization times are reduced to reduce loss of data.

NASA's Jet Propulsion Laboratory, Pasadena, California

A scheme for decoding a received doubly encoded binary-data signal provides for joint synchronization of two decoders. The scheme applies to a concatenated error-correcting channel coding communication system in which, at the transmitter, the data are first encoded by an interleaved Reed-Solomon code (a block code), then by a convolutional code.

In a two-code system of this type, the first code is called the "outer" code, while the second code is called the "inner code." In the receiver, the signal is processed first through a Viterbi decoder, then through a Reed-Solomon decoder. In the traditional approach to decoding, the two decoders are simply concatenated as two distinct stages, with no feedback between them (see Figure 1).

The correct functioning of each decoder depends on appropriate synchronization. In the Viterbi decoder, what is needed is node synchronization, which is the proper grouping of soft symbols (tentative or hypothesized data symbols) that correspond to a single information bit. In the Reed-Solomon decoder, frame synchronization (the detection of transport frames and the extraction of Reed-Solomon words) is needed. In most applications, data received prior to achievement of synchronization are lost.

In cases in which bit signal-to-noise ratios are high, synchronization times are short and therefore losses of data are small and are usually ignored. However, in cases in which signal-to-noise ratios are low, synchronization times can be long, resulting in loss of a significant fraction of all the data. Accordingly, a method of joint synchronization of both decoders was conceived so that, in effect, each decoder can help the other to become synchronized, thereby shortening the overall synchronization time and reducing the loss of data.

A joint-synchronization decoding system (see Figure 2) includes the customary processing units of a non-joint-synchronization decoding system; namely, a symbol buffer, Viterbi decoder, deinterleaver, and Reed-Solomon decoder. However, unlike the traditional system, processing functions are controlled partly by a joint-synchronization function that is implemented via several core synchronization-indicating algorithms. In this system, the three algorithms are a frame-marker correlator in the symbol domain, a frame-marker correlator in the bit domain, and an accumulated-metric-growth-rate indicator. It is worth noting that other synchronization-indicating algorithms could also be integrated into a joint-synchronization decoding system using the methodology below.

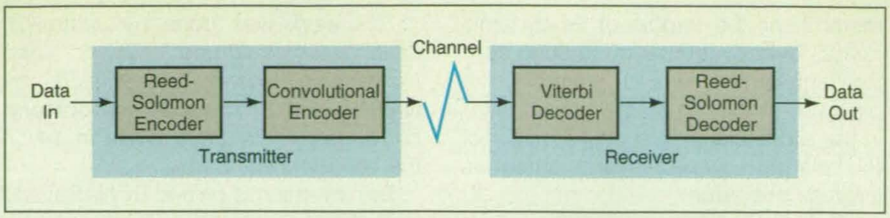


Figure 1. In a **Decoding System Without Joint Synchronization**, the two decoders operate independently of each other.

The frame-marker correlator in the bit domain computes a running correlation between the frame-marker pattern of bits and the actual pattern of bits at the output of the Viterbi decoder. When the correlation rises from near zero to the value that indicates that the frame-marker pattern is detected, the node-synchronization hypothesis is deemed to be true and, by definition, frame synchronization has been achieved.

The frame-marker correlator in the symbol domain computes a running correlation between (a) the soft symbols prior to processing in the Viterbi decoder and (b) the n-tuplet of soft symbols that corresponds to the encoded version of the frame-marker pattern. When the correlation rises to a value that indicates that the frame-marker pattern has been detected, it provides both frame and node synchronization prior to any decoding operation. The main disadvantage of this algorithm is that correlation can be computed over only part of the frame marker: For a frame marker of N bits and convolutional code of length K, only the symbols that correspond to the last N-(K+1) bits are known in the symbol domain. The symbols that correspond to the first K-1 bits of the frame marker are corrupted by the unknown previous contents of the encoder. Depending on N, K, and the bit signal-to-noise ratio, the partial correlation may degrade the correlation signal-to-noise ratio sufficiently to make synchronization difficult.

The accumulated-metric-growth-rate indicator examines the accumulated metric at all the Viterbi decoder states, computing a measure of the mismatch between the received stream of soft symbols and the stream of bits associated with each specific state. Even though the accumulated metric varies from state to state, its peak-to-peak variation is bounded by (constraint length -1) x (maximum branch metric). Because of this bound, it is common practice to monitor the rate of growth of a single selected accumulated metric for which, at high bit signal-to-noise ratio, there is a clear distinction between in-node synchronization and out-of-node synchronization. The distinc-

Multiple Pages Intentionally Left Blank

tion between these two synchronization conditions becomes more blurry as the bit signal-to-noise ratio decreases; the thresholds for detecting the in-lock and out-of-lock hypotheses must be chosen carefully to satisfy probability-of-detection and false-alarm requirements. Unfortunately, thresholds must be selected empirically, because measurement of the rate of growth does not lend itself to analytic expressions.

This work was done by Joseph I. Statman, Todd H. Chauvin, Kar-Ming Cheung, Jay Rabkin, and Mignon L. Belongie of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 63*** *on the TSP Request Card.*
NPO-19313

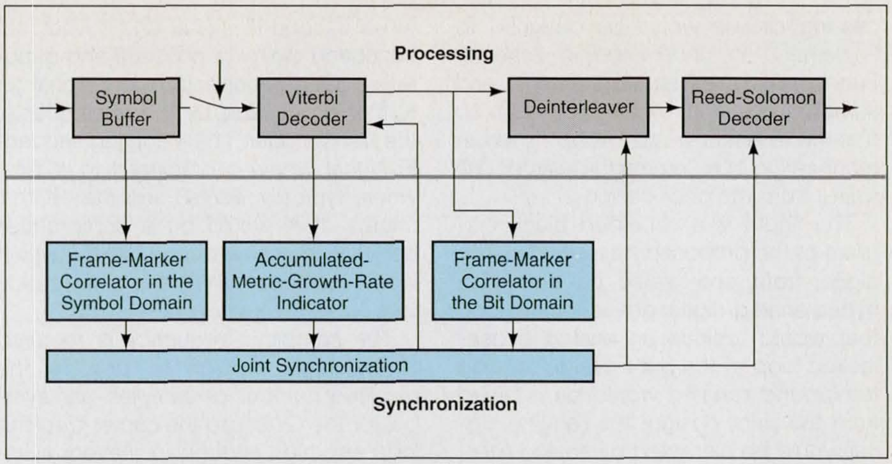


Figure 2. In a **Decoding System With Joint Synchronization,** feedback between the two decoders takes place in the joint synchronization subsystem.

Digital Baseband Architecture for Transponder

A proposed undersampling scheme would help conserve power.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed advanced transponder for a long-distance radio communication system with turnaround ranging would contain a carrier-signal-tracking loop that would include a baseband digital "front end." The baseline conceptual design of the proposed transponder is derived partly from a prior design. For reduced cost, the transponder would include an analog intermediate-frequency (IF) section and an analog automatic gain control (AGC) loop at the first of two IF mixers, as in the prior design. However, the second IF mixer would be redesigned to ease the digitization of baseband functions. To conserve power and provide for simpler and smaller transponder hardware, the baseband digital signal-processing circuits would be designed to implement an undersampling scheme. Furthermore, the sampling scheme and sampling frequency would be chosen so that the redesign would involve minimum modification of a command-detector unit (CDU) from the prior design.

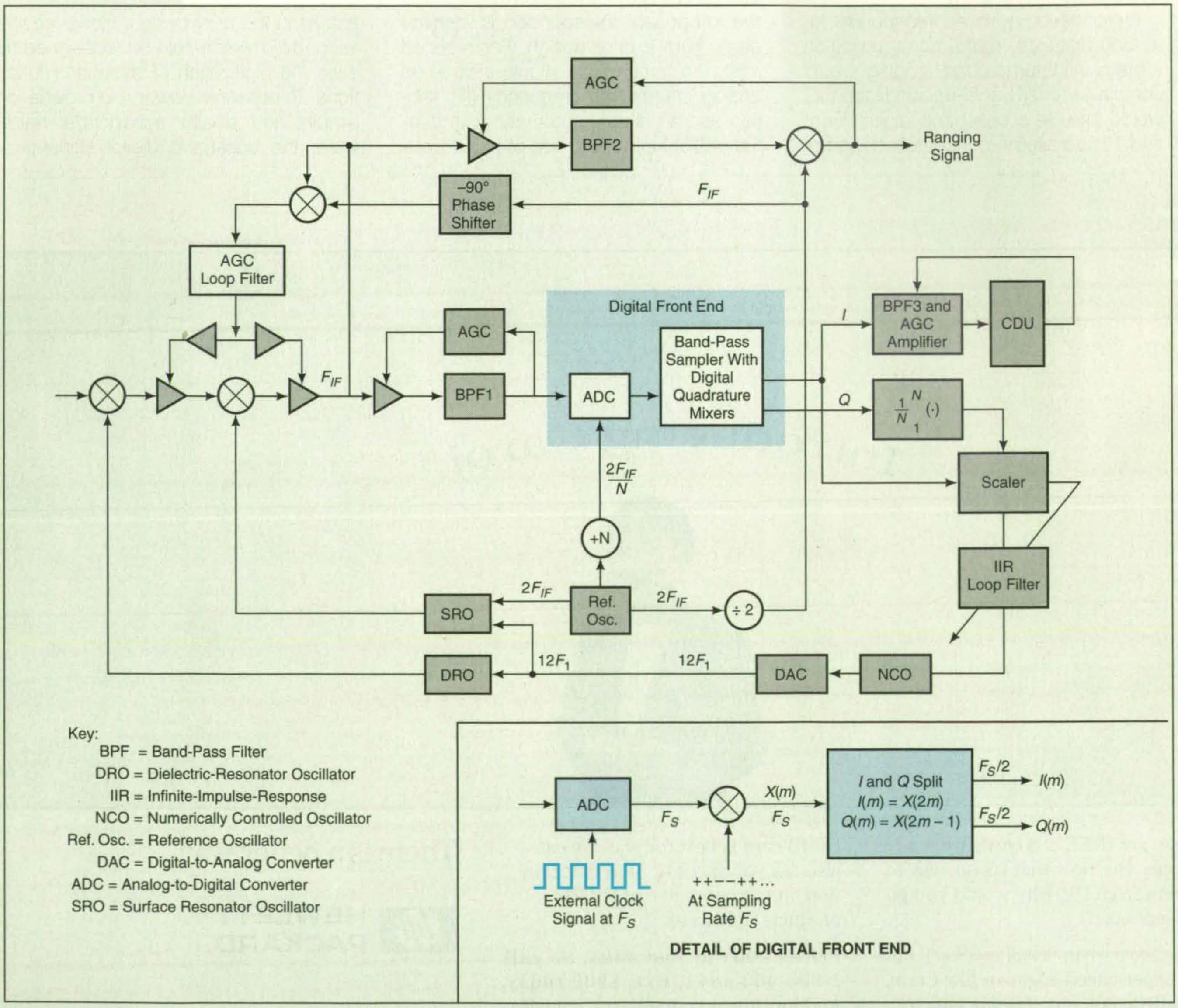
The figure is a simplified block diagram of the proposed transponder. The digital front end would be part of a hybrid analog/digital phase-locked loop that would replace an analog phase-locked loop of the prior design. Analog turnaround ranging would be retained from the prior design; the ranging signal would be extracted by analog filtering, then retransmitted without further processing.

The digital front end would include an analog-to-digital converter (ADC) followed by a band-pass sampler with digital quadrature mixers. The overall function of the digital front end would be to accept the analog band-pass-filtered second-IF signal and to put out baseband digital in-phase (I) and quadrature (Q) components of the signal for further processing by the remainder of the transponder. The incoming second-IF signal would be digitized to K bits, where typically, $4 \leq K \leq 8$ and the optimal choice of K would be a compromise between power and complexity (which would increase with K) and quantization loss (which would decrease with K).

The sampling frequency is required to be high enough to provide the required number of samples per symbol for the CDU and the carrier-tracking loop and high enough to prevent aliasing of the baseband signal with the image signals that occur at the sampling frequency, yet low enough to keep the cost of the ADC acceptably low. These competing requirements would be satisfied by a sampling frequency of $F_S = 4F_{IF}/(4n+1)$, where F_{IF} is the second IF, n is an integer that satisfies $n \leq F_{IF}/2BW - 1/4$, and BW is the bandwidth of the band-pass-filtered second-IF signal.

The I&Q sampling configuration illustrated schematically in the lower part of the figure would be a simplified configuration in which only one mixer (instead of separate I and Q mixers) would be used and the output of the mixer would consist of alternating I and Q samples. Ordinarily, when $n = 0$, it would be necessary to choose $F_S = 4F_{IF}$ to make it possible to utilize this configuration. However, when $n > 0$, F_S as given by the equation above would be less than $4F_{IF}$; that is why the proposed sampling scheme is characterized as an undersampling scheme.

This work was done by Tien M. Nguyen and Hen-Geul Yeh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 83*** *on the TSP Request Card.* *NPO-19330*



The **Digital Front End** would be designed with optimal choice of N and F_S to simplify the hardware and reduce the power consumption.

Improved Capacitive Liquid-Level Probe

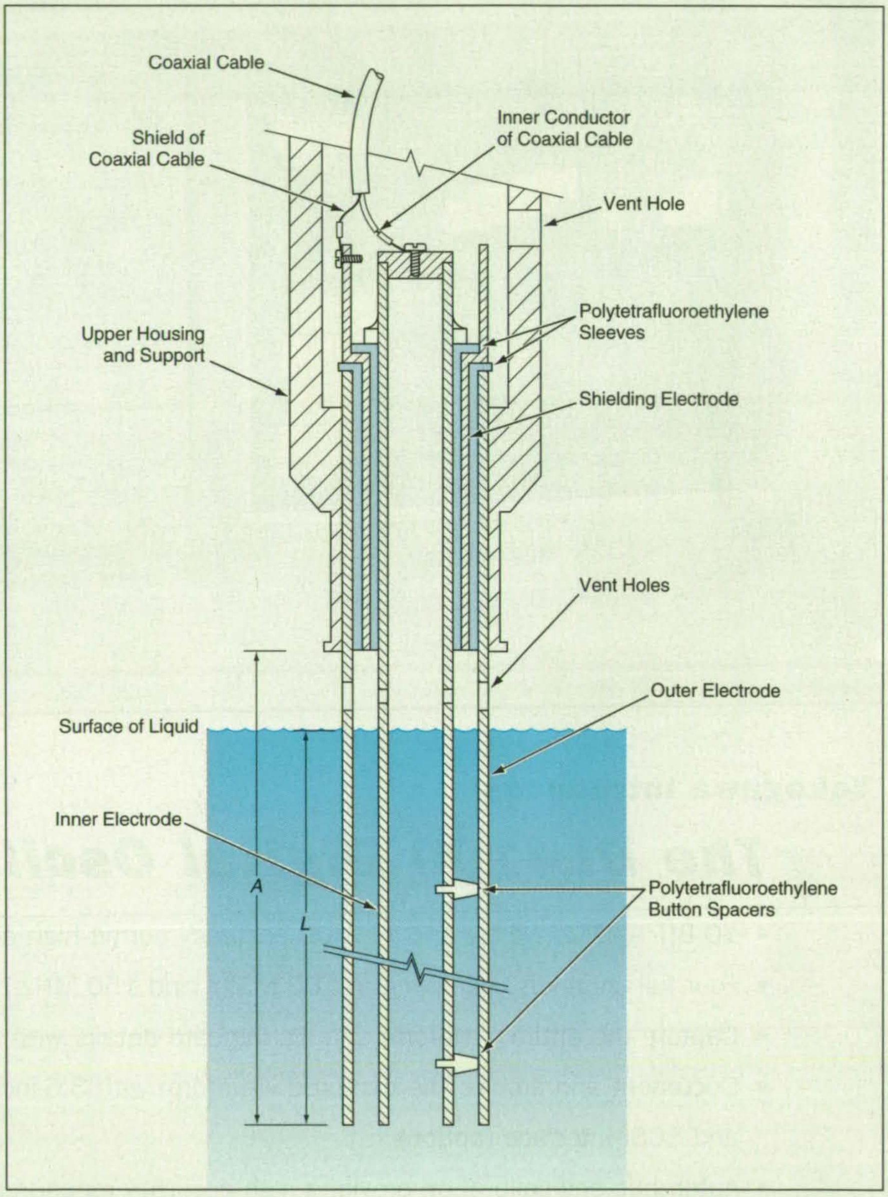
Spurious capacitive effects are reduced by careful design.

Lewis Research Center, Cleveland, Ohio

An improved capacitive probe was designed to measure the level of a dielectric liquid in a tank. In the original application, the liquid is hydrogen at low temperature, but the design principles are applicable to measurement of the levels of other dielectric liquids in various temperature ranges. The outstanding features of the design are those that make the probe insensitive to temperature-induced and other spurious capacitive effects that could otherwise distort the capacitive liquid-level readings, and those that make it possible to calibrate the probe mostly by calculation from first principles.

These features are achieved by careful attention to design details. The probe (see figure) includes two coaxial sensing electrodes and an intermediate shielding electrode held in alignment by polytetrafluoroethylene sleeves at the upper end. The shielding electrode extends only the length of the mounting hardware at the upper end. Polytetrafluoroethylene button spacers maintain the alignment between the sensing electrodes along the remainder of the length.

In operation, the outer electrode is grounded, while the inner electrode is driven by a capacitance-measurement voltage at a suitable measuring frequency (e.g., 2 kHz). The electronic measurement circuitry is located elsewhere in a safe environment and connected to the inner and shielding electrodes via a coaxial cable. Exploiting the driven-shield principle, the shielding electrode is excited at the same voltage as that applied to the central electrode: this eliminates the contribution of the upper mounting-hardware length to the measured capacitance and establishes a sharply defined upper boundary on the sensing length. It also eliminates the effect of the coaxial cable on the measured capacitance. In so doing, it eliminates the effect of the temperature dependence of the permittivity of the polytetrafluoroethylene sleeves and of the dielectric material in the coaxial cable. It does not eliminate the temperature-dependent effect of the polytetrafluoroethylene button spacers, but these spacers are so small that their effect on the measured capacitance is negligibly small in any event.



The **Shielding Electrode** is operated according to the driven-shield concept to eliminate spurious capacitive effects.

With the major spurious contributions to capacitance and temperature dependence of capacitance thus eliminated, the only factors that affect the measured capacitance significantly are the geometry of the electrodes, the level of the liquid, and the permittivities of the liquid and vapor. Neglecting the fringing effect at the open lower end of the sensing electrodes, the basic theory of electrostatics yields the following equation for the capacitance, C, between the coaxial sensing electrodes:

$C = [L\varepsilon_l + (A - L)\varepsilon_v]2\pi\varepsilon_0/\ln(D_2/D_1)$ where

L and *A* are lengths, as indicated in the figure; D_2 and D_1 are the inner diameter of the outer electrode and the outer diameter of the inner electrode, respectively; ε_l is the relative permittivity of the liquid; ε_v is the relative permittivity of the vapor; and ε_0 is the permittivity of the vacuum.

The basic calibration equation is obtained by inverting the foregoing equation to obtain the depth of immersion, *L*, of the electrodes as a function of the measured value of *C*. The calibration remains accurate to the extent to which the lengths and diameters of the electrodes and the permittivities remain accurate. The only calibration measurement and adjustment that one needs to perform is an initial zero-level ($L = 0$) reading and adjustment.

This work was done by Robert A. Ziemke of **Lewis Research Center**. *For further information,* ***write in 23*** *on the TSP Request Card.*
LEW-15560

Improved Piezoelectric Loudspeakers and Transducers

Features include efficiency and simplicity.

Langley Research Center, Hampton, Virginia

Loudspeakers and related acoustic transducers of an improved type feature both (1) the light weight and energy efficiency of piezoelectric transducers and (2) mechanical coupling efficiency approaching that of much heavier, less energy efficient electromagnetic loudspeakers. The active component of a transducer of this type is made from a wafer of "rainbow" piezoelectric material, which is ceramic piezoelectric material that has been chemically reduced on one face. The chemical treatment forms the wafer into a dishlike shallow section of a sphere. Both faces are then coated with electrically conductive surface layers that serve as electrodes.

The application of a varying electric potential to the wafer via the electrodes produces a curvature change; depend-

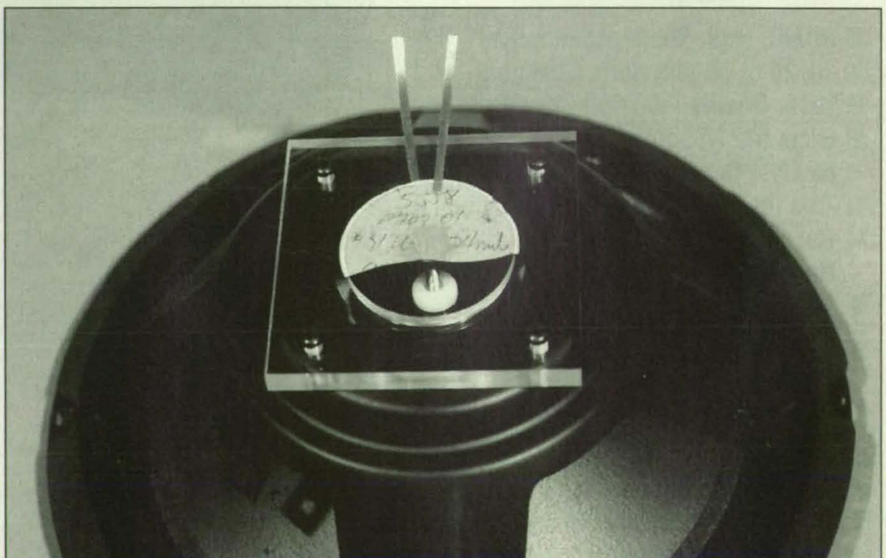


Figure 1. A **Piezoelectric Transducer of the Improved Type** described in the text is installed in a conventional loudspeaker in place of the original electromagnetic transducer. A section of the piezoelectric transducer has been removed to show the mechanical interface between the transducer and the speaker cone.

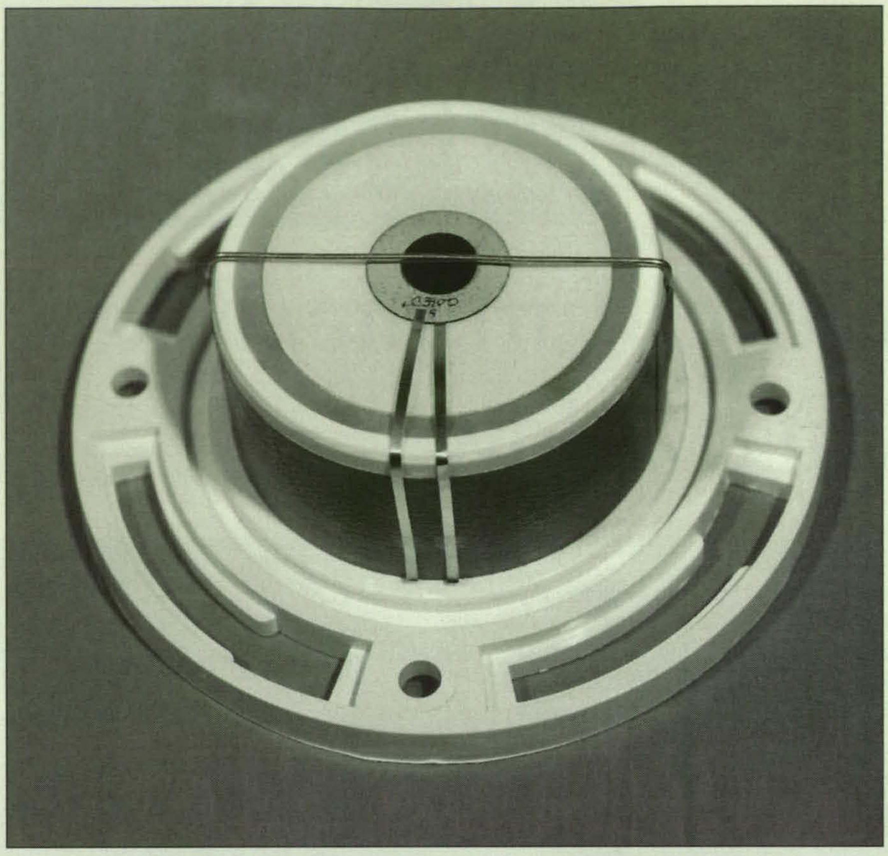


Figure 2. A **Planar-Diaphragm Loudspeaker** has been developed that utilizes the "rainbow" piezoelectric transducer as a diaphragm actuator.

ing on the polarity of the electric field, the wafer becomes flatter or more curved. If, for example, the outer edge of the wafer is attached to a rigid support, the wafer can transmit vibrations directly into the surrounding gas or liquid. The frequency response of piezoelectric wafers of this type covers the range from dc to 100 kHz. However, to effectively transmit vibrations through a medium at the low to mid-range portion of the audio frequency band, the wafer is coupled to a planar-type diaphragm or to the cone of a conventional loudspeaker.

A low to mid-range audio frequency driver has been developed that utilizes the "rainbow" wafer as a diaphragm actuator replacing the voice coil and permanent magnet found in a conventional loudspeaker. By applying a fixed amount of mechanical bias or prestress to the driver diaphragm and mounting the "rainbow" wafer in such a fashion that its motion – as it becomes more flat or more curved with electrical stimulus – adds or subtracts a varying amount of mechanical bias from the fixed portion of diaphragm bias, movement of the driver diaphragm is produced in direct proportion to the audio voltage applied to the wafer, thereby giving accurate reproduction of sound.

The "rainbow" wafer is well suited for this application since it is capable of providing 10 to 100 times the output mechanical motion of similar devices made from conventional piezoelectric materials; unlike some conventional piezoelectric transducers, these produce adequate output motions without the need for mechanical leverage devices to amplify the motions to acceptable levels. In selecting a wafer for use as a diaphragm actuator, the chemical composition, thickness, size, stiffness, and mass are considered for optimum transformation of the varying electrical potential to diaphragm motion. Important applications foreseen for these improved piezoelectric drivers include high-fidelity loudspeakers, and underwater echo ranging devices.

This work was done by Curtis Randall Regan, Antony Jalink, Richard F. Hellbaum, and Wayne W. Rohrbach of **Langley Research Center.** *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15138.

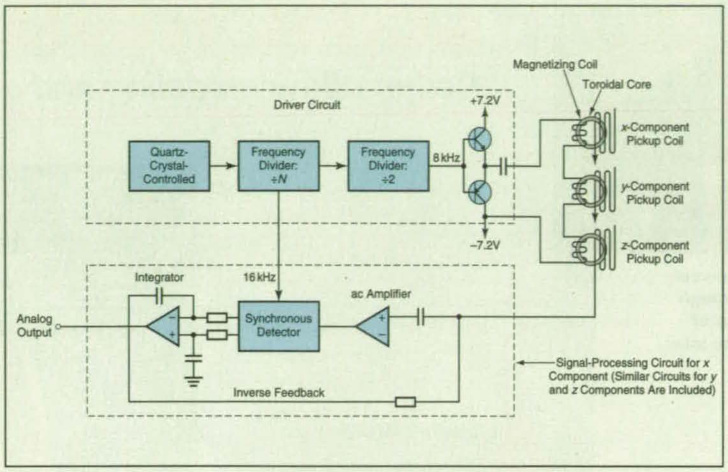
Small Magnetometer

Small toroidal cores are used.

NASA's Jet Propulsion Laboratory, Pasadena, California

A small, lightweight, low-power magnetometer measures the three-dimensional magnetic field. The magnetometer includes three toroidal cores — one for each dimension. The cores are made of a nickel/molybdenum/iron alloy and have a diameter of 0.625 in. (15.9 mm). They exhibit high sensitivity, low zero-point drift, and low noise. A magnetizing coil is wound on each core. A flat rectangular pick-up coil of enamel-coated copper wire is wound on a thin-walled machinable glass ceramic form that surrounds each core and is oriented with the axis of the pickup coil along the direction of the magnetic-field component to be measured by that coil. The three cores and associated coils are mounted 22 mm apart, with measurement axes orthogonal to each other.

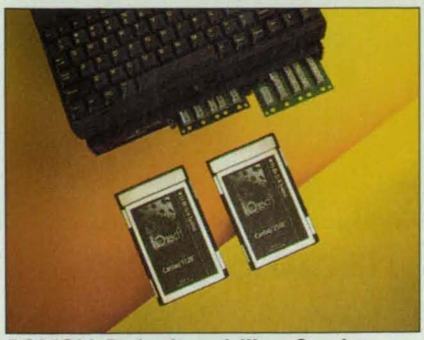
This magnetometer operates similarly to a conventional flux-gate magnetometer. A driver circuit supplies current to all three magnetizing coils in series, magnetizing the cores to saturation at alternating polarities at a frequency of 8 kHz (see figure). The outputs of the pickup coils are synchronously detected at twice the driving frequency for the following reason: In the absence of an external magnetic field, the outputs of the pickup coils consist only of odd harmonics of the driving frequency, whereas even harmonics also appear when an external magnetic field is present. Thus, those components of the pickup-coil outputs that are detected at twice the driving frequency are approximately proportional to the corresponding components of the external magnetic field. The proportionality is improved considerably; that is, the response is rendered more nearly linear, by use of feedback.



The **Magnetometer Circuit** includes a driver circuit and three analog signal-processing circuits (though only one is shown here). The output of the analog signal-processing circuit is proportional to one of the components (x, y, or z) of the external magnetic field.

This work was done by Falko Kuhnke, Gunter Musmann, and K. H. Glassmeier of Technische Universität Braunschweig, and Bruce Tsurutani of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 82*** *on the TSP Request Card.*

NPO-19283



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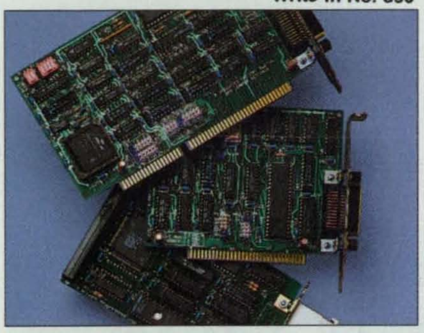

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Pseudocoherent Demodulation of DPSK Radio Signals

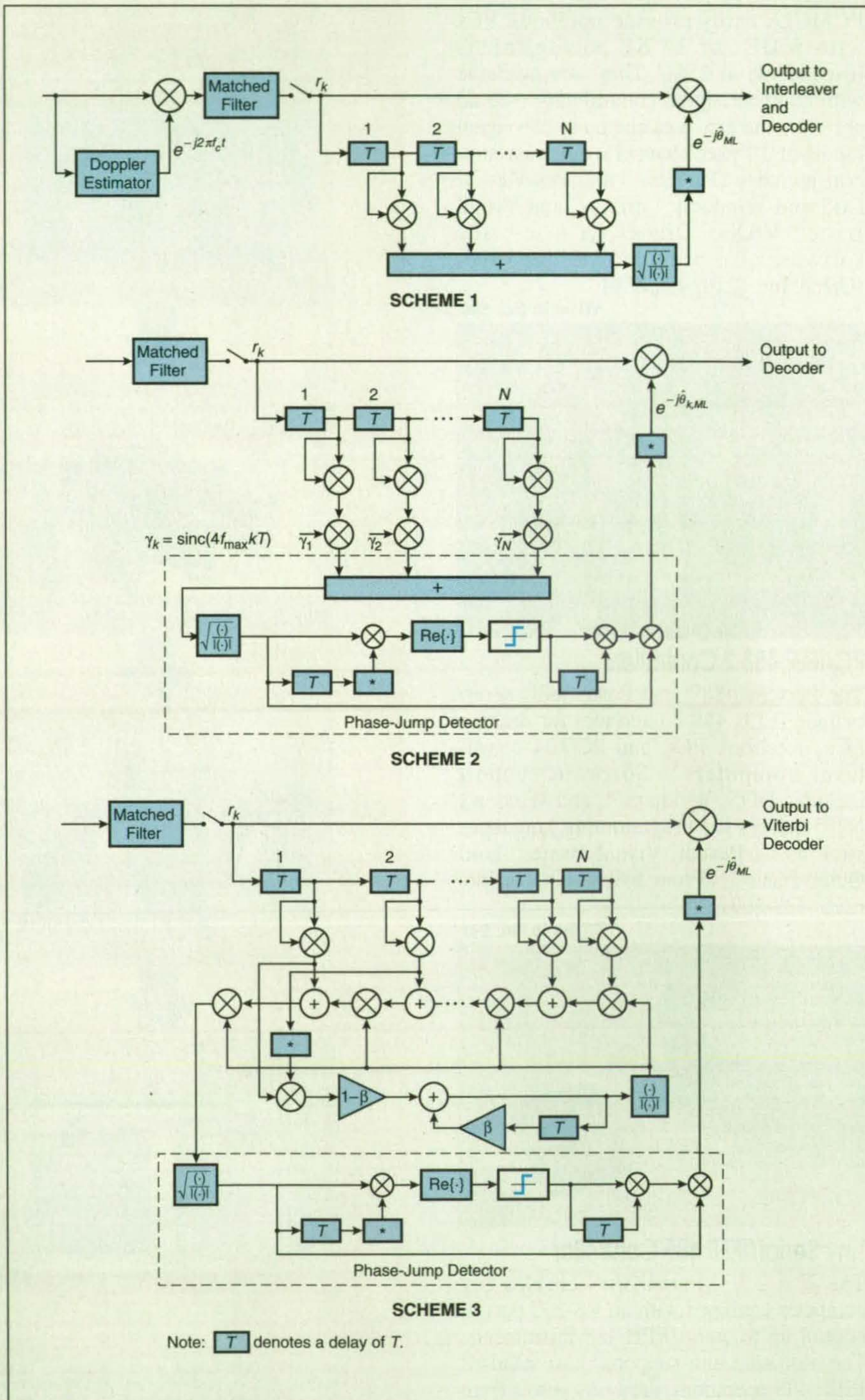
Three demodulation schemes have been proposed for land-mobile/satellite communications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three schemes for pseudocoherent demodulation of differential-phase-shift keyed (DPSK) radio signals have been proposed for use in land-mobile/satellite communications. Changing shadowing by buildings, vegetation, and terrain causes frequent and severe fading of signals, giving rise to a need for fast reacquisition of (that is, fast recovery of synchronization with) the signals. In the absence of a midband pilot signal, coherent demodulation is not an appropriate choice for fast reacquisition in the fading environment. The proposed pseudocoherent demodulation would enable fast reacquisition. It would also amount to a compromise between the two extremes of (a) coherent demodulation and (b) differentially coherent demodulation, for which the bit-error rates are greater than those of coherent demodulation by amounts that correspond to a difference of about 1 dB in the bit-energy/noise-energy ratio.

The proposed schemes (see figure) are based on maximum-likelihood estimation and detection during N-symbol observation periods, where N is an integer that is typically chosen between 5 and 15. The first scheme could be used if there were an external frequency estimator with very small frequency error variance. This scheme is based on maximum-likelihood estimation of carrier phase, assuming that the unknown frequency offset is perfectly compensated by the frequency estimator prior to the phase-estimation process.

The second scheme could be used if the frequency offset were small or if the receiver were equipped with an external frequency estimator. This scheme is based on direct maximum-likelihood estimation of a time-varying phase caused by the presence of the frequency offset. Because of the time-varying phase and the structure of the maximum-likelihood estimator, the demodulator is equipped with a 180°-phase-jump detector to resolve the periodic 180° phase ambiguities. Without the phase-jump detector, the differential decoder would fail at the end of each 180°-phase-jump period. The phase-



These **Schemes for Pseudocoherent Demodulation of DPSK Signals** are based on maximum-likelihood estimation in an observation period NT, where N denotes an integer (usually between 5 and 15) and T denotes one symbol period.

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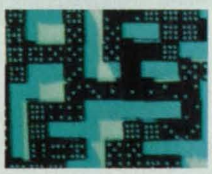

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jump detector would compare the present and the previous phase estimates for detection.

The third scheme could be used if the frequency offset were large and no external frequency estimator were used. This scheme involves a hybrid of a simple open-loop frequency estimator and a circuit that generates the maximum-likelihood estimate of carrier phase conditioned on perfect knowledge of the frequency offset. Because of the time-varying phase, this scheme also requires a 180°-phase-jump detector to resolve the periodic 180° phase ambiguities.

This work was done by Dariush Divsalar and Marvin K. Simon of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 44*** *on the TSP Request Card.*
NPO-19205

N-Consecutive-Phase Encoder

This encoder would enable the use of a binary preencoder of higher rate.

NASA's Jet Propulsion Laboratory, Pasadena, California

The *N*-consecutive-phase encoder (NCPE) is a conceptual encoder for generating an alphabet of *N* consecutive full-response continuous-phase-modulation (CPM) signals. The NCPE would enable the use of a binary preencoder of higher rate than can be used with a simple continuous-phase encoder (CPE). The NCPE would make it possible to achieve power efficiencies and bandwidth efficiencies greater than those of conventional trellis coders with continuous-phase frequency-shift keying (CPFSK).

The NCPE involves a representation of CPM signals in multiple time slots by

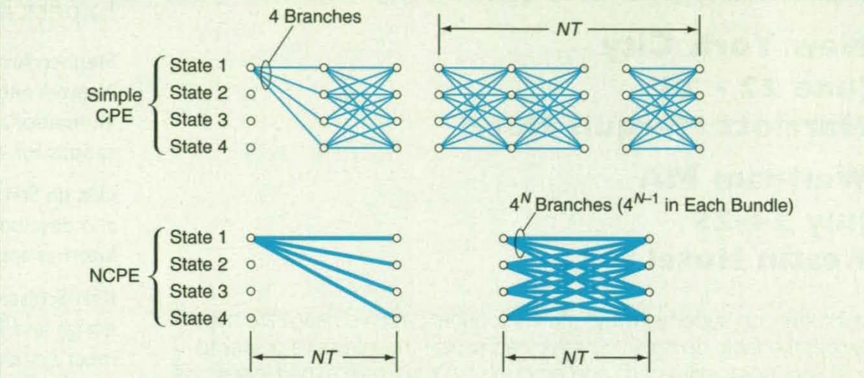


Figure 1. These **Trellis Diagrams** illustrate the relationships between simple CPE and NCPE for $M = 4$.

use of parallel transitions of the trellis code structure and of memoryless mapping. The point of departure for the theoretical development of the NCPE is recognition of the fact that a system that generates a CPM waveform can be decomposed into a time-invariant CPE and a time-invariant memoryless modulator (MM). This decomposition of CPM makes it possible to consider the CPE and the MM separately. The NCPE would operate in conjunction with an MM.

In a simple CPE, one signal from an alphabet of 2^q signals is used to transmit q-1 bits per time interval with a trellis-coded-modulation (TCM) scheme of rate $(q-1)/q$. In the NCPE, one signal from an alphabet of 2^{Nq} (which takes N time intervals) would be used to transmit Nq-1 bits every N time intervals with a TCM scheme of rate $(Nq-1)/Nq$, i.e., the NCPE makes it possible to design a binary preencoder with a rate higher than that of a simple CPE. Specifically, instead of adding one redundant bit every time slot of the CPM system, one redundant bit would be added every N time slots.

One special case of the generic NCPE is that of a trellis encoder for two consecutive quaternary (M = 4) CPSK signals. The top part of Figure 1 shows the state trellis structure of the CPE for the case of full-response CPM of modulation index $1/M$, where $M = 4$. By combining N time slots together, one can make the state trellis structure for an arbitrary window of duration NT (where T = the symbol period) for M = 4. This trellis structure, shown in the bottom part of Figure 1, can be implemented by the NCPE.

There are M^N branches leaving each state; these branches can be viewed as M bundles (which are represented by bold lines in the bottom part of Figure 1) and each bundle contains MN-1 branches, so that each bundle represents M^{N-1} parallel transitions. Each branch specifies an N-consecutive CPM signal of duration NT. Therefore, each branch in the bottom part of Figure 1 can be represented by an $(N+1)$-dimensional vector, the elements of which are from the set, $\{0,1,2,3,...,M-1\}$.

In a theoretical design study, the case was specialized further to N = 2 and by use of a set-partitioning technique, a conceptual preencoder for two-state, trellis-coded, 4-CPFSK with a coding rate of 3/4 was designed. Figure 2 shows some results of a numerical simulation and an asymptotic analysis of performance of a conceptual system that contains the conceptual encoder, in comparison with the corresponding results for an uncoded conceptual 4-CPSK system. These results show that the performance with coding can be expected to exceed that without coding by the equivalent of several dB in the bit signal-to-noise ratio.

This work was done by Dariush Divsalar of Caltech and Ho-Kyoung Lee and Charles Weber of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 80*** *on the TSP Request Card.*

NPO-19181

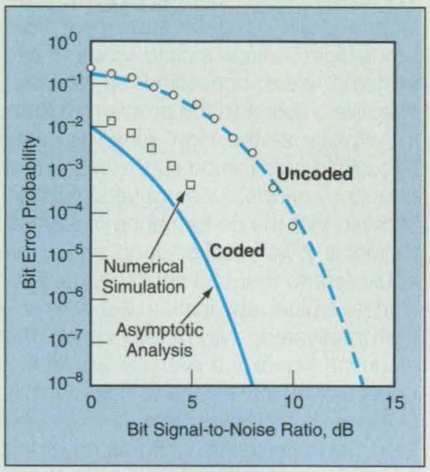


Figure 2. **Bit-Error Performances** of a system with and a system without the NCPE coding scheme were computed theoretically.

Parallel Digital Phase-Locked Loops

Each of M filters would process $1/M$ of the spectrum of a signal.

NASA's Jet Propulsion Laboratory, Pasadena, California

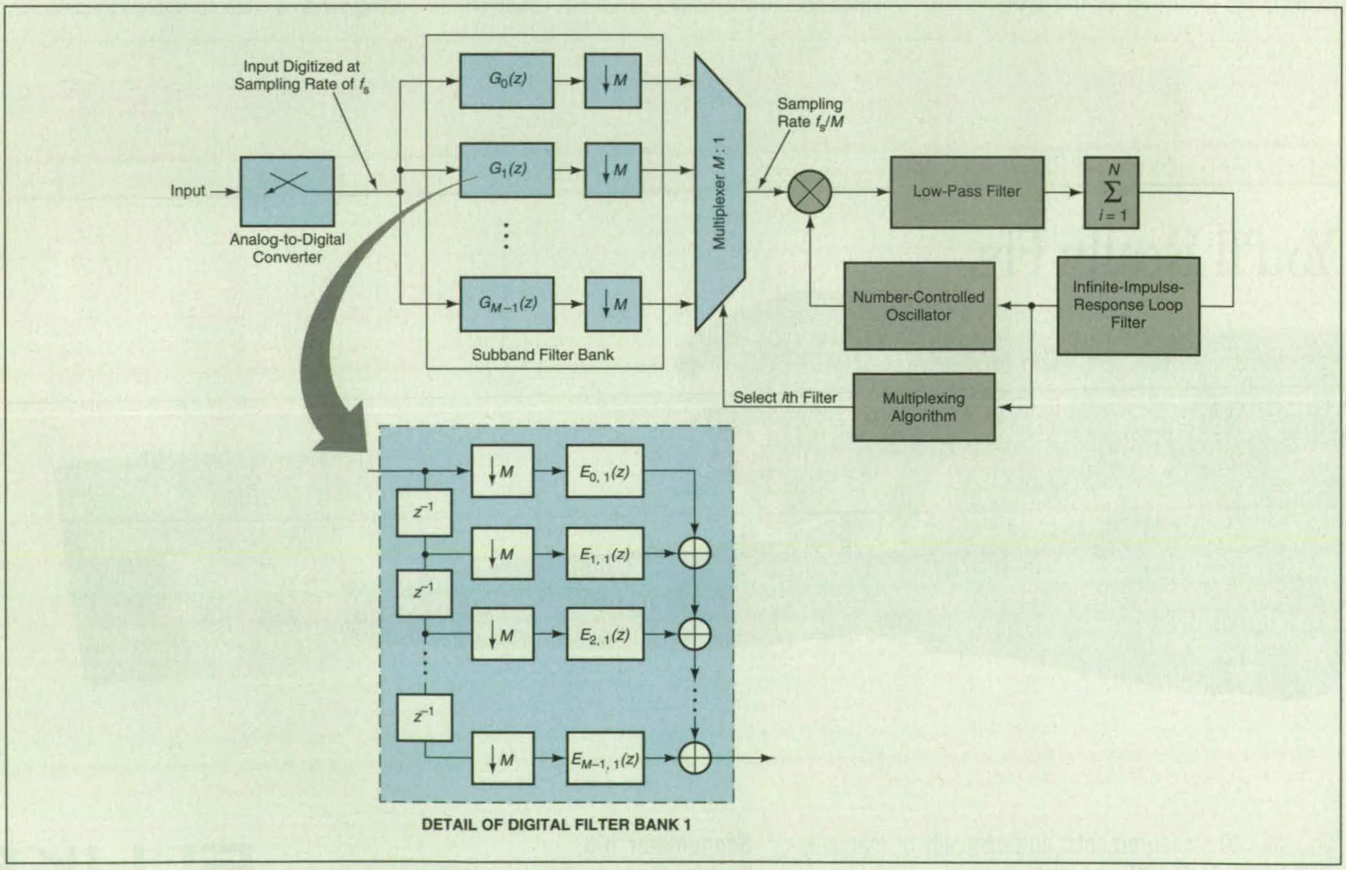
Wide-band microwave receivers of a proposed type would include digital phase-locked loops in which band-pass filtering and down-conversion of the input signals would be implemented by banks of multirate digital filters operating in parallel. Called "parallel digital phase-locked loops" to distinguish them from other digital phase-locked loops, these systems were conceived as a cost-effective solution to the problem of filtering signals at the high sampling rates needed to accommodate the wide input frequency bands. A computer simulation showed that the performance of a parallel digital phase-locked loop would be equivalent to that of a conventional one.

In a typical application like the one that motivated this development, the incoming signal is a sinusoid with a frequency of tens of gigahertz. The signal is Doppler-shifted such that it might be found anywhere within a frequency band 500 MHz wide. The Nyquist sampling criterion therefore requires a sampling rate of at least 1 GHz for tracking the phase and frequency of the Doppler-shifted signal. Although advances in digital integrated circuitry have made it possible to sample at such a high rate, it is still not cost effective to perform filtering at rates above 100 MHz.

A system of the proposed type would circumvent this obstacle, making it possible to use digital signal-processing circuitry that operates at clock speeds of 75 MHz or less. It would do this by effectively dividing the spectrum of the incoming sampled, digitized signal into M parts, each of which would be processed by digital filtering circuits at $1/M$ x the full sampling rate. For example, in the original application, M could be 20, so that each digital filter would operate at a clock speed of 50 MHz.

In the proposed filtering scheme, the sampled, digitized signal would be fed to a bank of M subband digital filters, each of which would, itself, be a subbank containing M stages of filtering and of decimation by a factor of M (see figure). The outputs of the parallel digital filters would be fed to the digital phase-locked loop via a multiplexer. Inasmuch as the input signal would be a continuous-wave tone, it would occupy only one filter at any given time; therefore, only the output of that filter would have to be processed by the digital phase-locked loop. Accordingly, the multiplexer would operate under control of an algorithm that would select the applicable filter on the basis of the estimated Doppler frequency shift, the estimated frequency of the sampled, digitized input signal, and the frequency of the number-controlled oscillator in the digital phase-locked loop.

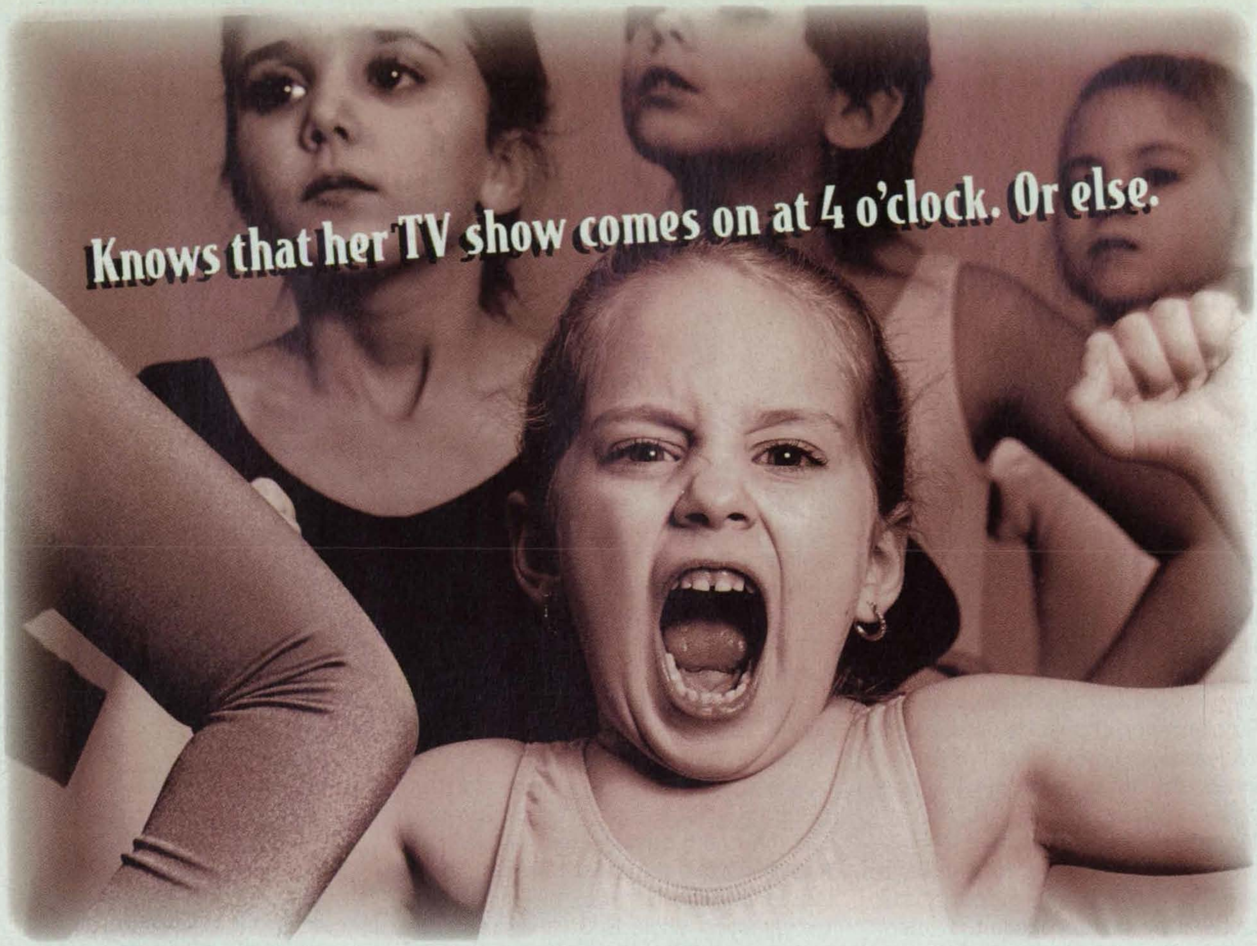
This work was done by Ramin Sadr, Biren N. Shah, and Sami M. Hinedi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 84*** *on the TSP Request Card.* *NPO-19044*

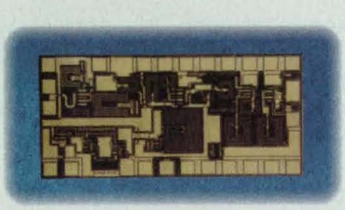


In a **Bank of M Parallel Digital Filters**, each filter would operate at $1/M$ x the sampling rate of the input signal. In this figure,

$$G_i(z) = \sum_{k=0}^{M-1} E_{k,i} z^{M-k}$$

denotes the z-transform response function of the filter for the ith subband, and "$\downarrow M$" signifies decimation by a factor of M.





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Frequency-Channelized SAR Processing for Multiple Angle Looks

This technique has yielded data on the directionality of radar back scatter from agricultural fields.

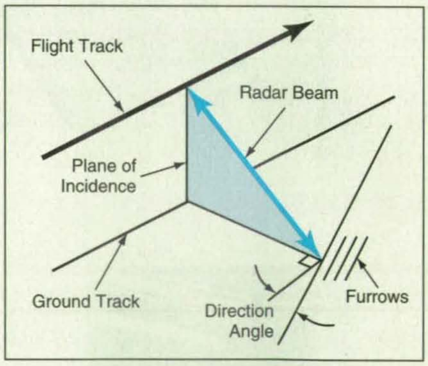
NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for processing synthetic-aperture-radar (SAR) signals exploits the fact that the center frequency of the frequency channel of the data being processed is linked directly to the squint angle and, thus, to the azimuth angle. The technique also exploits the fact that in multilook SAR data processing, the total bandwidth of each SAR polarization channel is divided into N (typically, $N = 16$) equal frequency channels, the data in each of which are processed separately.

Heretofore, the results of such frequency-channelized processing have not been saved as output data because they have constituted intermediate data products. However, in the present technique, the results from the N channels are regarded as N coregistered but otherwise independent sets of data, each constituting a picture of the SAR backscatter at a unique squint angle. The juxtaposition of data from the N channels can thus be used to study the radar backscatter from the scene as viewed from different azimuth angles or, equivalently, from different positions along the ground track of the SAR aircraft.

In the original application for which this technique was devised, it was used to study the variation in the radar-backscatter cross section of agricultural fields as a function of direction angles. As shown in the figure, the direction angle is defined as the angle between the furrows in a field and the plane of incidence of the radar beam. The maximum backscatter is expected to occur when the radar beam is looking across the furrows; that is, when the direction angle is 0°; this effect is called the Cardinal effect. When the present technique was applied to SAR data from agricultural fields in La Mancha, Spain, the Cardinal effect was indeed observed, although the variation with direction angle was even stronger than predicted, especially near 5°. It has been conjectured that Bragg resonance, which was not included in the mathematical model used previously to compute the Cardinal effect, could be the main cause of the stronger observed angular dependence.

This work was done by Pascale C. Dubois, Eric J. Rignot, and Jacob J. van Zyl of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 26*** *on the TSP Request Card.*
NPO-18899



The **Direction Angle** affects the radar-backscattering cross section.

Enhanced Boiling-Metal Cooling of Vanes Exposed to Hot Gases

A self-powered jet pump would increase circulation of coolant.

Marshall Space Flight Center, Alabama

Incorporation of automatic, self-powered jet pumps has been proposed to enhance boiling-liquid-metal cooling of vanes exposed to hot gases, according to a proposal. In the original intended application, the vanes and probes would be thrust-vector-control devices inserted in supersonic flows of hot gases in rocket-engine nozzles; this cooling concept may also be applicable to vanes and blades in high-performance turbine engines.

According to an older version of this cooling concept, liquid metal boils inside a vane or probe, carrying away heat in the resulting convection current. In experiments on vanes and probes inserted in solid-propellant rocket-motor nozzles during operation, coolant vapor pressures were found to be excessive, and convection currents alone were not able to transfer sufficient heat to external coolant reservoirs; as a result, the operating lifetimes of the vanes and probes were of the order of only 20 s.

The jet pump in the proposed version would provide additional circulation of coolant in the form of vapor-pumped jets of liquid coolant, analogous to the periodic jets of steam-pumped liquid water in a coffee percolator. The pump and a recirculating tube attached to it would be implanted in the tip of the vane or probe to be cooled. As in the coffee percolator, the coolant vapor would periodically force a jet of boiling coolant liquid from the hottest part of the vane or probe, out through the recirculation tube, and into the coolant reservoir, where it would deposit its heat in the solid coolant, causing the solid coolant to melt. The melted coolant would then circulate within the cooling passages of the vane or probe. The frequency of repetition of jets would typically range up to several hundred cycles per second.

In a further improvement, additional axial and transverse slots would be added to the coolant passages in the vane or probe and to the coolant reser-

voir. These slots would reduce the stresses caused by thermal expansion and contraction of the solid coolant.

This work was done by I. B. Osofsky of Sparta, Inc., for **Marshall Space Flight Center**. *For further information,* ***write in 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 20]. Refer to MFS-26210.

Characterizing SOI Wafers by Use of AOTF-PHI

Polarimetric spectral images yield data on thicknesses of layers and distributions of imperfections.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental nondestructive method of characterizing the layers of a silicon-on-insulator (SOI) wafer involves a combination of (1) polarimetric hyperspectral imaging by use of acousto-optical tunable filters (AOTF-PHI) and (2) computational resources for extracting pertinent data on the SOI wafers from polarimetric hyperspectral images. SOI wafers are important because it is likely that in the future, low-power very-large-scale integrated circuits will be fabricated on them. An SOI wafer consists of a thin layer of silicon (e.g., tens to hundreds of nanometers thick) on a layer of silicon oxide (e.g., about 1 μm thick) on a silicon substrate of convenient thickness.

It is desirable to be able to characterize the silicon and silicon oxide layers in order to assess the uniformity and quality of SOI wafers and of circuitry fabricated on them. AOTF-PHI was originally developed for use in remote sensing, but it also affords capabilities that are attractive for characterization of SOI wafers. AOTF-PHI offers high spectral resolution (fractional wavelength resolution of 10^{-2} to 10^{-4}) and both ease and rapidity of optical-wavelength tuning (one need only change the frequency of the radio-frequency signal used to excite a transducer on an AOTF).

The method takes advantage of the fact that the silicon and silicon oxide layers are thin enough to give rise to interference patterns in white light. Accordingly, an SOI wafer to be characterized is illuminated with white light and an AOTF-PHI apparatus is used (see Figure 1) to decompose the resulting image (spatial interference pattern) into spectral and polarization

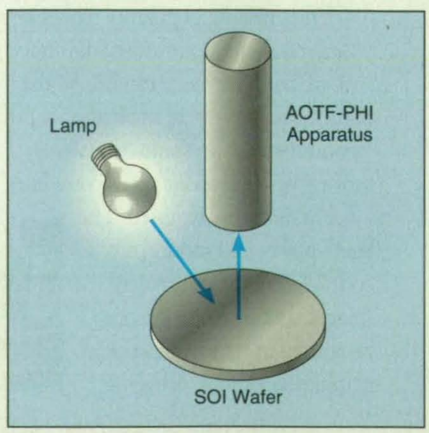


Figure 1. An **AOTF-PHI Apparatus** resolves the white-light interference pattern of an SOI wafer into polarization and spectral components.

components. The resulting polarimetric spectral image data can be used to characterize the layers.

For example, the thicknesses of the top silicon and silicon oxide layers at a given location can be estimated by finding the thicknesses for which the theoretically computed reflectance spectrum matches or most nearly matches the reflectance spectrum measured at that location (see Figure 2). The local density of imperfections can be estimated from a reduction in the local interference contrast at the given location.

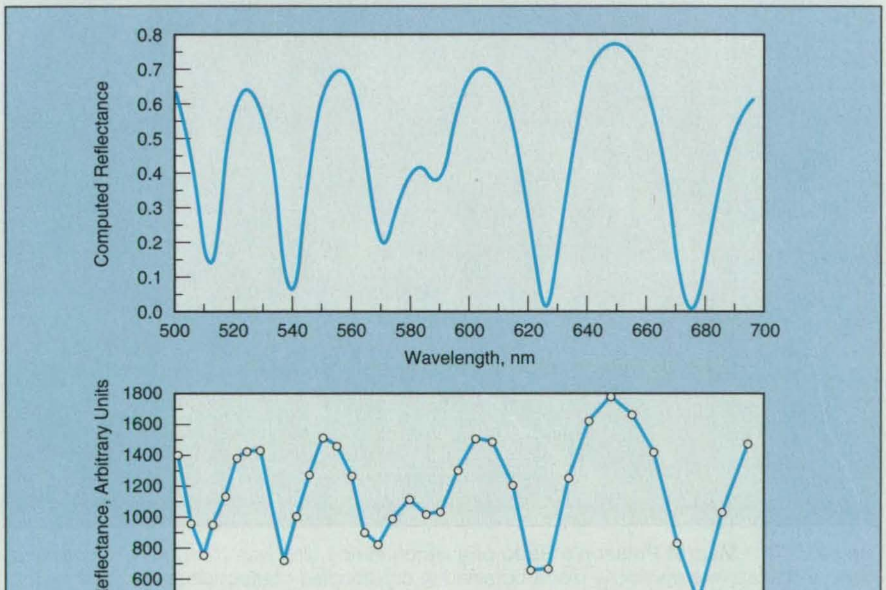


Figure 2. The **Computed Reflectance Spectrum** for a top silicon layer 720 nm thick on a silicon oxide layer 1 μm thick resembles the reflectance spectrum measured at one location on an SOI wafer.

One of the primary goals of further efforts to apply AOTF-PHI to characterization of SOI wafers is to implement all of the processing of polarimetric spectral image data in special-purpose hardware for the sake of processing speed. This would enable characterization of SOI wafers in real time for on-line monitoring and adjustment of production. It would also accelerate the application of AOTF-PHI to other applications in which there is a need for high-resolution spectral imaging, both with and without polarimetry.

This work was done by Li-Jen Cheng of Caltech, Guann-Pyng Li of the University of California at Irvine, and Deyu Zang of Metro Laser, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 47*** *on the TSP Request Card.*
NPO-19445

Imaging Inhomogeneities From Dry-Coupled Ultrasonic Scans

Information is extracted from shear and compressional waves.

Lewis Research Center, Cleveland, Ohio

A method of imaging the spatial distribution of selected physical properties and microstructure of a specimen of material is based on dry-coupled contact ultrasonic pulse/echo scanning (see Figure 1). This method offers a rapid, nondestructive alternative to destructive metallographic sectioning to obtain a picture of the inhomogeneity of a specimen. It would take about a month of work by a skilled technician to obtain the equivalent information by metallographic sectioning.

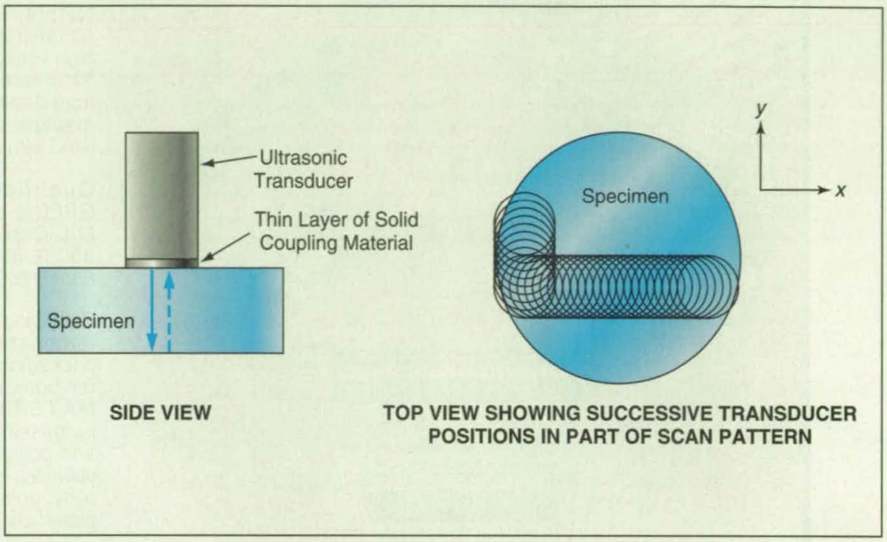


Figure 1. The **Ultrasonic Transducer** is scanned across the top surface of the specimen. At each of many positions on a two-dimensional grid on the top surface, ultrasonic pulse/echo measurements are taken and processed.

Dry ultrasonic coupling is not new, but heretofore it has been applied to measurement at one location. In the present method, it is applied in a computer-controlled scan across a surface of the specimen, and the data acquired in the scan are digitized and processed by use of interactive software to obtain maps of the velocities of sound. Local variations in this map can be correlated with local variations in pore volume fractions.

In ultrasonic measurement by use of wet coupling, the ultrasonic transducer and the specimen or at least part of the specimen are immersed in water or other suitable liquid. If the specimen is porous, the liquid can enter pores and thereby alter the ultrasonic properties of the specimen in such a way as to mask or distort the quantities that one seeks to measure. In some cases, the liquid can react chemically with the specimen. Dry coupling does not entail these disadvantages.

Whereas liquid coupling supports the propagation of longitudinal (compressional) sound waves only, dry coupling supports the propagation of transverse (shear) waves as well as longitudinal waves. This makes it possible to extract more information about the specimen by using waves of both types. For one thing, transverse waves may provide increased sensitivity for detection of some defects. Furthermore, maps of Poisson's ratio (ν) can be constructed from maps of the longitudinal- and shear-wave velocities (V_L and V_S, respectively) by use of $\nu = [(V_L^2/2) - V_S^2]/(V_L^2 - V_S^2)$.

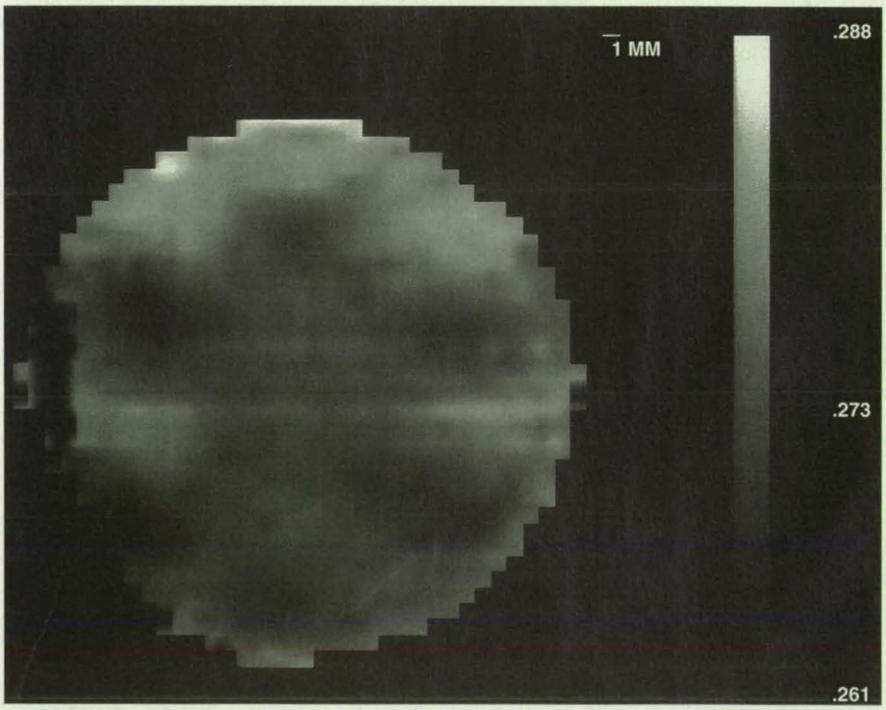


Figure 2. This **Map of Poisson's Ratio** of a silicon nitride disk was computed from longitudinal and shear-wave-velocity maps obtained in dry-coupled contact ultrasonic scanning of the disk.

The velocity and Poisson's-ratio maps (see Figure 2) assist in the development of materials and fabrication of material specimens by revealing inhomogeneities in the specimens. The velocity and Poisson's-ratio data can also be used to refine finite-element mathematical models of the mechanical properties of specimens for which ideal properties were previously assumed.

This work was done by Don J. Roth of **Lewis Research Center**. *For further information,* ***write in 55*** *on the TSP Request Card.*
LEW-15733

Measuring Temperature by Laser-Induced-Grating Spectroscopy

Temperature is computed from the speed of laser-induced counter-propagating acoustic waves.

Lewis Research Center, Cleveland, Ohio

The temperature of a gas can be measured by a technique based on laser-induced-grating spectroscopy. The essence of the technique is to set up counter-propagating acoustic waves via a laser-induced diffraction grating of known fringe spacing, then probe the grating with another laser beam to measure the frequency of the acoustic waves, then compute the speed of sound from the frequency and the wavelength (which equals the fringe spacing), then compute the temperature from the known relationship between the temperature and the speed of sound.

In laser-induced grating spectroscopy, a pulsed laser beam is divided into two phase-coherent and time-coincident pulsed beams (the pumping beams) that are made to intersect in the region of gas to be probed. The intersecting beams create interference fringes; that is, an alternating pattern of peaks and nulls in intensity (see Figure 1). The gas absorbs some of the laser energy and thus becomes heated at the intensity peaks. This rapid, spatially periodic heating at the interference peaks results in sudden thermal expansion and launches counter-propagating acoustic waves, the wavelength of

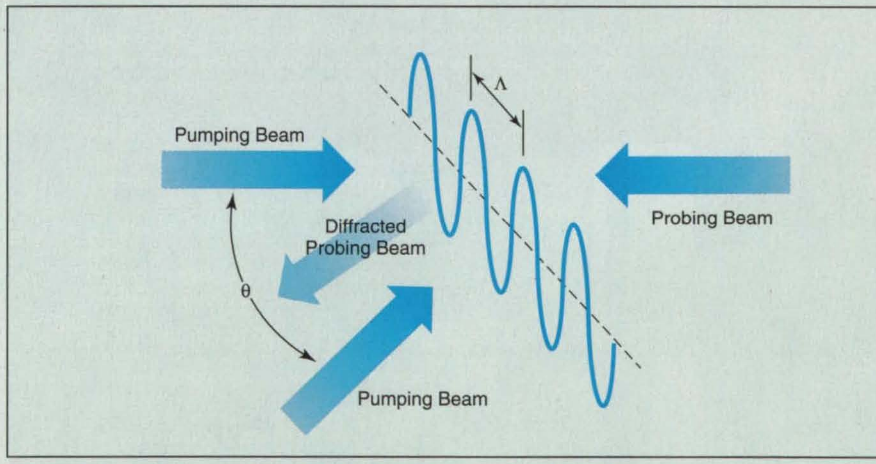


Figure 1. **Interference Between Intersecting Pumping Laser Beams** gives rise to spatially periodic heating, which in turn, creates an oscillating diffraction grating that is probed by another laser beam.

which matches the distance between successive interference peaks.

The counter-propagating acoustic waves cause the density of the gas to oscillate about its equilibrium value. The index of refraction and other density-dependent optical properties also oscillate with the density. The resulting spatially periodic, temporally oscillating variation in the optical properties is similar to that of a Bragg diffraction grating. In the present technique, a third (probing) laser beam, variably delayed from the pumping beams, is made to pass through this laser-induced grating. The laser-induced grating diffracts the probing beam, and the diffraction efficiency varies with the acoustic oscillation. Thus, the period of the acoustic oscillation (τ) can be obtained from a measurement of the time-varying intensity of diffraction of the probing beam (see Figure 2).

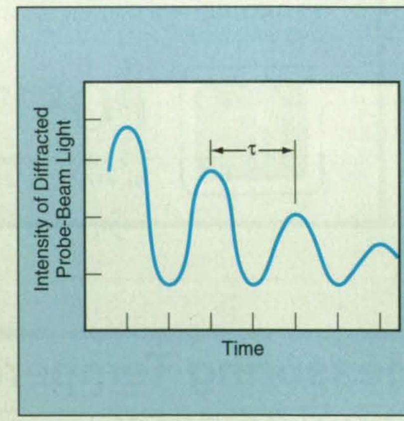


Figure 2. The **Oscillations in Diffracted** probe-laser intensity correspond to oscillations of counter-propagating acoustic waves generated by the spatially periodic heating.

The interference-fringe spacing, Λ (equal to the acoustic wavelength), is known from the laser wavelength and the angle of intersection of the two time-coincident laser beams. Known properties of the gas include the ratio (γ) between the specific heat at constant pressure and the specific heat at constant volume and the molar mass (M_o). Also known is the ideal-gas constant (R). Then by rearranging the fundamental equations for the speed of sound, one can compute the absolute temperature (T) of the gas from $T = (M_o/\gamma R)(\Lambda/\tau)^2$.

This work was done by Randall L. Vander Wal of NYMA, Inc., for **Lewis Research Center**. *For further information,* ***write in 100*** *on the TSP Request Card.*
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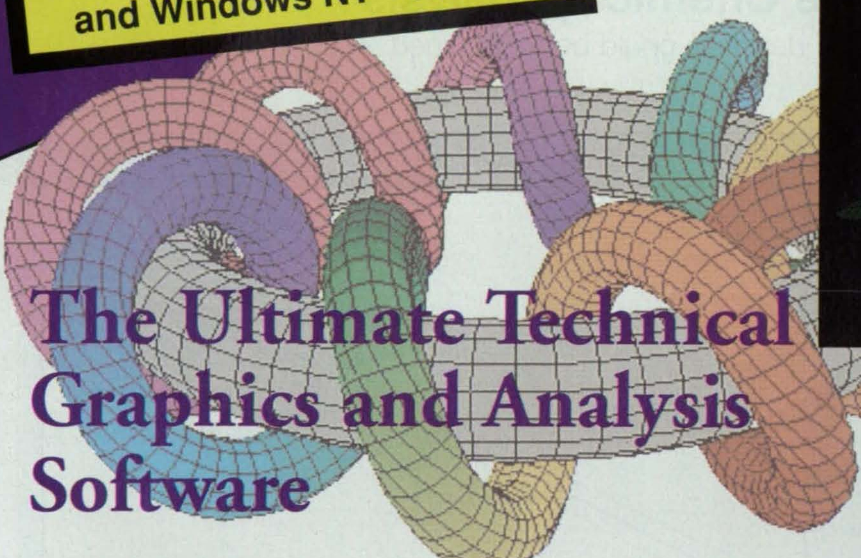

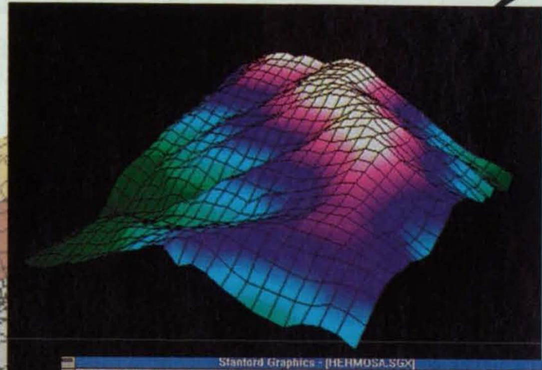

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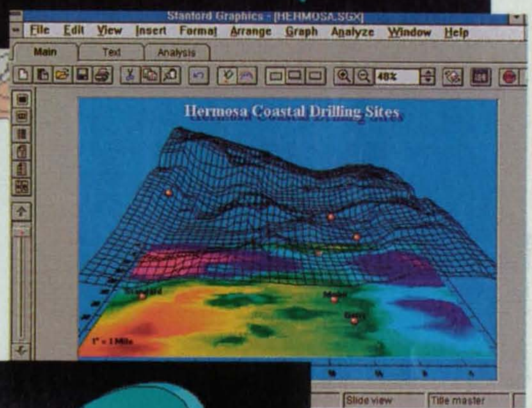

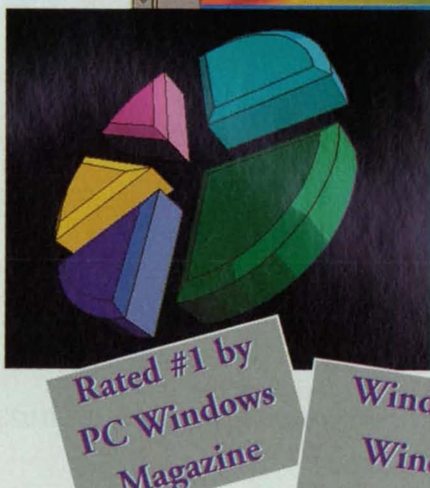

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Materials

Multivariate Quantitative Chemical Analysis

Chemical compositions, strengths, and densities could be determined.

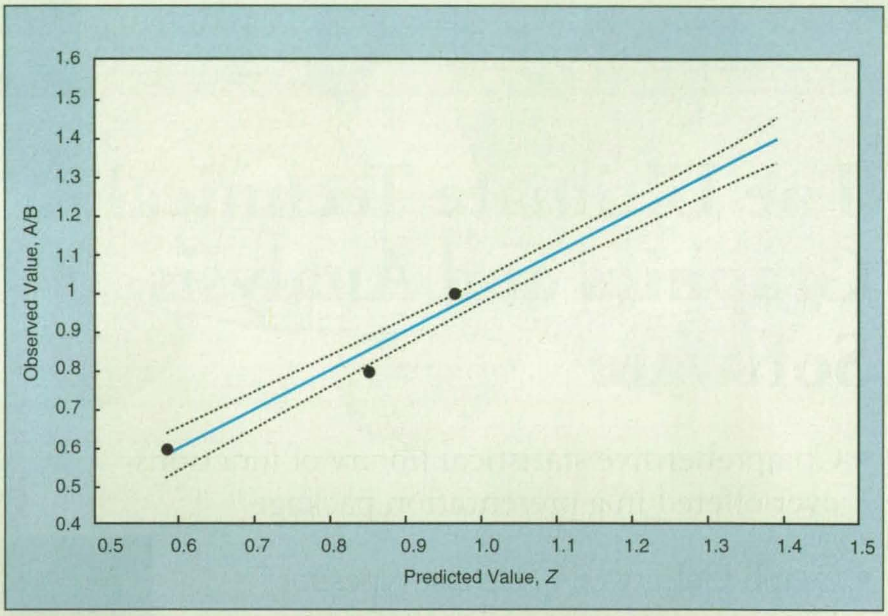
Marshall Space Flight Center, Alabama

A technique of multivariate quantitative chemical analysis has been devised for use in determining the relative proportions of two components (called "*A*" and "*B*") that were mixed and sprayed together onto an object to form a thermally insulating foam. The technique is potentially adaptable to other materials, especially in process-monitoring applications in which it is necessary to know and control critical properties of products via quantitative chemical analyses of the products. Thus, in addition to chemical composition, the technique could also be used to determine such physical properties as densities and strengths.

In the application of the technique to the sprayed foam, a specimen of the foam is quantitatively analyzed by one or more techniques, yielding *N* different measurements X_i (i = 1 to *M*). It is assumed that the ratio between the relative concentrations of *A* and *B* can be estimated from

$$Z = a + \sum_{i=1}^{M} b_i X_i$$

where *Z* is the estimated *A/B* ratio. To be able to apply this equation to a specimen of unknown composition, one determines *a* and b_i values in a statistical regression analysis on the X_i variables from a set of calibration specimens, the true *A/B* ratios of which can be determined by independent means.



Predicted and Observed Values are displayed on the correlation plane.

In the original foam case, *M* = 2 variables were chosen: these were the intensities of the spectral peaks at wave numbers of 1,510 cm^{-1} and 1,067 cm^{-1} on a Fourier-transform infrared (FTIR) spectrogram. The regression analysis in this case yielded

$$Z = 0.02349\,X_1 - 0.02494\,X_2$$

where X_1 and X_2 denote the intensities (in arbitrary units specific to the instrumentation used) of the 1,510 cm^{-1} and 1,067 cm^{-1} peaks, respectively (see figure).

This work was done by David G. Kinchen and Mary Capezza of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 89*** *on the TSP Request Card.*
MFS-28803

Polyethylene/Potassium Titanate Separators for Ni/H_2 Cells

Experimental separators have been fabricated on a paper-making machine.

Lewis Research Center, Cleveland, Ohio

Paperlike composites of polyethylene fibers and potassium titanate pigment are being developed to replace paperlike asbestos separators in nickel/hydrogen rechargeable electrochemical cells. Like other asbestos products, the asbestos separators are being phased out because of their potential for adversely affecting health.

The separator in a nickel/hydrogen cell must satisfy a number of requirements: It must (1) act as a reservoir for a potassium hydroxide electrolyte, (2) act as a highly ionically conductive bridge between a hydrogen-gas anode and a nickel hydroxide cathode, (3) resist the passage of gaseous oxygen, (4) resist penetration by loose active nickel cathode material, and (5) be thermally and chemically stable in the cell environment. Data gathered in preliminary experiments suggest that the polyethylene-fiber/potassium titanate-pigment composites will satisfy these requirements.

More precisely, the results of preliminary experiments show that neither a

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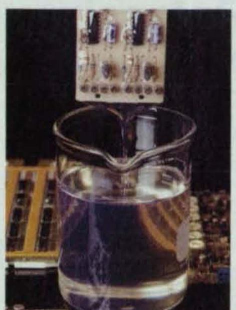

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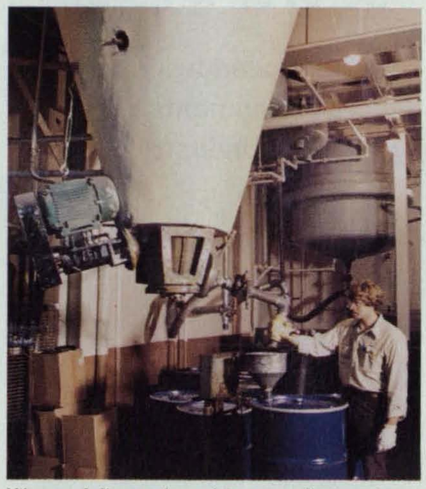

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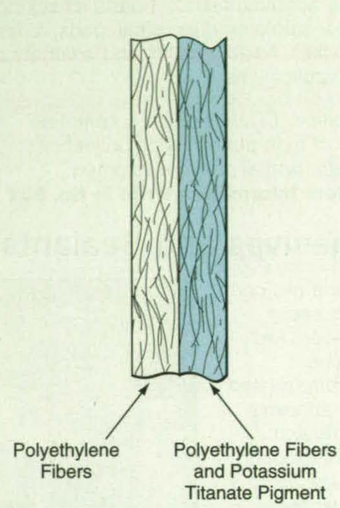
polyethylene sheet alone nor a polyethylene/potassium titanate sheet alone could perform satisfactorily as a separator, but that adequate separators could be made as two-ply laminates of both materials (see figure).



A **Two-Layer, Paperlike Composite** of polyethylene fibers and potassium titanate pigment shows promise for replacing asbestos as a separator material in nickel/hydrogen electrochemical cells.

The polyethylene layers would impart sufficient resistance to passage of oxygen bubbles, while the polyethylene/potassium titanate layers would retain the electrolyte to the necessary extent.

A laminated separator can be made by using thermal calendering to bond a layer of polyethylene paper to a layer of polyethylene/potassium titanate paper. Analysis of experimental data showed that the optimum concentration of potassium titanate in the layer that contains it is about 60 weight percent and that the optimum areal mass densities of the polyethylene and polyethylene/potassium titanate layers are 51 and >75 g/m², respectively. The optimum calendering conditions for making laminated separators appear to be a temperature at or slightly above ambient, a low pressure [about 5 psi (34 kPa)], and a single calender nip.

This work was done by William E. Scott of Miami University for **Lewis Research Center.** *For further information,* ***write in 75*** *on the TSP Request Card.*
LEW-15473

Preparation of Strong, Dense Potassium ß″-Alumina Ceramic

Analysis of the applicable chemical kinetics has led to improvements in processing.

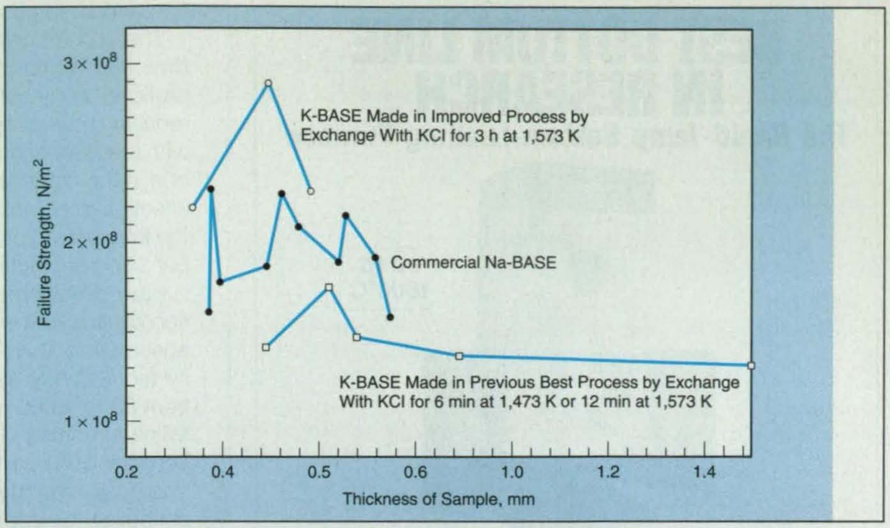
NASA's Jet Propulsion Laboratory, Pasadena, California

An improved process for making mechanically strong, dense, phase-pure potassium ß″-alumina solid electrolyte (K-BASE) results in a material superior to all previous K-BASE preparations and similar to commercial Na-BASE in strength, phase purity and high-temperature ionic conductivity. Potassium-based alkali-metal thermal-to-electric conversion (AMTEC) cells are expected to operate efficiently at lower heat-input temperatures and lower rejection temperatures than do sodium-based AMTEC cells, making them appropriate for somewhat different applications.

High-quality (phase-pure) K-BASE ceramic with density approaching 100 percent and sufficient mechanical strength is necessary for building potassium-based AMTEC cells. Previous attempts to produce K-BASE ceramic from Na-BASE ceramic were only partially successful because, variously, processing conditions near the decomposition boundary of the ß″ phase led to mixed-phase material, or preparative conditions led to porous or microcracked ceramic because of incomplete sintering or relief of stress. Previous attempts at making K-BASE from commercial Na-BASE by ion exchange with KCl vapor left the K-BASE with loss of K_2O and containing the ß-alumina phase, which is a poor ion conductor, when the substitution of K for Na was carried out at temperatures above 1,473 K. On the other hand, ceramics prepared at temperatures more than 100 K lower were significantly weakened, and samples prepared by rapid firing at much higher temperatures had densities substantially below 100 percent, which gives rise to degraded conduction behavior.

In an effort to identify processing conditions that would yield improved K-BASE, the applicable chemical kinetics were analyzed: The kinetics of decomposition of the potassium ß″-alumina-phase, changes in decomposition, changes in crystal structure, and sintering were mapped with respect to temperature and chemical activity in a series of tests to determine processing conditions for producing superior K-BASE ceramics by ion exchange with KCl vapor.

In the improved process, the Na-BASE ceramic pieces to be converted to K-BASE ceramic are covered with a blanket of finely divided, K_2O-rich K-BASE powder to control K_2O activity during subsequent ion exchange with KCl vapor/air or KCl vapor/oxygen mixture (or, alternatively, K_2O vapor from a $KAlO_2$ source) at a typical temperature of 1,625 K. At this temperature, creep (annealing) occurs without decomposition of the β″-alumina phase and without loss of K_2O as long as the K_2O activity is maintained. The resulting ceramic is relatively strong, has the correct composition, and is only about 1.5 percent more porous than was the starting Na-BASE. The figure shows the results of strength tests of samples made under several different processing conditions.



The **Improved Process** yields a K-BASE ceramic stronger than both the best previous K-BASE ceramic and the commercial Na-BASE ceramic from which it is made.

This work was done by Roger M. Williams, Barbara Jeffries-Nakamura, Margaret A. Ryan, Dennis E. O'Connor, Adam Kisor, Stanley J. Kikkert, Robert Losey, and Jerry W. Suitor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 81*** *on the TSP Request Card.*
NPO-19209

Thin Semiconductor/Metal Films for Infrared Devices

Spectral responses of absorbers and reflectors can be tailored.

NASA's Jet Propulsion Laboratory, Pasadena, California

Thin cermet films that are composites of metals and semiconductors are undergoing development for use as broadband infrared reflectors and absorbers. This development extends the concepts of semiconductor and dielectric films that have been used as interference filters for infrared light and visible light, respectively.

The bulk of a film of this type includes a thin layer of a semiconductor containing small metal particles distributed either uniformly or in graded concentration through the thickness. The complexity of interactions between infrared radiation and this composite material can be exploited, by suitable choice of composition and microstructure, to achieve desired optical effects. Most notably, the addition of metal particles increases the effective index of refraction (n) and affects the effective index of absorption (k). Thus, by controlling the film-deposition process to achieve a specified profile of volume fraction of metal particles as a function of depth, one can tailor the overall spectral reflection and absorption properties of the film.

These composite films offer advantages over semiconductor films that do not contain metal particles. The addition of metal particles contributes additional thermal conductivity, thereby reducing thermal gradients and the associated thermal stresses, with resultant enhancements of thermal stability. Because values of n in the composite films can be made large, the same optical effects can be achieved with lesser thicknesses. By decreasing the thicknesses of the films, one not only decreases their weights but also contributes further to reductions of thermal stresses.

Early development efforts have been directed toward deposition of films that would exhibit high emissivity (equivalently, high absorptivity) at wavelengths from 5 to 50 μm and high reflectivity (equivalently, low emissivity or absorptivity) at wavelengths from 50 to 1,000 μm. Films of amorphous (with respect to crystalline structure) Ge containing Ag particles and amorphous Si containing Au particles have been deposited by cosputtering. The cosputtering process offers advantages of scalability and suitability for deposition on surfaces of lightweight composite-material structures. Furthermore, residual stresses in deposited films can be controlled through selection of process parameters.

The experimental Ge:Ag and Si:Au films made by cosputtering exhibited enhanced n and k, as expected, with measured values that approximate theoretically computed values. One of the predicted and measured characteristics of these films illustrates an advantage over dielectric films that have been developed for the same purposes: Attempts to extend the absorption properties of dielectric films into the infrared spectral region have resulted in undesirably low emissivities at some wavelengths and in undesired oscillations in reflectivities as functions of wavelength. However, the composite films do not exhibit these oscillations; instead, they exhibit broadband reflectivities and absorptivities.

This work was done by James L. Lamb and Channamallappa L. Nagendra of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 29*** *on the TSP Request Card. NPO-19320*

Nafion™ Coats for Electrodes in Liquid-Feed Fuel Cells

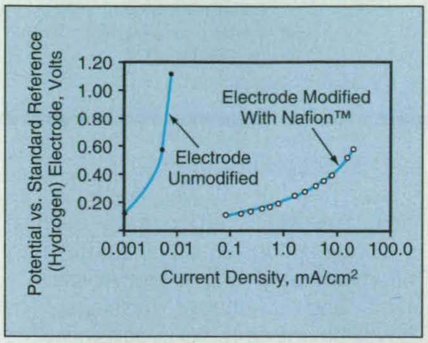
Coating or impregnation with a commercially available material enables oxidation of organic liquid fuels.

NASA's Jet Propulsion Laboratory, Pasadena, California

Nafion™ has been found to be useful for coating or impregnating electrodes in direct-oxidation, liquid-feed fuel cells. In such a cell, an aqueous solution of methanol, formaldehyde, or other water-soluble organic fuel is circulated past an anode, where the fuel is oxidized. A commercially available electrode for the oxidation of organic fuels usually contains 15 to 30 percent polytetrafluoroethylene (PTFE) as a binder, and works only with gaseous fuel. To make such an electrode work with liquid fuel, one must coat or impregnate it with a suitable wetting agent that does not interfere with the kinetics of oxidation or degrade the electrode.

Nafion™ was investigated for use in this application because of its known combination of desirable characteristics: It is a perfluorinated, hydrophilic, proton-conducting ion-exchange polymer that exhibits relatively high thermal and electrochemical stability and is not detrimental to the kinetics of electrochemical processes. It is available in solubilized form and can be used to apply stable coats to the surfaces of electrodes.

In preparation for experiments to test the efficacy of Nafion™ coating, commercial Pt, Pt/Sn, and Pt/Ru gas-diffusion-type electrodes containing PTFE were obtained. Some of the electrodes were left bare, while others were coated and impregnated by dipping them for 5 minutes in a solution of 1 percent Nafion™ in methanol, then drying in vacuum to remove not only the methanol but also higher alcohols from the Nafion™ formulation.



These **Galvanostatic Polarization Curves** illustrate the effect of treating a (Pt/Sn)/C electrode with Nafion™. The measurements were taken in an aqueous solution of 1M HCHO + 0.5M H_2SO_4 at a temperature of 40 °C.

In the experiments, galvanostatic polarization curves were obtained for the electro-oxidation of methanol and of formaldehyde in sulfuric acid electrolytes, on both the bare and the Nafion™-impregnated electrodes (see figure). The curves show that impregnation of the electrodes with Nafion™ is necessary for the oxidation of methanol and formaldehyde. The performances of experimental liquid-feed methanol fuel cells that contain Nafion™-impregnated electrodes have been found to exceed those of prior methanol fuel cells.

This work was done by Sekharipuram R. Narayanan, Subbarao Surampudi, Gerald Halpert, Eugene Vamos, and Harvey A. Frank of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 293*** *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

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Machinery

Computational Simulation of a Nuclear Engine

NESS is used to perform design analysis.

The Nuclear Engine System Simulation (NESS) computer program was developed to satisfy a need for an accurate, stand-alone software tool for preliminary design analysis of a nuclear thermal propulsion (NTP) engine system. The NTP-engine-design mathematical models and associated computer programs heretofore available were developed during the NERVA program in the 1960s and early 1970s; each is highly unique to the NERVA design or else is a modified version of a liquid-propulsion-system mathematical model. The NTP-engine-based liquid design models available heretofore lack the integrated design of key NTP-engine-design features in such areas as reactor, shielding, multi-propellant capability, and multiply-redundant pump-feed fuel systems.

NESS is intended to support current and future efforts to perform design studies of engine systems and stages. In the development of NESS, the NTP version of the Expanded Liquid Engine Simulation (ELES) computer program of Science Applications International Corp. (SAIC) was modified extensively to include Westinghouse Electric Corporation's near-term and next-generation solid-core-reactor design mathematical models — ENABLER I and ENABLER II, respectively. These models are based on the near-term and upgraded versions of the solid-core ENABLER NTP reactor-design concept. The ENABLER I model provides a near-term solid-core reactor design based on the NERVA reactor. ENABLER II provides a more advanced reactor design, with flow paths and scaled fuel, reflecting state-of-the-art technology, and yielding reactor designs with higher power densities and lower weights.

The NESS computer code is used for rapid, preliminary detailed design analysis of both the reactor and key engine systems. This code designs the reactor, turbomachinery, tankage, nozzle, lines, and valves in terms of both weight and operating characteristics. NESS is capable of modeling expander, gas-generator, and bleed cycles, along with multiply-redundant propellant-pump feed systems. Engine systems can be designed and evaluated for both pump-out and normal operating conditions, with an option available for automated iteration of pump design to satisfy both operating conditions. Turbopump-design options include the efficient axial multistage pump along with the traditional centrifugal pump.

Principal outputs of NESS include (1) operating characteristics and weights of reactors, (2) such engine-system parameters as performances, weights, dimensions, pressures, temperatures, and mass flows, and (3) operating characteristics of turbopumps under both design and off-design operating conditions. The propellant is modeled as hydrogen in all cycles, with oxygen as needed in the gas-generator cycle. NESS is easy to use, runs quickly, and is flexible enough to efficiently address a wide variety of solid-core-NTP-engine-system design options. Because of its modular nature, NESS has great potential for further upgrades in its design and technology options and its analysis capabilities.

As a result of an initial effort at validation, the NESS program is deemed accurate enough to support preliminary efforts to design engine and vehicle systems and to analyze missions. The development of NESS is considered to be one of the key steps needed to support NTP design. NESS can be a valuable element of a design tool when integrated into an advanced NTP-engine-design-system work station.

NESS is written in FORTRAN 77 for DEC VAX-series computers running VMS and IBM PC-series computers running MS-DOS using version 5.01 (or later) of the Lahey FORTRAN compiler F77L/EM-32. It requires a minimum of 1.4Mb of virtual random-access memory (RAM) under VMS and 1.5Mb of RAM under MS-DOS. Under both, NESS requires 4Mb of disk memory space for compilation and linking. Sample input and output data are included. NBS+_PH2, a program for calculating properties of hydrogen, is included with NESS. NBS+_PH2 is also available separately (LEW-15505, *NASA Tech Briefs* Vol. 18 No. 5 (May 1994), page 72). The standard distribution medium for NESS is a set of two 5.25-in. (13.335-cm), 1.2Mb, MS-DOS-format diskettes. The contents of the MS-DOS-format diskettes are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. NESS is also available on a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format or on a TK50 tape cartridge in DEC VAX BACKUP format.

This program was written by J.T. Walton of **Lewis Research Center**, *C. M. Schiel and D. G. Pelaccio of Science Applications International Corp., and L. J. Petrosky of Westinghouse Electric Corp. For further information,* ***write in 170*** *on the TSP Request Card.*
LEW-15586

Burt Rutan Makes Vellum Fly

Two years after the Voyager completed its record-shattering around-the-world flight, you could still find its designer, Burt Rutan, working at a drafting table with pencil and paper.

Hardware wasn't the problem. He had computers. His company could buy any design system worth owning. What kept Burt grounded was software. CAD so clumsy, it squashed creativity. Or so weak, it simply couldn't do his job.

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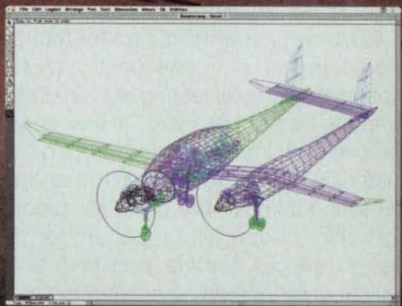

Burt's creativity and willingness to explore uncharted territory is exemplified by this sneak peek at one of his latest designs produced (of course) in Vellum.

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From GD&T symbols to NURB splines to DXF and IGES file format translators, Vellum has every professional design and drafting tool your job demands. And each tool is endowed with an expert system called the Drafting Assistant™—built-in intelligence that instantly makes every designer more productive. Even on enormously complex jobs.

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Mechanics

Predicting Fatigue Lives Under Complex Loading Conditions

A mathematical model simulates cyclic isothermal fatigue tests.

The Cyclic Damage Accumulation (CDA) computer program performs high-temperature, low-cycle-fatigue life prediction for materials analysis. It was designed to account for the effects on creep-fatigue life of complex loadings that involve such factors as thermomechanical fatigue, hold periods, waveshapes, mean stresses, multiaxiality, cumulative damage, coatings, and environmental attack. Several features of CDA make it practical for application to actual component analysis using modern finite-element or boundary-element methods. Although it has been developed for use in predicting the crack-initiation lifetimes of gas-turbine-engine materials, it can be applied to other materials as well.

CDA implements a mathematical model based on continuously cycled isothermal fatigue testing and includes many features that make it well suited for use with modern high-temperature materials. It uses total strain rather than inelastic strain for the basic life prediction; this is especially important for the design of gas turbine engines, since typical components have small inelastic strains when they are designed for useful lives in the thousands of cycles. Ratios for stresses and other calculated quantities are calculated with respect to reference conditions, rather than absolute levels; this helps to reduce the sensitivity to the accuracy of the constitutive modeling. CDA was designed to predict crack initiation, not total failure, with the definition of initiation being the development of detectable cracks with size of at least 0.030 in. (0.76 mm) at the location being considered.

CDA is written in FORTRAN 77 for execution on IBM PC-series and compatible computers running IBM OS/2 version 2.1. The source code has been optimized for the WATCOM F7732 compiler version 9.5, and the distribution medium includes both a MAKE macro for use with this compiler and a sample executable code, which was created by use of this compiler. The CDA source code has also been successfully implemented on Sun-series computers running SunOS. Requirements for implementation of CDA under OS/2 include an 80386 or higher central processing unit and a minimum of 7MB of disk space. Requirements for random-access memory vary depending on the size of the problem being solved. The standard distribution medium for this program is a set of two 3.5-in. (8.89-cm), 1.44MB, MS-DOS-format diskettes. The contents of the diskettes have been compressed using the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE v2.04g, is included. Upon request, CDA will be provided on 3.5-in. (8.89-cm) diskettes in UNIX tar format. This version of CDA was released in 1994.

This program was written by Michael A. McGaw of **Lewis Research Center** *and R. S. Nelson and L. A. Janitor of United Technologies Corp. For further information,* ***write in 62*** *on the TSP Request Card.*
LEW-15965

Materials

Predicting Fatigue Lives of Metal-Coated Nickel-Alloy Parts

The main intended application is to turbine airfoils.

The LAYER computer program performs thermomechanical-fatigue-life prediction for coated, nickel-based anisotropic materials. Metallic coatings are routinely used in gas turbine engines to protect hot-section airfoils from environmental degradation. With the addition of the coatings, however, turbine-airfoil-life prediction is complicated because the coatings are primary fatigue-crack-initiation sites. LAYER is intended to provide gas-turbine-airfoil designers with means to accurately project service lifetimes.

Given the differences in thermal expansion and creep between the coating and substrate alloys, nonlinear analysis of the cyclic history of a coating/substrate composite is considered necessary for accurate life prediction. Although nonlinear turbine-airfoil analyses have been executed for uncoated airfoils, the highly nonlinear coating behavior essentially eliminates the possibility of conducting coated-airfoil analyses within an acceptable time frame. LAYER, which implements a simplified structural-analysis technique, has been developed to analyze the nonlinear behavior of such a composite at a predetermined critical location.

The base airfoil material considered is the Pratt & Whitney Aircraft single-crystal alloy PWA-1480. Two different generic types of oxidation-resistant metallic coating are considered. The first, PWA-286, is a low-pressure-plasma-sprayed (LPPS) NiCoCrAlY overlay coating. The second coating is a diffusion aluminide, NiAl, designated PWA-273. Although LAYER has been developed for predicting crack initiation in metallic coated PWA-1480, it can be extended to other materials as well.

Input to the LAYER code can come from any available elastic or nonlinear component cyclic analysis — finite element, boundary integral element, or hand calculation. The LAYER code can readily include the influence of multiaxial loading on crack-initiation life; for example, the biaxial effect of coating/substrate thermal-expansion mismatch that occurs during thermal cycling.

LAYER is written in FORTRAN 77 for IBM PC-series and compatible computers running OS/2 2.1 and Sun-series computers running SunOS 4.x. The program requires approximately 10MB of disk space for installation and 4MB of random-access memory for execution. Sample executable codes are included on the distribution medium for IBM PC OS/2 platforms. The source code has been optimized for use under OS/2 with the WATCOM F7732 compiler, v9.5, but requires no modification for compilation under SunOS. Sample test problems and their results are also included on the distribution medium to aid in verification of correct operation. The standard distribution medium for LAYER is a 3.5-in. (8.89-cm), 1.44MB, MS-DOS-format diskette. Alternate distribution media and formats are available upon request. The contents of the diskettes have been compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE v2.04g, is included. This version of LAYER was released to COSMIC in 1994.

This program was written by Michael A. McGaw of **Lewis Research Center** *and D. M. Nissley of United Technologies Corp. For further information,* ***write in 156*** *on the TSP Request Card.*
LEW-15967

Mechanics

Acoustic Detection of Loose Particles in Pressure Sensors

Computer analysis of sounds from vibration tests reveals particle-impact noise.

Marshall Space Flight Center, Alabama

A particle-impact-noise-detector (PIND) apparatus is used in conjunction with a computer program that analyzes the output of the apparatus to detect extraneous particles trapped in pressure sensors. In essence, the PIND apparatus and program implement an instrumented and computerized version of the intuitive "shake-and-rattle" method.

Typically, the extraneous particles in pressure sensors consist of such manufacturing debris as solder balls, metallic shavings, and wire fragments; it is necessary to detect and eliminate them because they give rise to spurious peaks and depressions in sensor readings. Although the particles could be found by disassembly and visual inspection of the insides or by x-ray inspection without disassembly, it is not practical to perform such close inspection of every sensor in a system that contains many sensors. The PIND method was devised as a practical alternative.

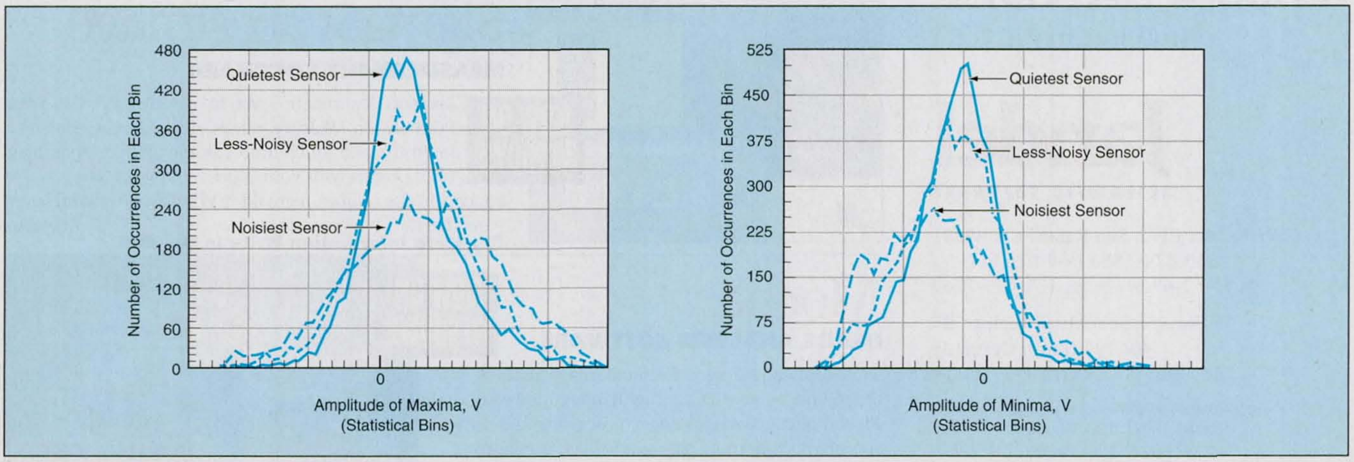
A PIND tester is essentially a shaker equipped with a microphone that measures the noise in the pressure sensor or other object being shaken. The shaker applies a controlled vibration (e.g., a damped sinusoidal acceleration). The output of the microphone is recorded and expressed in terms of voltage, yielding a history of noise that is subsequently processed by the computer program. Data are taken at a sampling rate sufficiently high (10,000 samples/second) to enable identification of all impacts of particles on the sensor diaphragm and on the inner surfaces of sensor cavities.

The computer program helps to analyze the statistical characteristics of the measurement data. In general, the amplitude of a noise peak generated by impact of a particle is proportional to the mass of a particle, and the overall noise level increases with the number of particles. A PIND test of a sensor that contains a large number of trapped particles yields many noise peaks with large and widely differing magnitudes. The program sorts out all maxima (three consecutive points with their points changing from positive to negative) and minima (three consecutive points with their slopes changing from negative to positive) and then arranges them in order of ascending amplitude.

For a random noise signal, either a maxima or a minima can have a positive or negative value in amplitude. The range of amplitude of both maxima and minima is divided into a number of bins specified by the user. The sorted maxima and minima are placed into these bins according to their amplitude. The number of occurrences in each bin is then plotted against a value of amplitude representative of the data in the bin (see figure). The distributions of maxima and minima on plots generated in this way show large standard deviations in the case of a sensor that contains many trapped particles, because testing of such a sensor generates a large number of peaks that are away from the mean value. Furthermore, the larger the amplitude of the noise level, the larger is the mass of the particles. On the other hand, the plot made from a test of a relatively quiet sensor that contains few trapped particles exhibits a small standard deviation, because most of the peaks are clustered around the mean value.

The capability of the PIND-test/computer analysis method to identify sensors that contain extraneous particles has been confirmed by x-ray and visual inspections. Computer analysis correctly identified (a) the one of several sensors that contained the largest amount of extraneous material and (b) the one of several sensors that contained the heaviest single trapped particle. The only limitation of the method occurs in a case of an extraneous particle that cannot be detected by PIND testing because it is lodged tightly in a confined space inside the sensor. Fortunately, however, a tightly lodged particle does not contaminate a sensor reading.

This work was done by Lloyd C. Kwok of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 17*** *on the TSP Request Card.*
MFS-30015



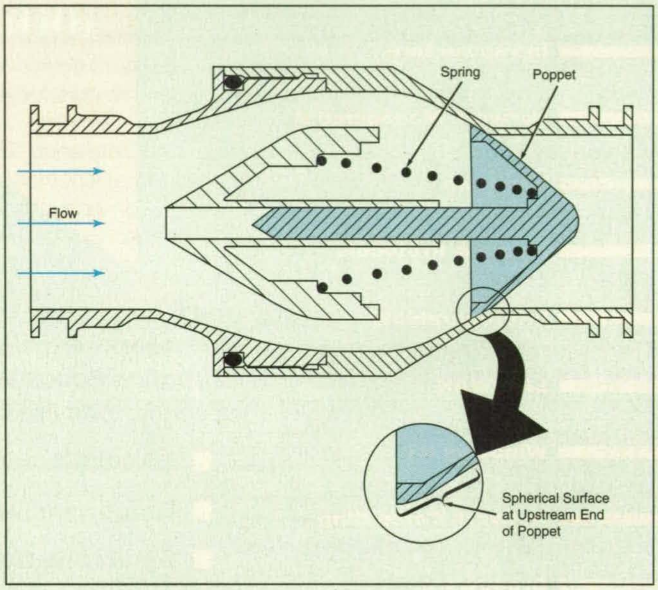
Statistical Distributions of Amplitudes of maxima and minima in the data from a PIND test can be used to distinguish between among three sensors that contain different numbers of trapped extraneous particles.

Low-Leak, High-Flow Poppet Valve

A partly spherical poppet surface provides a tight seal.

Marshall Space Flight Center, Alabama

The figure illustrates a valve with a conical poppet that has been modified to incorporate a smooth transition to a segment of a sphere at the upstream end of the cone. The spherical surface constitutes the sealing surface of the poppet; it results in a leak rate equivalent to that of a ball-type poppet, and extremely low flow losses.



The **Modified Valve** includes a spherical sealing surface at the upstream (wide) end of the conical poppet.

The spherical surface also enables the use of a loose fit for guiding the poppet, with resulting lower manufacturing cost, high reliability, and long operating life.

This work was done by John N. Tervo of Allied-Signal Aerospace Co. for **Marshall Space Flight Center**. *For further information,* ***write in 87*** *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 20]. Refer to MFS-28834

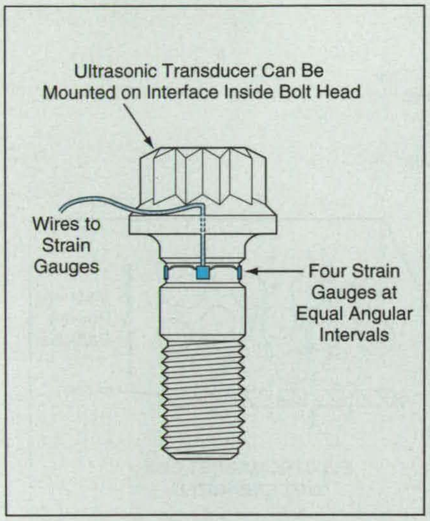
Instrumented Bolt Measures Load in Two Ways

Ultrasonic measurements can be verified by strain-gauge measurements.

Marshall Space Flight Center, Alabama

A bolt has been instrumented to allow both ultrasonic and strain-gauge measurements of the tensile load in the bolt during installation and use of the bolt in a structure. The bolt head design allows an interface for an ultrasonic transducer to be installed, while a shallow chamfered circumferential groove on the bolt shank contains four strain gauges at equal angular intervals wired as a full-bridge transducer (see figure).

The doubly instrumented bolt was devised for use in studying errors in ultrasonic measurements of bolt loads. An objective of such a study is to make it possible to rely on ultrasonic measurements in the future by making suitable corrections in design, fabrication, and/or testing. In the application that prompted this development, three standard deviations of the errors in ultrasonically determined bolt loads amounted to somewhat more than 21 percent, whereas a three-standard-deviation error of no more than 10 percent is considered acceptable in that application. Strain gauges are suitable for use as standards of comparison because they can provide load measurements with errors of only 0.7 – 2.0 percent.



The **Instrumented Bolt** accommodates four strain gauges mounted in the shallow groove on the shank, plus an ultrasonic transducer in the head.

The groove that holds the strain gauges is cut to a depth less than that of the bolt thread. This depth is small enough not to weaken the shank significantly or interfere with an ultrasonic signal. The edges of the groove are chamfered at 45° to reduce reflection of ultrasound from them. The strain-gauge leads are brought out of the bolt head through a narrow axial passage and an axial groove cut at the same depth as the circumferential groove. Standard strain-gauge mounting methods are used, with compensation for effects of bending and temperature.

This work was done by D. E. Smith, G. R. Melvick, T. J. Klundt, R. L. Everton, and M. Eggett of Thiokol Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 12*** *on the TSP Request Card.*
MFS-28972

Machinery

Compressor Has No Moving Macroscopic Parts

Slugs of magnetic powder are made alternately more and less porous to pressurize a fluid.

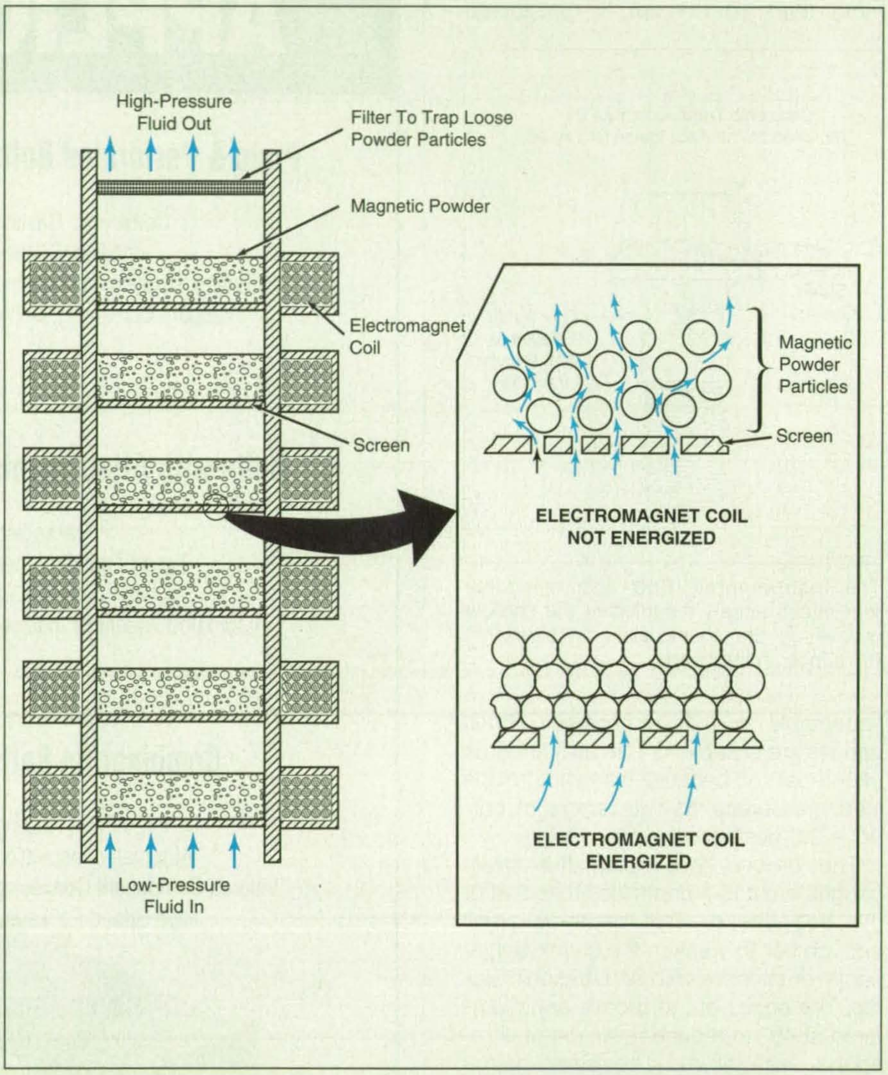
Goddard Space Flight Center, Greenbelt, Maryland

A compressor that contains no moving macroscopic parts functions by the alternating piston and valve actions of successive beds of magnetic particles. The compressor can be fabricated relatively easily because there is no need for precisely fitting parts that rotate or slide on each other. There is also no need for a lubricant fluid that could contaminate the fluid to be compressed. Still another and very important advantage is that this compressor can operate continuously, eliminating the troublesome on/off cycling (and the concomitant voltage and current transients) of other compressors, and decreasing the consumption of energy.

The compressor (see figure) includes a stack of cells, each containing a dry, fine stainless-steel powder supported by a screen. The stainless steel has a high iron content (about 85 percent) so that the powder is magnetizable. The particles of powder are approximately spherical, with a diameter of about 38 μm. The screen is made of a mesh that is coarse enough to allow the fluid to flow freely, but fine enough to retain the powder.

An electromagnet coil is wrapped around each cell. When the coil in a first cell is not energized, the powder in that cell is loose, and the fluid can flow through it relatively easily. When the coil is energized, the resulting magnetic field packs the powder particles together tightly, restricting the flow of fluid. The magnetic field also causes the mass of powder to expand somewhat, as a solid piston, compressing the fluid into the space above. The fluid thus flows into a second cell, in which the electromagnet coil is initially unenergized so that the fluid can flow into it. The electromagnet coil in the second cell is then energized, forcing the fluid into a third cell, and so forth.

The excitation of the coils is phased, under microprocessor control, to pass a volume of fluid from cell to cell. The fluid acquires a higher pressure in each successive cell. When a powder piston has forced the fluid toward the powder piston in the next cell, its coil is deenergized; the powder relaxes, and the cell accepts a new charge of fluid. The cycle is repeated, producing a pulsed flow of pressurized fluid from the topmost cell.



Phased Cells push fluid from bottom to top, adding increments of pressure as they do. Each cell contains magnetic powder particles that are loose when the electromagnet coil is deenergized, but tightly packed when the coil is energized.

An axial tube can be placed within the stack to carry coolant if needed. If space is at a premium, the coils can be placed inside the cells.

This work was done by Max Gasser of **Goddard Space Flight Center**. *For further information,* ***write in 31*** *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 20]. Refer to GSC-13565.

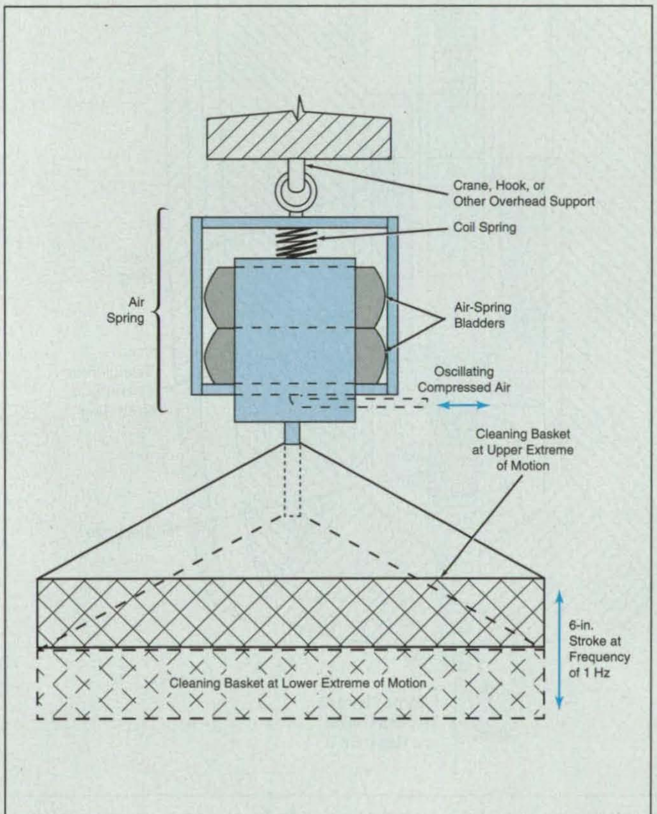
Mechanical Agitation for Aqueous Cleaning

An air spring shakes a cleaning basket.

Marshall Space Flight Center, Alabama

A cleaning basket that is placed in an aqueous cleaning solution can be mechanically agitated by an air spring, as shown in the figure. Mechanical agitation was desired in the original application because about 90 percent of aqueous cleaning in most applications is believed to be effected by mechanical agitation, with only 10 percent effected by chemical activity.

Previously, air bubbles were used in the original application to get mechanical cleaning action. A prototype air-spring unit was tested, and a great improvement in cleaning action was observed. A similar unit could be built for a cost between $450 and $600 (1992 prices), the exact cost depending on the size and load of the cleaning basket.



Compressed Air at Oscillating Pressure is supplied to the air spring to produce repeated vertical motion of a cleaning basket immersed in an aqueous cleaning solution.

This work was done by Gene E. Morgan and Timothy J. Hosking of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 94*** *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 20].

Refer to MFS-29962.

Manufacturing/Fabrication

Swirl Ring Improves Performance of Welding Torch

A vortex helps to focus the arc column.

Marshall Space Flight Center, Alabama

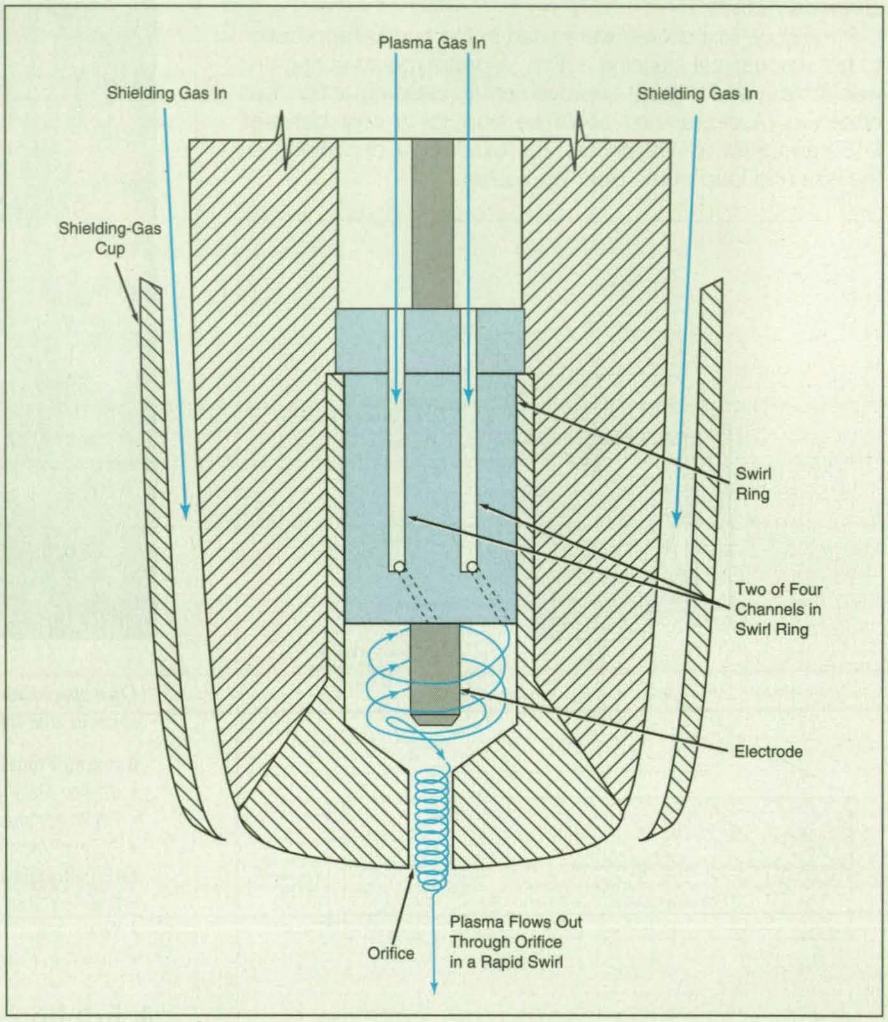
A plasma-arc welding torch has been modified to create a vortex in the plasma gas to focus the arc into a narrower and denser column. The modified torch can be used in both keyhole and nonkeyhole welding modes.

The modification consists in the addition of a swirl ring inside the torch, as shown in the figure. The swirl ring contains four channels and it surrounds the welding electrode, so that gas that flows along the electrode is forced to flow along these channels. Angled holes at the downstream end of the channels cause the gas to flow out with a swirling motion, forming the desired vortex.

The vortex results in a narrower and more nearly symmetrical weld bead and a narrower heat-affected zone than are contained in conventional plasma arc welding without the vortex. Degradation of the electrode and orifice is more uniform with the vortex welding arc, and the need to rotate the torch during operation to compensate for asymmetry in the arc is reduced or eliminated.

This work was done by William F. McGee and Daniel J. Rybicki of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 111*** *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 20]. Refer to MFS-28828



The **Swirl Ring** contains four channels with angled exit holes to force gas to swirl as it flows out of torch past the tip of the electrode.

Computing Surface Coordinates of Face-Milled Spiral-Bevel Gear Teeth

Data on tooth surfaces are needed for finite-element analyses of stresses and strains.

Lewis Research Center, Cleveland, Ohio

Surface coordinates of face-milled spiral-bevel gear teeth can be computed by a method that involves numerical solution of the governing equations. A numerical method must be used because the nature of the equations is such that closed-form algebraic solutions do not exist as they do for parallel-axis gears (spur gears). The numerical solutions for the surface coordinates are needed to generate mathematical models of tooth surfaces for use in finite-element analyses of stresses, strains, and vibrations in meshing spiral-bevel gears.

The governing equations describe the basic gear design and the kinematics of the cutting or grinding machinery used to fabricate the gear. The surface of a gear is an envelope of the family of surfaces traced out by the motion of the surface of the head cutter that is used to machine the gear. The points on the tooth surface generated by the motion of the cutter are points of tangency to the cutter surface during cutting. The conditions necessary for existence of the envelope are expressed by the equation of meshing, which states that a line perpendicular to the generating surface must be perpendicular to the relative velocity between the cutter and the gear-tooth surface at the point in question.

Coordinate transformations constitute an important part of the problem. It is necessary to be able to locate any point on the surface of the head cutter in a coordinate system rigidly attached to the gear being cut. Homogeneous coordinates are used for this purpose so that rotations and translations of vectors can be described simply by multiplying transformation matrices. The matrices are derived from equations that describe the shape of the head cutter and the motions of the head cutter and the workpiece in the stationary coordinate system of the gear-cutting machine.

The transformation equation obtained from the matrix multiplications gives the location of a surface point, in the coordinate system attached to the gear, as a function of (a) the machine-tool settings, (b) basic gear-design data, and (c) the parameters u, θ, and φ_c. In this equation, u and θ are coordinates of a point on the surface of the head cutter in a coordinate system attached to the head cutter, while φ_c is the roll angle of the cradle, which is part of the gear-cutting machinery as shown schematically in Figure 1.

The problem then becomes one of finding the values of the parameters u, θ, and φ_c to insert in this equation to generate the surface coordinates. The correct values are those that satisfy the equation of meshing. Three equations that are nonlinear in these parameters are derived. Because they are nonlinear, they are solved numerically by use of commercially available subroutines. A program called "SURFACE" incorporates these subroutines and solves the equations to generate coordinates for a 10-by-10 grid of surface points on each side of the gear tooth. The coordinates are then fed to the PATRAN computer program, which uses them to generate a finite-element mathematical model of the gear (see Figure 2).

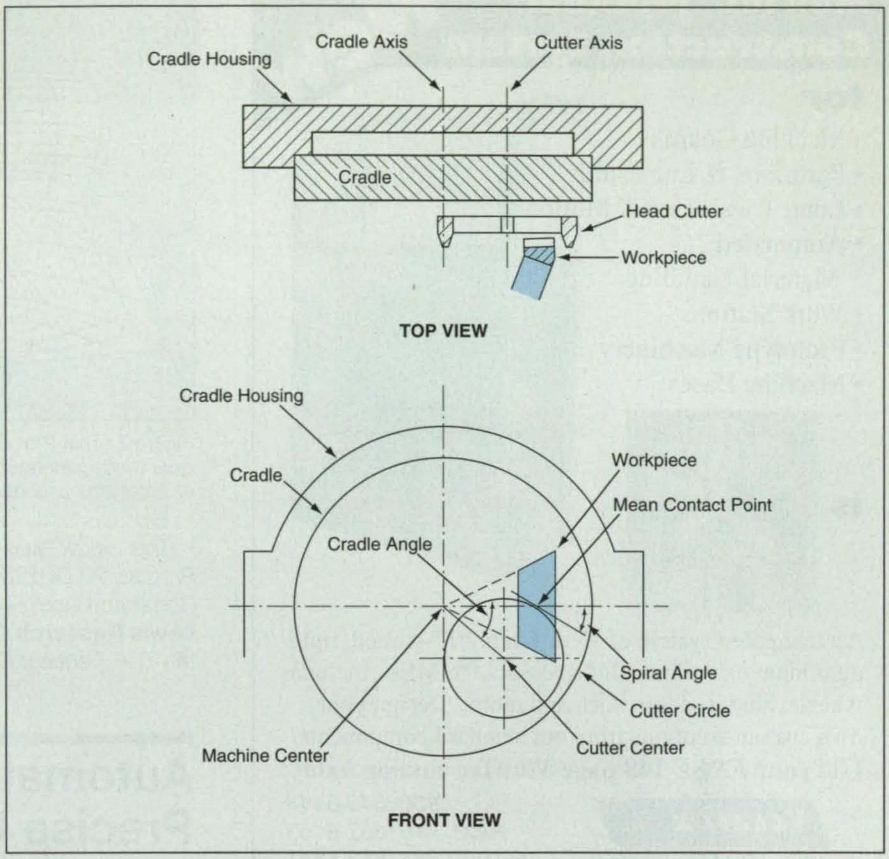


Figure 1. The **Geometric Relationships** between surface points on the workpiece and the head cutter must be taken into account via kinematical and coordinate-transformation equations in order to generate gear-tooth surface coordinates.

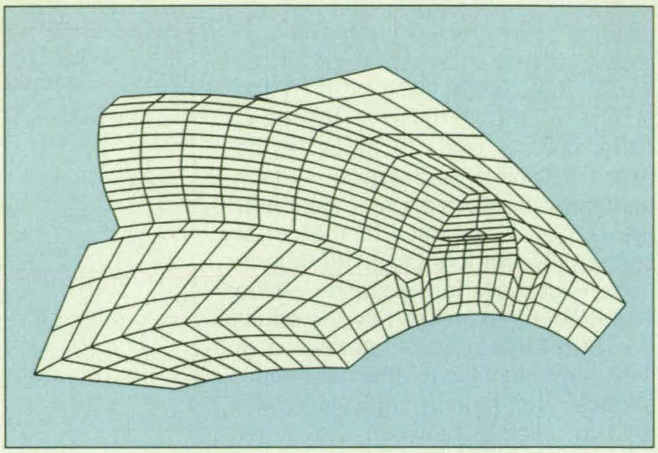


Figure 2. This **Plot Shows a Mathematical Model** of a spiral-bevel gear tooth generated by use of the SURFACE and PATRAN computer programs according to the method described in the text.

This work was done by Robert F. Handschuh of the Propulsion Directorate of the U. S. Army Aviation Systems Command and Faydor L. Litvin of the University of Illinois for **Lewis Research Center**. *For further information,* ***write in 8*** *on the TSP Request Card. LEW-15916*

Automated Inspection and Precise Grinding of Gears

Automated inspection provides corrections that increase the precision of machine tool settings.

Lewis Research Center, Cleveland, Ohio

A method of precise grinding of spiral bevel gears involves automated inspection of gear-tooth surfaces followed by adjustments of machine-tool settings to minimize differences between the actual and nominal surfaces. In many respects, this method is similar to the method described in "Computerized Inspection of Gear-Tooth Surfaces" (LEW-15736), *NASA Tech Briefs*, Vol. 18, No. 7 (July, 1994), page 73. This method eliminates most of the subjective decision-making involved in an older inspection method, in which an inspector compares contact patterns obtained by running sets of gears under light load in a rolling-test machine. The automated-inspection method yields gears of higher quality, with significant reduction in manufacturing and inspection time. For a typical spiral bevel gear of the type used in helicopter transmissions,

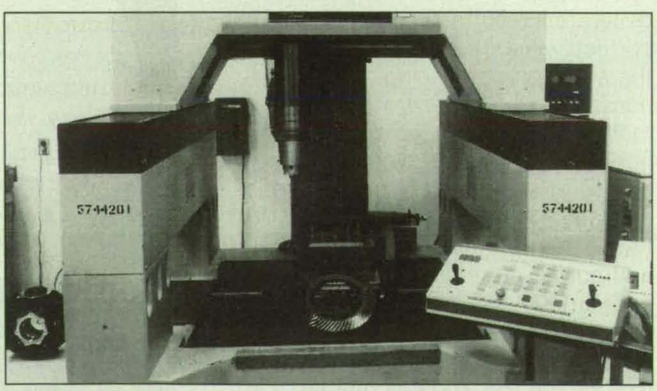


Figure 1. A **Gear Is Placed on the Indexing Table** of the coordinate-measuring machine. The probe is brought into contact with the gear teeth at many points to measure the shapes of the teeth for comparison with those of a master gear.

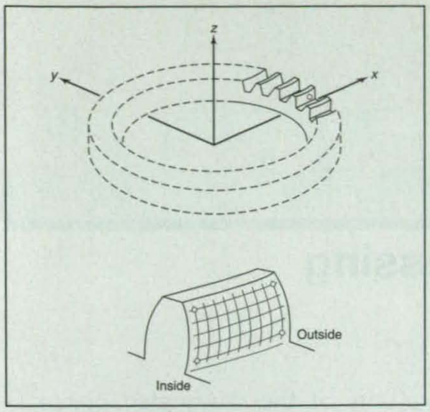


Figure 2. **Nominal Points of Contact** between the probe and the gear-tooth surface define a grid for mapping the surface and comparing with the corresponding surface of the master gear.

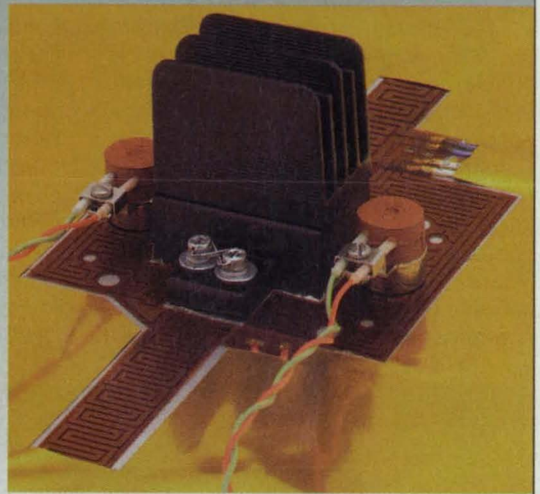
the reduction in time is about 7 3/4 hours, and cost is reduced accordingly.

In this method, automated in-process inspection of spiral bevel gears is accomplished by use of a computer-controlled multiple-axis coordinate-measuring machine with a contact probe (see Figure 1). The machine operates in conjunction with software that both (1) enables rapid optimization of the spiral bevel gear-tooth geometry during initial development of the tooth form and (2) makes it possible to maintain the developed tooth geometry during production with greater precision than was previously achievable.

During inspection, each working surface of each spiral bevel gear tooth is probed with the coordinate-measuring machine. To obtain the three-dimensional coordinates, 45 points are used (see Figure 2). A matrix of error data is then generated by comparing the three-dimensional map data on the actual surfaces with stored map data on nominal surfaces, which are those of a master reference gear. The nominal-surface data are generated in advance by similar measurements on the reference master gear.

Among the data stored in the computer are the elements of a corrective or sensitivity matrix that expresses the relationships between changes in gear-tooth surfaces and changes in machine-tool settings. The computer multiplies the error matrix by the corrective matrix to obtain changes in machine-tool settings to drive the error matrix toward zero. Thus, the precision of the gear-tooth surfaces can be enhanced initially and thereafter maintained in iterative cycles of grinding, measurement, and adjustment of machine-tool settings.

This work was done by Harold Frint (deceased) and Warren Glasow of United Technologies Corp. for **Lewis Research Center**. *For further information,* ***write in 56*** *on the TSP Request Card.*
LEW-15371



Mathematics and Information Sciences

Software for Diagnosis of Parallel Processing

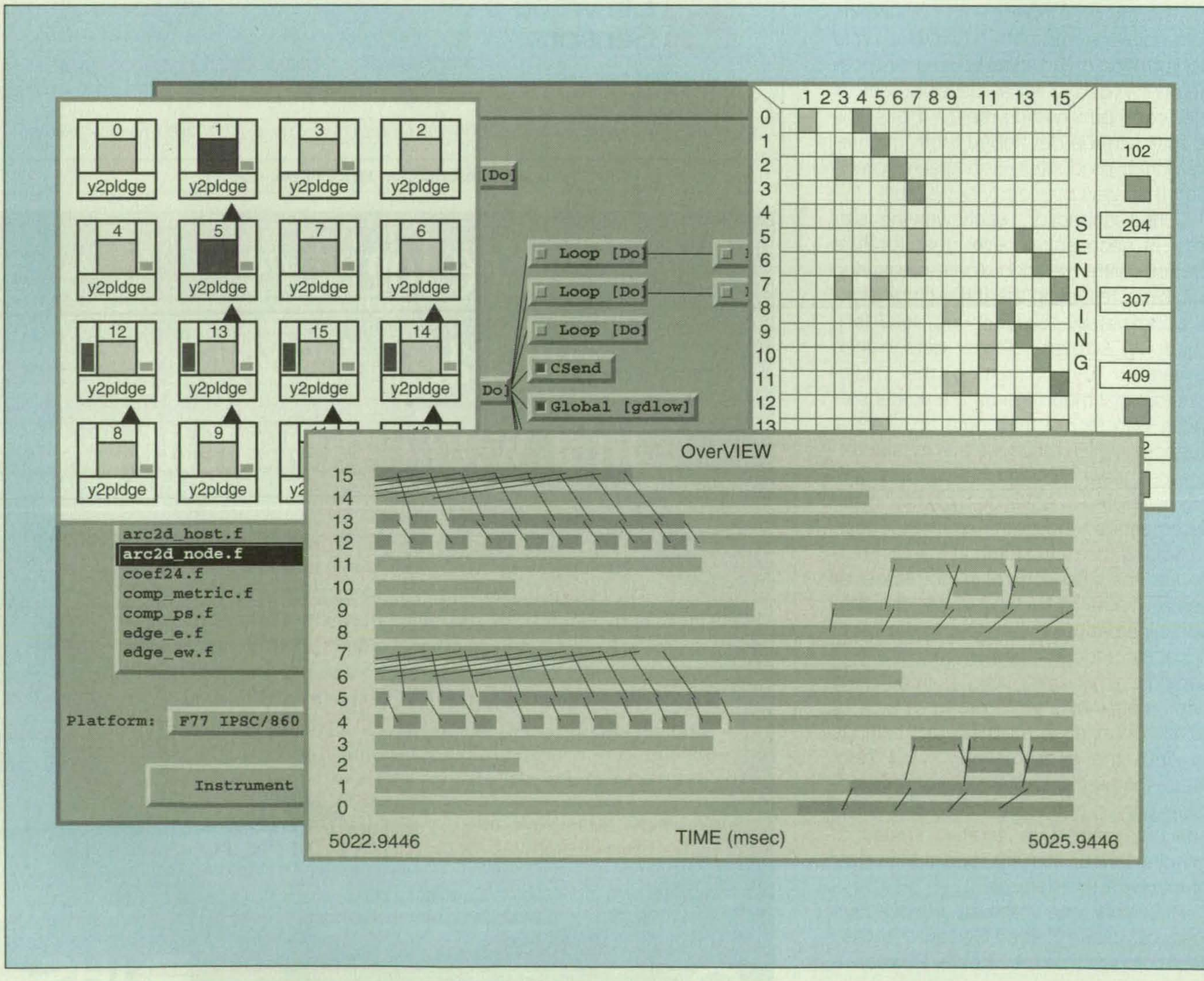
Data on performance can be displayed in graphical form.

Ames Research Center, Moffett Field, California

The Ames Instrumentation System (AIMS) computer program is a package of software tools that measure and analyze the performances of parallel-processing application programs. AIMS helps a programmer to debug and refine, and to monitor and visualize the execution of, parallel-processing application software for the Intel iPSC/860 (or equivalent) multicomputer (which comprises multiple processors interconnected in hypercube configuration). Performance data collected by AIMS are displayed graphically on computer workstations that support X-Windows.

With little or no intervention by the user, AIMS inserts software components called "event recorders" into the application software at various locations to trace the flow of control. These event recorders indicate the types and times of occurrence of the events at the designated points in the application software. The execution of the application software can then be easily reconstructed from the records generated by the active event recorders.

This technique offers important benefits for the evaluation of parallel processing — benefits not found in the techniques used previously to evaluate serial processing. For example, inserted event recorders collect



A **Sample of AIMS'** animated views is shown with the graphical interface instrumentor.

only the data needed — no more and no fewer. Moreover, inasmuch as it is implemented at the source-code level, the source code instrumentation technique is portable; a parallel program can be studied on different computers in different computing languages.

AIMS includes three principal software components, which function as follows:

- The source-code instrumentor inserts event recorders (which are function calls to a library of monitor software) directly into the application source code with little intervention by the user. By use of a mouse, the programmer simply selects specific modules and procedure calls (see figure); AIMS does the rest.
- The run-time performance-monitoring library provides a set of active event recorders to measure and record various aspects of program performance, such as message-passing overhead, processor-synchronization overhead, and processor time spent in specified parts of the application program.
- The visualization tool set processes the gathered execution data and displays them graphically. By use of animated diagrams, it shows how the application program interacted with the multiprocessor. The programmer clearly sees the state of the multiprocessor, the processing bottlenecks, and the imbalances of processing loads among the component processors. It also displays statistical views of the execution of the entire program; these help the programmer decide where the animated views should be focused.

AIMS has been used to measure the performance parallel applications developed under the high-performance computing-and-communications program. It helped identify execution bottlenecks and showed where these applications can be improved.

This work was done by Philip Hontalas of **Ames Research Center** *and Jerry Yan and Charles Fineman of Sterling Software. For further information,* ***write in 18*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 20]. Refer to ARC-13218.

Obstetrical Forceps Would Limit Force on an Infant's Head

Fiber-optic strain gauges would also measure the applied forces.

Marshall Space Flight Center, Alabama

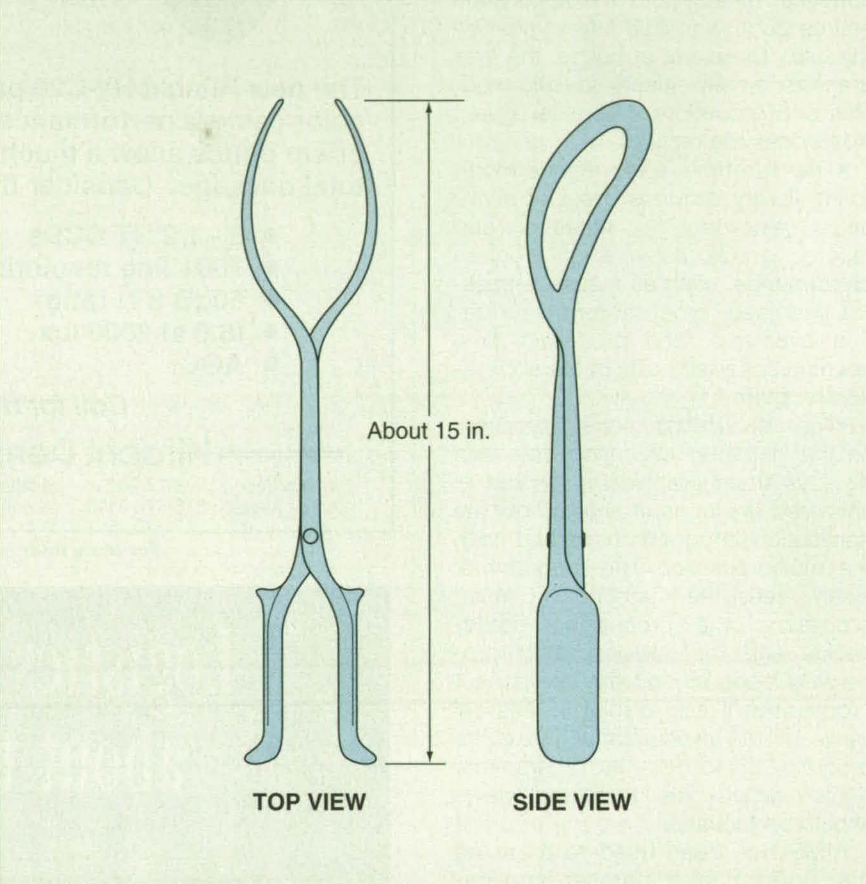
A type of improved obstetrical forceps have been proposed to reduce injuries to newborn infants. These forceps would replace conventional steel obstetrical forceps, which can cause injury because they are rigid and unyielding and provide no means for measuring and limiting the forces applied to the infants' heads.

The improved forceps would be fabricated mostly of thermoplastic material. Reinforcing fibers could be added in the hinge region of the forceps. The combination of material, size, and shape would be chosen to make the forceps yield elastically by an amount that would keep the applied force from rising beyond a maximum allowable value. Fiber-optic sensors for measuring strains would be embedded in the forceps. The strain measurements would be used to compute the tensile and compressive forces applied to an infant's head.

The sensing mechanism for the fiber-optic sensors would be a Fiber-Bragg-type reflection grating. These gratings would be written holographically using interfering beams of UV laser on the core of the optical fiber at the designated sensing location. The wavelength of Bragg reflection in each sensor would vary with the spatial period and with the spatially varying index of refraction of the grating and would thus be indicative of the combined effects of thermal expansion and strain.

To enable the computational separation of the effects of temperature from the effects of the applied forces, it may be necessary to use two grating elements for each force to be measured. One of them would be positioned and oriented so as not to be strained and would thus provide a measure of temperature only. The strain reading of the other one could then be corrected for temperature to obtain a pure strain (and, hence, force) reading.

The thermoplastic material and dimensions would be chosen to allow relatively large displacement of the head-gripping tips of the forceps without incurring permanent deformation of the forceps. This design provision would ensure that, as the forceps came into contact with the infant's head, the arms of the forceps would begin to deform and would continue to deform until the handles were pressed against each other. Forceps could be designed with cross sections tailored to different sizes of infants' heads. Since most thermoplastic materials are viscoelastic, calibration of each forceps would be necessary before each use. If forceps were made of a clear thermoplastic, then measurements of the photoelastic effect could be used to determine fatigue of the plastic material. A clear plastic would also enable the use of a holographic image in the forceps arms to produce a visible, color readout of the load applied to an infant's head.



The **Thermoplastic Obstetrical Forceps** would limit and measure the forces applied to an infant's head.

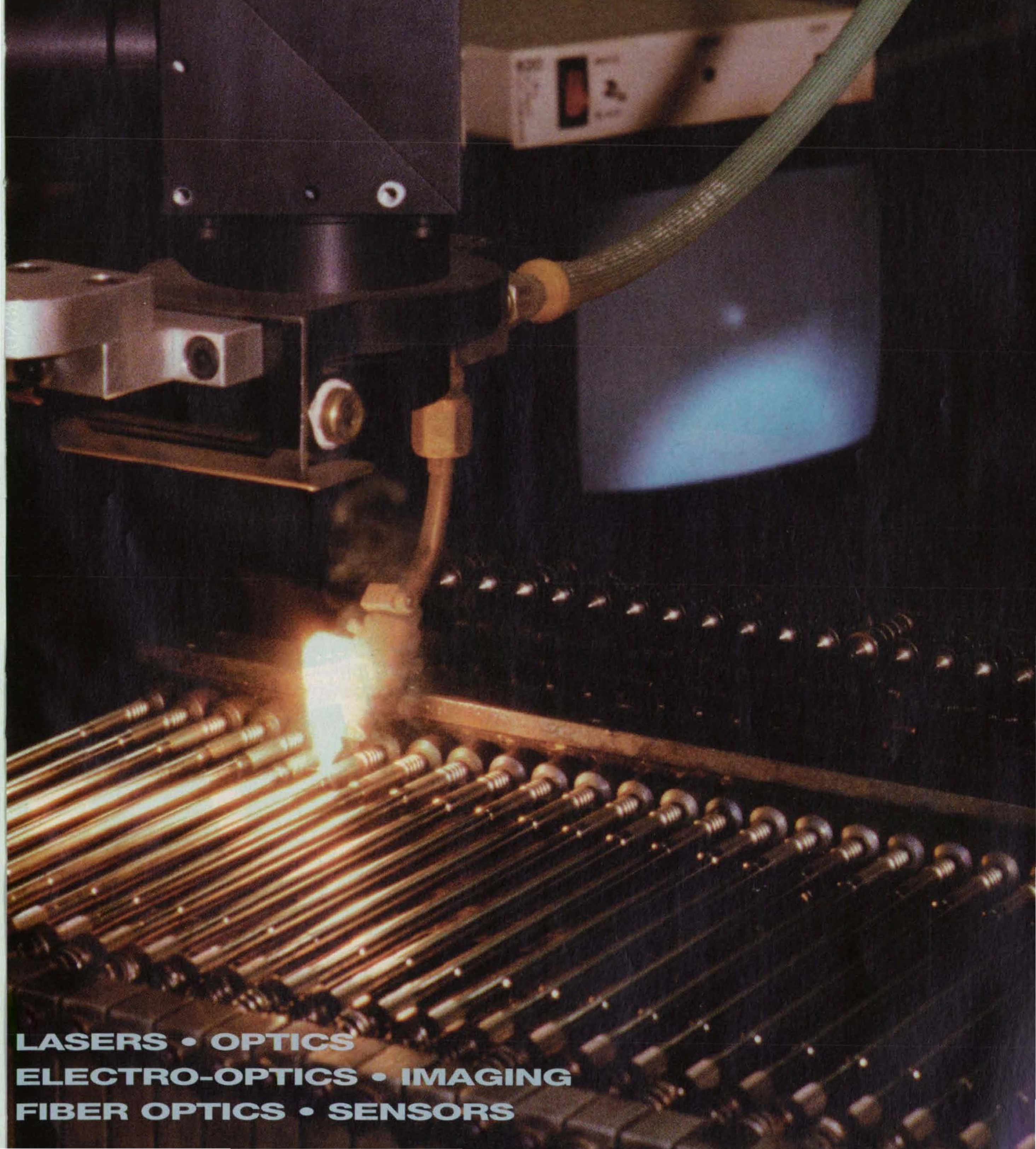
This work was done by Stan Smeltzer and Seth Lawson of **Marshall Space Flight Center**. *For further information,* ***write in 30*** *on the TSP Request Card.*

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 20]. Refer to MFS-28973.

FEDERAL LAB

LASER TECH BRIEFS

REPORTING THE LATEST FEDERALLY-DEVELOPED PHOTONICS TECHNOLOGY



LASERS • OPTICS

ELECTRO-OPTICS • IMAGING

FIBER OPTICS • SENSORS

EDITORIAL NOTEBOOK

News of the Industry and Federal Labs

• Synrad Inc. (Bothell, WA) has received US patent 5,409,314 for the technology applied in its Power Wizard power meters. These meters supply a reading of laser power by measuring the rate of change of the rise in target temperature when it is placed in the beam's path. Along with the prior cooling rate and absolute temperature, the rate of change enables calculation of the average power of the incident beam. The meters are usable with any laser between 10-2000 mW (Model PW-2) and 1-250 W (PW-250), and within the wavelengths 190-11,000 nm.

• Cree Research (Durham, NC) and Philips Electronics North America Laboratories (Briarcliff, NY) have joined forces in a two-year effort to develop blue-emitting laser diodes based on nitride materials grown on silicon carbide wafers. A final agreement on sharing funding of approximately $4 million is in the works, and the Advanced Research Projects Agency of the Department of Defense has committed another $4 million. The partners aim to further the state of the art of gallium nitride material and device technology to come up with injection lasers useful for high-density commercial memory systems and for lightweight military countermeasure systems, covert communications, and chemical-biological battlefield reagent detection.

• Affinity Inc. (Ossipee, NH) has been chosen by Fibertek (Herndon, VA) and GE Corporate Research and Development (Schenectady, NY) to design and build an integrated cooling system to be used in the development of multikilowatt diode-pumped lasers. The program is part of the Precision Laser Machining Technology Reinvestment Project award from ARPA.

• Air Force Phillips Laboratory (Albuquerque, NM) signed cooperative research and development agreements with Aerojet (Azusa, CA) for sensor development and with Xinetics Inc. (Littleton, MA) for adaptive optics research. Aerojet will deliver radiation-hardened mid-, long-, and very-long-wavelength IR focal-plane-array detectors to Phillips for testing. Xinetics will assess a high-voltage amplifier circuit board developed by the Air Force with the company's low-cost deformable mirrors driven by piezoelectric and lead magnesium niobate electrostrictive materials.

• EarthWatch Inc. (Longmont, CO) has selected Eastman Kodak's Microelectronics Technology Division (Rochester, NY) to supply the focal plane arrays (FPAs) for its first commercial remote sensing satellites. Known as EarlyBirds, they will offer imagery of the Earth with 3-meter resolution. The FPA consists of four Kodak KAI-1001M image sensors precisely aligned and mounted on a custom ceramic substrate for a total of 4 million pixels per assembly. Launch of the first EarlyBird satellite is scheduled for the first months of 1996.

• U.S. Laser Corp. (Wyckoff, NJ) has received an order for 10 Model 406-2 1-kW continuous-wave Nd:YAG lasers from Armco Inc. (Butler, PA), a manufacturer of high permeability electrical steel for large power transformers. Armco uses a patented laser domain refinement method to reduce domain-wall motion loss in the material, increasing transfer efficiency of the transformer. The low-divergence version of the laser, developed under an SBIR Phase II program for explosive ordnance disposal, will enable Armco to increase the speed and throughput of the processing line. In addition, U.S. Laser has been awarded a Phase II SBIR grant of $850,000, sponsored by the Air Force Aeronautical Systems Center at Eglin AFB, FL, for a low-loss fiber optic beam delivery system for high-power CW Nd:YAG lasers.

• In March an industry-government group unveiled the first national standards for the photonics industry workforce. The document, called the *National Photonics Skills Standard for Technicians*, results from one of 22 skill-identification projects funded by the U.S. Department of Education and based on the Secretary's SCANS (Secretary's Commission on the Achievement of Necessary Skills) Report. It springs from eighteen months' work by the Center for Occupational Research and Development (Waco, TX), a nonprofit public service organization, and participating engineers, scientists, technicians, and manufacturers from both industry and educational centers. The standard spells out what workers should know and be able to do to succeed on the job, specifying tasks, knowledge components, and tools or pieces of equipment. It also provides schools and universities with photonics curriculum guidance to meet industry needs. The 36-page publication is available for $18.50 from CCI, PO Box 21206, Waco, TX 76702-1206; (800) 231-3015. The tasks and knowledge components in the document can be accessed without charge on-line at this Internet address: http://www.spie.org/photonics_ed.html.

• A cooperative research and development agreement (CRADA) between Oak Ridge National Laboratory (ORNL, TN) and Supercond Technology (Atlanta, GA) envisions a multi-lane traffic monitoring system that will ease potential tieups in Atlanta during the 1996 Summer Olympic Games, which are expected to draw two million visitors. Supported by the Department of Energy, engineers at Oak Ridge and Supercond are teaming to develop "intelligent highways" by integrating fiber optics into a variety of materials, including composites and concrete for use in transportation systems. Sensors in Atlanta highway surfaces will transmit information about the number of cars, their speed, and the degree of area congestion to a central monitoring facility. Supercond will lead the commercialization effort. ORNL is managed for DOE by Martin Marietta Energy Systems.

• In March Coherent Inc. (Santa Clara, CA) concluded an agreement to acquire the assets of the non-telecommunications diode-pumped solid-state (DPSS) laser business of ATx Telecom Systems Inc. (Naperville, IL), formerly Amoco Laser Company. The California company was granted exclusive license under 24 US patents relating to diode-pumped lasers for all fields of use other than telecommunications, with the right to sublicense. Coherent sees the agreement as key to a broadened line of DPSS lasers in the CW green, Q-switched green, and Q-switched IR wavelengths used in medical, industrial, and other commercial applications.

• Technology Management & Funding Inc. (TMF) announced that it has acquired an equity position in Laser Ablation Systems Inc. (LAS, Albuquerque, NM), developer of a pulsed carbon dioxide laser system that strips paint from large structures. The Princeton, NJ, company, which helps fund and commercialize early-stage technology, is focusing on finding partners for LAS in two paint-stripping sectors, ships and aircraft, and is in discussion with shipyards interested in establishing ship-refurbishing businesses. LAS has set up two working systems, a 2-10-kW laser at Ogden Air Force Base (UT) and a 0.5-5-kW portable unit. Advantages include reduction of the disposable waste stream to a fraction of its original volume and adaptability to robotics applications.

• Applied Image Inc. (Rochester, NY) has acquired the Image Products Group division of PSC Inc. (Webster, NY). The Group's product lines include computer output microfilm (COM) forms, electronic forms designs, bar-code film masters, and retroreflective specialty bar-code labels. These lines will become part of Applied Image's Imaging Division, one of three operating divisions. The other two are the Instruments Division, specializing in software and instrumentation for image analysis of printing quality, metal finishes, and biomedical applications, among other things; and Glasstec, which manufactures and machines ball, plano, flat, spherical, and cylinder optics.

More Power & *New* Technology.

RS 860HF – 6kW CO_2 high frequency laser

DC 020 – 2kW CO_2 diffusion cooled laser

CW 020 – 2kW CW Nd:YAG laser

Applied.

The operative words being *more* and *new*. The key word being *applied*. With the introduction of three new laser systems, Rofin-Sinar continues to lead the way in developing the kinds of laser technologies that can be applied... applied to a variety of cutting, welding and surface treatment tasks.

The three new technologies represent Rofin's willingness to listen to the needs of the industrial marketplace and matching those needs by developing simple, flexible, reliable and easy to use lasers.

RS 860HF – a high frequency powered 6kW CO_2 laser engineered to achieve maximum productivity. High power with more stable discharge and greater control of the beam. Ceramic electrodes have replaced conventional DC anode/cathode to virtually eliminate contamination during operation and reduce maintenance procedures. Compact design minimizes floor space and allows for easy integration into automated processing systems.

DC-020 – a diffusion-cooled 2kW CO_2 laser with correcting optics and waveguide structure to generate high beam quality. The diffusion-cooled design eliminates the need for complex gas circulation and associated cooling systems. The system requires virtually no gas – less than one liter versus 95 liters/hour for units in the same power range. The construction minimizes moving parts, which greatly reduces maintenance schedules.

CW-020 – a 2kW CW Nd:YAG laser for both cutting and welding applications. Simple and compact with high power and high beam quality. Three ways of delivering output for processing flexibility – continuous wave, pulsing or a combination of both. Includes a new fiber optic beam delivery system with sensors to detect heat build up for safety and a newly-designed connector to minimize power loss at the fiber interface.

Rofin-Sinar Laser – where the words *more* and *new* are actually *applied*.

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For More Information Write In No. 495

Understanding Laser Beam Welding

Laser beam welding is a manufacturing process that continues to expand into new industries and applications because of its advantages in achieving deep penetration and in minimizing heat input. The trend to automate fusion welding processes has also led to expanded use of lasers, as computers are installed to improve product quality through more precise manufacturing control.

Laser beam welding is ideally suited for automation, since the beam can be precisely positioned with optical elements located away from the fusion zone. In addition, fiber optics are now capable of transmitting kilowatts of laser power and are used to carry the laser beam to the end of robotic welding arms.

Laser beam welding differs most significantly from traditional electric-arc welding processes in the mode of energy transfer. Unlike electric-arc energy transfer, laser energy absorption by a material is strongly affected by many factors, including the type of laser, the incident power density, and the base metal's reflectivity and surface condition.

Two important figures of merit to help characterize laser welding are the energy transfer efficiency and the melting efficiency. Energy transfer efficiency is the ratio of the heat absorbed by the workpiece to the incident laser energy. Melting efficiency is the ratio of the heat necessary to just melt the fusion zone to the heat absorbed by the workpiece. Thus energy transfer efficiency indicates how much of the laser's energy is absorbed by the part, and melting efficiency indicates how effectively that absorbed energy is used to produce melting.

Both efficiencies are extremely important in manufacturing, and both require an accurate determination of the heat input to the part to be made. Since measurements of heat input to the workpiece are difficult, there has been widespread confusion and lack of agreement in the welding community as to the magnitude of these two efficiencies. This lack of understanding among laser users has led to unsubstantiated claims about the high melting efficiency of the laser beam welding process. Lasers are often believed to be superior to other welding processes and to have performance characteristics that are exceptional.

At Sandia National Laboratories in Albuquerque, NM, the laser beam welding process has been modeled and studied extensively in recent years because of its importance in joining high-value precision components that require superior levels of quality. Knowing the heat input has been particularly important at Sandia because welding applications in the Department of Energy's weapons complex require the selection of welding processes to minimize heat input to the workpiece and to reduce distortion and thermal damage to heat-sensitive components.

To understand the laser beam welding process and to help quantify these efficiencies, Sandia researchers have made extensive measurements of the net heat input to the workpiece through the use of a Seebeck envelope calorimeter (see Figure 1). In experiments using a carbon dioxide laser to weld 304 stainless steel, they have found that the energy transfer efficiency for laser beam welding can vary over a range of 20-90 percent, depending primarily on the incident laser-beam irradiance. These results as shown in Figure 2 also indicate that the energy transfer efficiency reaches a high and approximately constant value at an incident beam irradiance of about 4.0 MW/cm2. The figure also shows that the depth of weld penetration can be varied while still maintaining high levels of energy transfer efficiency.

Optimizing the Process

For manufacturing engineers these results provide new insight into the laser welding process. During weld schedule development, a knowledge of energy transfer efficiency can be used to optimize

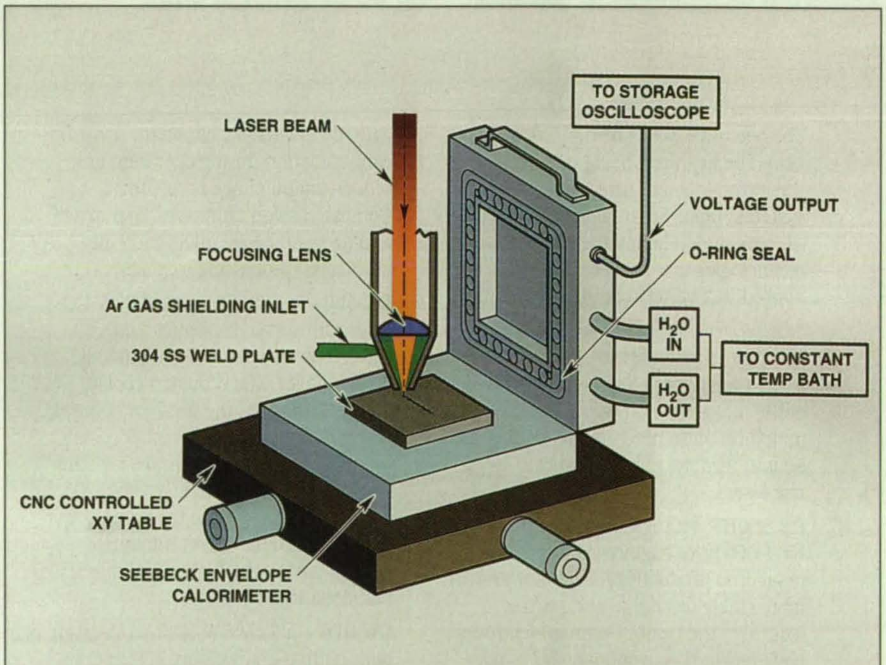


Figure 1. Carbon dioxide laser beam welding calorimetric experimental setup.

At Sandia, quantification of process efficiencies offers manufacturing engineers a simple prediction methodology.

the process and assure weld quality. For example, one can select a range of process parameters that will make transfer efficiency invariant and thereby assure that uncontrolled changes in the laser's spot size do not result in either an increase or a decrease in the absorbed power.

It is not uncommon for welding engineers to develop weld schedules in which the incident laser beam is defocused. This situation leads to the reflection of a high fraction of the beam power. In a pulsed Nd:YAG laser application at one of Sandia's laser welding vendors, the negative consequences of defocusing were dramatically demonstrated when a change in the production fixture tooling led to unapparent but catastrophic drilling of many expensive components. Clearly if one can operate in the plateau region of Figure 2 a more robust welding process can be assured.

The Sandia team has also learned a great deal about the laser's ability to minimize heat input during welding. They have found that the weld's process variables and joint geometry can dramatically affect the melting efficiency and that all fusion welding processes can be optimized to produce the same maximum melting efficiency. The laser really possesses no intrinsic advantage for high melting efficiency. It is apparent from the Sandia research that the primary advantage of the laser process in minimizing heat input to the part stems from its ability to make very small or especially deep welds that cannot be made with other processes.

A Quick Way to Estimate

To simplify the analysis of laser welding, the researchers employed dimensionless parameters to present diagrammatically experimental data that have resulted in equations that can be readily used to estimate the efficiencies of the process. This simple prediction methodology is notable because it requires only a knowledge of the weld schedule and the material properties in order to estimate melting efficiency. The straightforward mathematical relationship between these parameters can be used to quickly estimate the heat input to the part based on the size of the weld or for other optimization tasks such as selecting levels of travel speed and heat- source power that will reduce thermal damage to the weldment.

For the applications engineer to decide on the cost-effectiveness of the laser beam welding process, the model can be used to examine important processing details and to determine the ultimate capabilities of a specific laser before it is purchased. To determine the required functional characteristics of the laser for an application, one must consider the production feed rates to be obtained, the size of the fusion zone to be melted, the thermal properties of the materials, and the process efficiencies. All of this information can be obtained from the dimensionless parameter model.

In addition to continuing this work, the Sandia team is planning to do new calorimetric studies on other materials with other lasers. This research also includes accurate measurements of the laser beam's spot size to provide needed understanding of its propagation through focusing optics. Laser welding is clearly the welding process of the future, but its application can often be limited by a lack of knowledge of the process. Sandia anticipates an increase in the application of laser beam welding and so seeks to extend understanding of the process.

Material for this resource report was supplied by Phillip Fuerschbach of Sandia National Laboratories. For further information, contact Mr. Fuerschbach at Dept. 1831, Albuquerque, NM 87185-0340; (505) 845-8877; E-mail pwfuers@sandia.gov.

Alternatively, inquiries may be directed to the Alliance for Photonic Technology, 851 University Blvd., Bldg. 1, Suite 200, Albuquerque, NM 87106-4339; (505) 272-7001. LTB

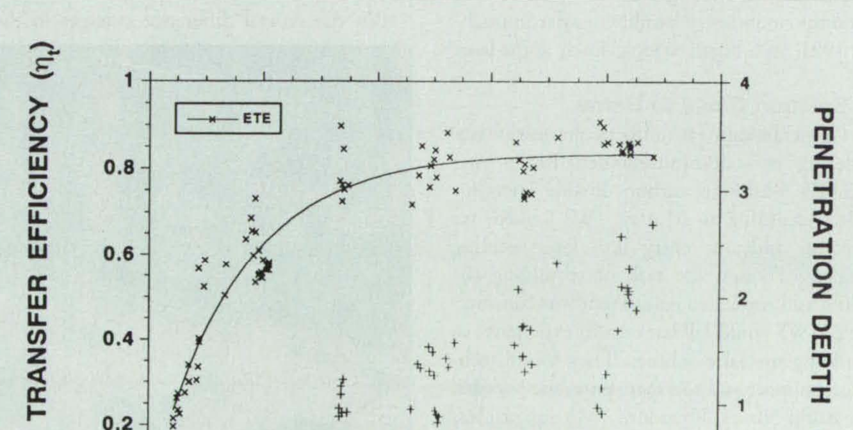


Figure 2. Variation of measured energy transfer and weld penetration with beam irradiance for carbon dioxide laser welds on 304 stainless steel.

BRIDGING THE GAP

For one small company, the laser led the way from aerospace specialization to a host of commercial applications.

The story of a small Saginaw, Michigan, company called Special Welding Services (SWS) has a point to make about moving from the limited sphere of aerospace specialization into the larger commercial arena. It was a transition made possible by the rapidly growing maturity of laser technology in the past decade, augmented by the foresight and resourcefulness of SWS's staff.

SWS got its start in 1967, when its principal line of business was to weld fuel-injector nozzles for jet engines. At that time electron-beam (E-beam) welding was the only technology that could provide the high quality that the aerospace and defense industries required. But by the same token the process was so expensive and time-consuming that it was self-limiting.

Soon, according to Jay Morley, president of SWS, the company (then called Advanced Technologies Inc.) began looking for ways to expand its business apart from E-beam welding. It moved into building custom machine tools and fabricating equipment. In 1984, the welding and the fabrication functions separated. With the E-beam market sufficiently strong to support the company, SWS was on its own.

These years saw increasing aerospace engine and airframe orders and newly developed medical implants, both sectors using exotic stainless and titanium alloys. Yet the next impetus for expansion came from a different, if not entirely unexpected, direction. The automotive industry, SWS's gargantuan Michigan neighbor, began experimenting with ways to reduce vehicle size and weight, and SWS took on many prototype E-beam welding jobs.

But, Morley says, "we realized that costs and processing time of that technology would be prohibitive to any production volume the automotive industry would consider normal." In 1991 SWS began to look closely at the laser.

A Solution Close to Home

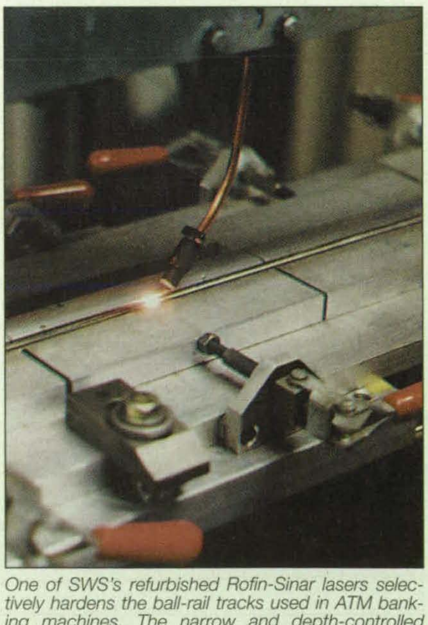
Coincidentally, an auto plant nearby was offering two decommissioned Rofin-Sinar RS-975 5-kilowatt carbon dioxide lasers for sale. According to Morley, "We looked, we bought, and our entry into laser welding began." Though the task of rebuilding the aging and neglected equipment was considerable, SWS could fall back on its experience in building special machines. They found technical support and the spare parts they needed at Rofin-Sinar's Plymouth, MI, plant, just two hours' drive away. Though the power supplies and peripherals such as wiring had to be completely overhauled, the laser resonator and its optics were still in good shape, Morley says. A new computer-numerical control unit was added to the systems to bring them into the nineties. The first laser was up and running by early 1992.

SWS constructed a laser lab within its plant, putting the operating unit and the power supply on the roof above the lab. Mirrors deliver the beam to the welding workstation below, where the control unit is also located. The workstation's X-Y-Z table has tooling to add a rotational axis when required.

Morley and his colleagues were pleased with the results of the first few jobs with the laser. Though the E-beam continues to deliver the highest-quality weld needed for demanding aerospace applications, he points out that the laser is also a high-energy-density technique, and that quality is not substantially inferior. Moreover, the laser can do many jobs two to three times faster or more than the older technique previously used.

One example is a tubular part used in a power tool for the construction industry. Internal machining requirements dictated that the 7-inch barrel be constructed from two pieces welded together. The assembly was to be reciprocating within bearing surfaces, so runout between the two ends had to be within 0.005 in. total indicated reading, and critical machined features radially located within a ±1° tolerance. Both the E-beam and the laser system could meet the requirements.

But the crucial difference emerges in the speed of the two competing techniques. The carbon dioxide laser can weld three barrels per minute. By contrast, using the E-beam means that the welding must be done in a lead-lined chamber of limited size and in a 1×10^{-4} Torr vacuum. Taking time for loading and vacuum pumping into account, the E-beam can deliver only one barrel every five minutes.



One of SWS's refurbished Rofin-Sinar lasers selectively hardens the ball-rail tracks used in ATM banking machines. The narrow and depth-controlled heat-affected zone makes straightening easy and crack-free.

Using the laser, Morley calculates, cuts costs by a factor of 20. With a projected 150,000 units a year, the saving is substantial.

Other jobs the laser can do include transmission prototype components and production parts, as a backup for auto companies' own production capabilities. SWS also laser-welds a ball valve part in yearly quantities of 400,000. In another laser application, the company heat-treats the bearing-surface area of ball rails used in the sliding mechanism of ATMs. The laser's ability to limit the heat-affected zone means localizing the hardening to the predefined area and depth, so the rails can be easily straightened without cracking or breaking.

A Distinct Advantage

Last year SWS added a 500-W Rofin-Sinar RSY 500P Nd:YAG laser to its welding machine shop. This system has one distinct advantage over carbon dioxide lasers: the ability to deliver the beam via fiber optics, which increase flexibility of delivery and improve control over energy density at the weld site.

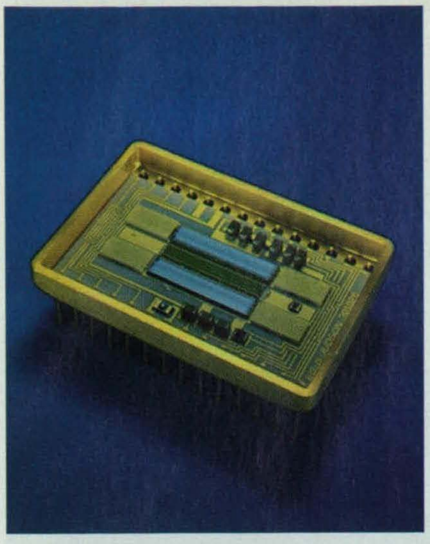
Except for some short-run prototype work, SWS is currently using the Nd:YAG laser almost exclusively for welding orthoscopic needles. Surgeons use these needles, about a quarter-inch in diameter, to penetrate bones during surgery. Welding is needed because the instrument is made of two dissimilar materials, an austenitic stainless-steel hollow shaft and a hardened martensitic stainless tip.

Morley points out that SWS averages 350 needle assemblies per hour with the laser, about three and half times the number with the E-beam. With a projected 300,000 units per year, one laser suffices—with time left over for other jobs—whereas one E-beam could not meet this requirement.

Morley points out that the refurbished lasers have a record of 95 percent up-time, in spite of being more than a decade old. SWS has grown tenfold since 1984, when it split off as exclusively a welding shop. As he investigates new laser technology, Morley expects even more rapid growth in the future.

"We do different things with the lasers every day," he observes. "I am constantly amazed at the range and diversity of the laser's applications. I'm like a kid in a toy shop.

"We do a lot of development work, even for our competition in the laser business, who then take it into production. But we are rapidly getting to the point that we can handle all production runs. We plan to increase our floor space by about 28,000 square feet within five years," Morley says, "and 20,000 of that will house lasers."



NIR Linear Arrays

Low cost NIR linear photodiode arrays are now available for wavelengths ranging from 800 to 1800 nm. InGaAs and Ge arrays with pixel sizes ranging from 50x100µm to 0.1x2.5mm are available in lengths up to one inch for highly sensitive liquid nitrogen, TE cooled and room temperature applications such as spectroscopy, imaging, far-field beam analysis and astronomy.

Write in No. 484

IR Detectors in Dewars

EG&G Judson offers standard dewars for 77° Kelvin detector operating temperature. Repumpable metal dewars are recommended for laboratory or R&D use. Advantages include rugged construction, low cost, long hold time, optional mounting flanges and a wide range of window material. Long life, permanently sealed glass dewars as well as dewars with custom configurations are also available upon request.

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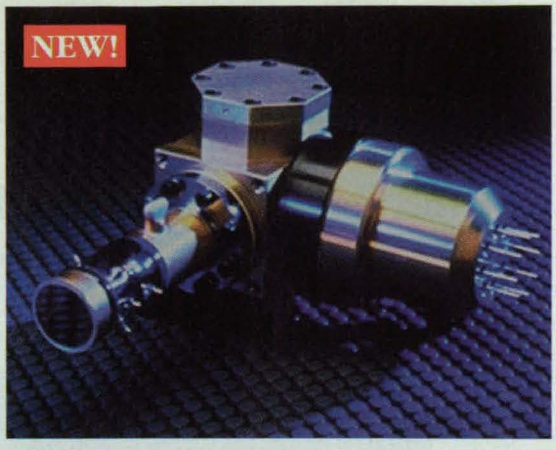

Stirling Coolers

Fully integrated detector/cooler assemblies for 77° Kelvin operation are now available in production quantities. Integral rotary coolers weigh less than one pound and run at less than five watts of input power. Dual opposed piston split stirling linear cooler assemblies are available where low microphonics and 24-hour operation are the primary concerns.

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Try some of the world's most advanced IR detector technology.

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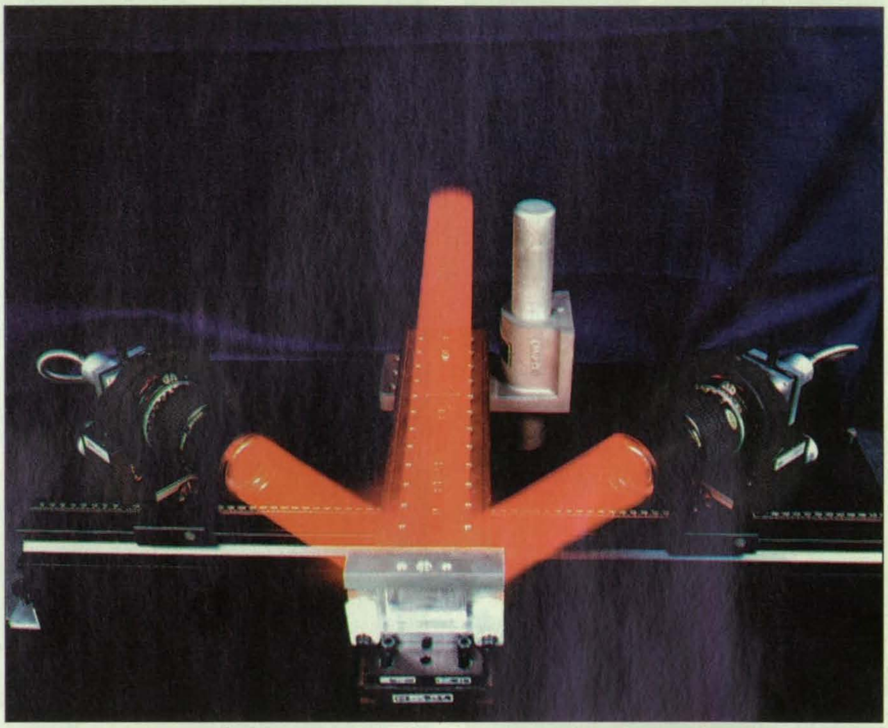
Diffraction Moiré Interferometry for Deformation Research

The technique increases understanding of phenomena such as stress and fracture in most materials.

Idaho National Engineering Laboratory, Idaho Falls, Idaho

Diffraction moiré interferometry is an important new tool in material properties research. The method yields highly accurate measurements of deformation in a variety of materials, and is especially useful in studying complex, anisotropic structures. With the newly developed INEL moiré hardware, it is now possible to perform such measurements in the field for nondestructive testing and lifetime fatigue estimates. An area with great potential is such a system to monitor the mechanical condition of critical components of large structures such as bridges, tanks, piping, aircraft components (struts, wing assemblies, etc.), pressure vessels, submarine hulls, or other components with high risk factors.

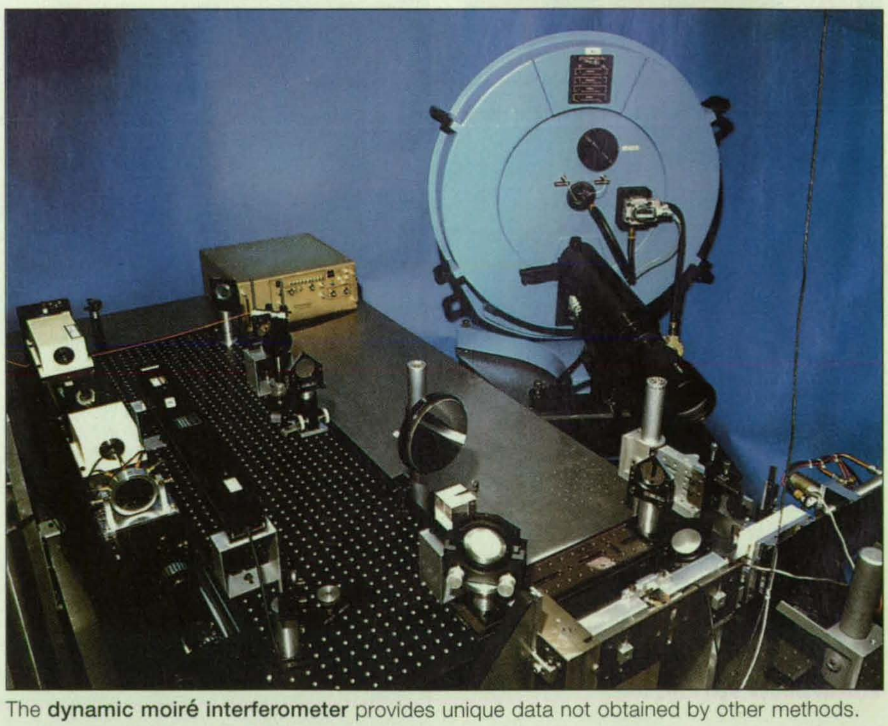
The series of diffraction moiré interferometers developed at INEL used advanced fiber optic devices to greatly simplify the design and utilization of the systems. They range from briefcase size to a handheld unit, and all incorporate the latest advances in automated phase-shifting data acquisition and analysis. Every effort has been made to reduce the complexity of the equipment, of its operation, and of the data analysis, and to improve the stability of the system. This is in sharp contrast to the more conventional moiré apparatus, which utilized complex discrete optical and mechanical components and hand analysis of the data.



In the **fiber optic moiré interferometer** system, two beams are projected by the output lenses converging on the specimen grating. The resulting beam leaves the grating and is directed to the back of the system. This illustrates the flexibility permitted by the optical fibers.

The portable moiré interferometer is a compact, fully featured device suitable for most deformation research needs. It can be configured for uniaxial or biaxial distortion measurements, with a resolution of 10 nm (equivalent to 5 microstrain over a 50-mm sample). It is possible to adapt the system for less sensitivity if large deformation is expected.

The handheld moiré interferometer has fixed sensitivity, and is uniaxial (biaxial displacements can be recorded in two successive measurements), but retains the resolution of the portable system with even simpler operating requirements. Both systems can be taken from storage and be ready to take data in less than 20 minutes.



The **dynamic moiré interferometer** provides unique data not obtained by other methods.

A third system, while much more complex, expensive, and specialized, permits unique measurements of very

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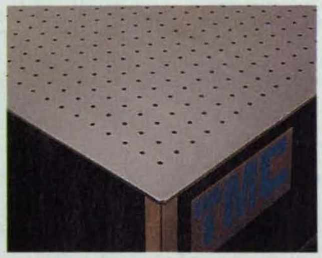

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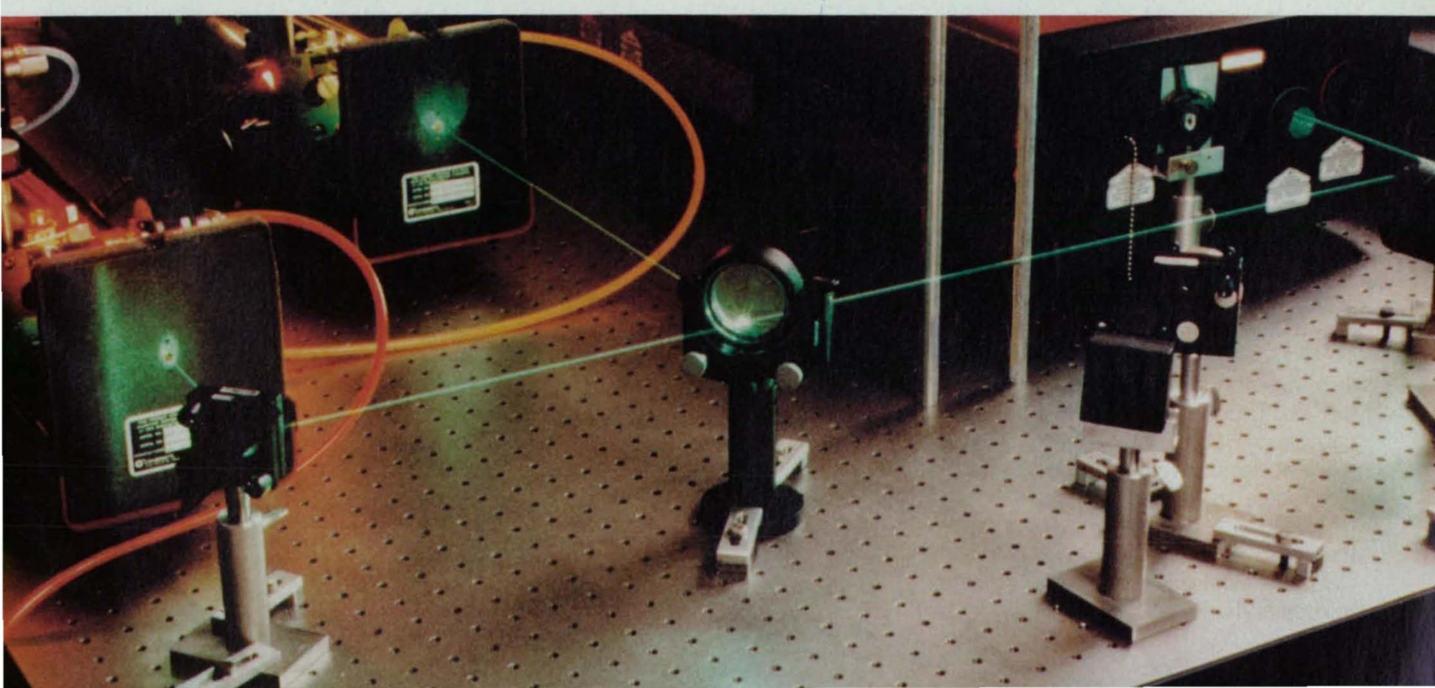


rapidly deforming objects. The dynamic moiré interferometer combines diffraction moiré high-speed pulsed lasers and high-speed photography to aid in the understanding of impact, fracture, and failure. Unlike the other INEL interferometers, this system is not suitable for use by nonexperts, but provides unique data not obtained by other methods.

This work was done at the **Idaho National Engineering Laboratory**, *a facility operated for the US Dept. of Energy by Lockheed. For more information on the commercial transfer of this technology, contact Charles W. Briggs, Office of Research and Technology Applications, PO Box 1625, Idaho Falls, ID 83415-3805; (208) 526-0441; FAX (208) 526-0876; E-mail: cwb@inel.gov*

Ferroelectric Thin-Film Capacitors as Ultraviolet Detectors

Advantages include rapid response, solar blindness, and relative invulnerability to ionizing radiation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Ferroelectric thin-film capacitors may prove useful as solar-blind detectors of ultraviolet radiation. These detectors would compete with such other ultraviolet detectors as charge-coupled devices (which are not solar-blind and are vulnerable to ionizing radiation) and photocathodes with multichannel-plate amplifiers (which involve several disadvantages and complications, including recovery times longer than 1 μs and the need for high-voltage power supplies).

The principal ferroelectric materials under consideration for use in these devices are perovskite titanates (lead zirconate titanate, strontium titanate, and barium titanate), which feature gaps of 3 to 4 eV between the valence and conduction electron-energy bands (energy "bandgap") and which are relatively invulnerable to ionizing radiation. Ferroelectric ultraviolet detectors offer additional advantages of response times ≤ 1 ns, no need for high-voltage power supplies, low power consumption (power needed only by the associated sensing circuits), operation at room temperature, and availability of fabrication technology to incorporate them into silicon-based integrated circuits to form compact, lightweight arrays of detectors and sensing circuitry.

Heretofore, the high-speed photoeffects of ferroelectric capacitors have been considered as the basis for nondestructive optoelectronic readout of the contents of ferroelectric memory devices, as described in "Optically Addressable, Ferroelectric Memory With NDRO" (NPO-18573), *NASA Tech Briefs*, Vol. 18 No. 3, (March 1994), page 32 and "Rapid, Nondestructive Readout From Ferroelectric Memory" (NPO-18551), *Laser Tech Briefs*, Vol. 1 No. 1, (September 1993), page 28. To exploit the photovoltaic property, a ferroelectric capacitor is constructed by sandwiching the ferroelectric layer between two metal electrodes, one of which is semitransparent (see Figure 1). Experiments have shown that illumination of the semitransparent electrode with photons of energy equal to or greater than the bandgap of the ferroelectric material gives rise to a photocurrent that includes a component attributable to the remanent polarization in the ferroelectric material (this polarization represents the stored datum to be read out) and a polarization-independent component.

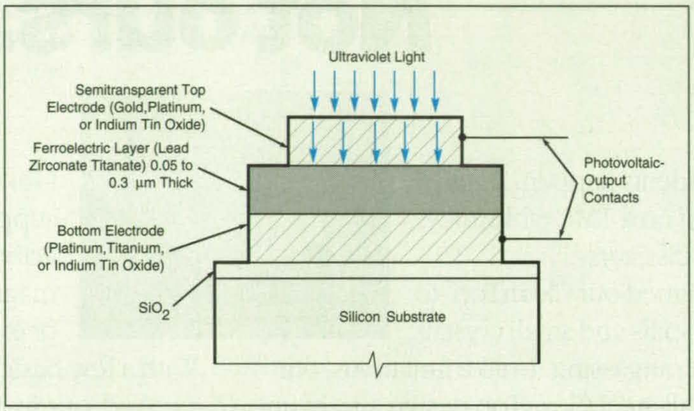


Figure 1. A **Ferroelectric Capacitor** can be made to function as a photovoltaic detector of ultraviolet photons by making one of its electrodes semitransparent.

The polarization-independent component of photocurrent has been tentatively attributed to the fact that the Schottky barrier at the illuminated interface between the semitransparent electrode and the ferroelectric layer is taller than the Schottky barrier at the interface between the other electrode and the ferroelectric layer. Therefore, it has been proposed that to take better advantage of the photovoltaic effect for detecting ultraviolet photons, the device should be fabricated with a dominant Schottky junction at the illuminated interface (see Figure 2) so that the electric field in the device would separate the photogenerated charge carriers more efficiently, allowing less recombination time. The charge-carrier-trapping mechanisms would be minimized by ensuring that absorption of the incident photon flux occurs primarily at the illuminated interface. Yet another improvement would be to optimize the thickness of the ferroelectric film to form a resonant optical cavity.

This work was done by Sarita Thakoor of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 135*** *on the TSP Request Card.*
NPO-18695

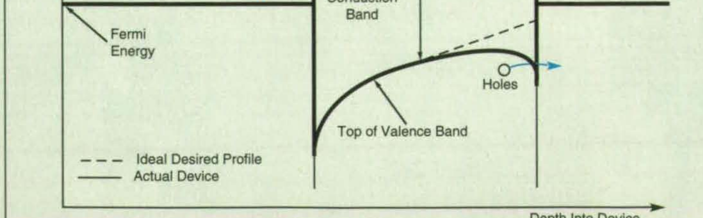


Figure 2. The **Photovoltaic Effect Can Be Exploited More Fully** by making the Schottky barrier at the illuminated semitransparent-electrode/ferroelectric interface taller than the Schottky barrier at the other electrode/ferroelectric interface.

Laser-Beam-Alignment Controller

Operation is controlled by fuzzy logic.

Lewis Research Center, Cleveland, Ohio

A digital electronic control system based on fuzzy logic has been developed to automate the alignment of a spatial filter with a laser beam. The spatial filter includes a pinhole that can be moved along the x and y axes (which are perpendicular to the optical axis) and a lens that can be moved along the z axis (the optical axis, nominally coincident with the axis of the laser beam). The control system imitates the actions of a human technician in performing the x, y, and z adjustments.

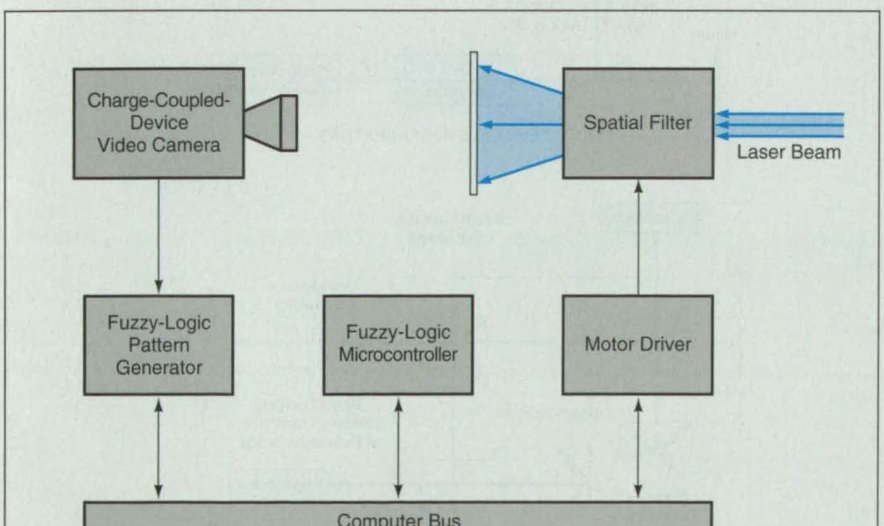
A fuzzy-logic controller was chosen for this task, instead of a neural-network controller, primarily because a fuzzy-logic controller is cheaper and, in the particular application, can be set up and operated with less preparation and less computational overhead. Fortuitously, a human technician's actions in adjusting a spatial filter can be described by a set of fuzzy rules. In addition, fuzzy-logic circuitry can flexibly accept inputs and produce outputs in data formats compatible with those of the rest of the system.

The immediate purpose of the adjustments is to maximize the intensity of the spot of light formed by projecting the laser beam onto a translucent target, eliminate diffraction rings in the spot, and center the spot on the optical axis. To quantify the spot of light for processing into adjustment control signals, a video image of the spot is digitized to as many as 6 bits in each pixel in an array of 128 × 116 pixels. Then, operating at the video frame rate by processing the digitized image data from all the pixels simultaneously on parallel paths, the system compares the digitized image with each of five stored reference patterns.

The arithmetic result of the comparisons is a Euclidean or Hamming distance between the digitized image and each reference pattern. An increase in such a distance measure can be regarded, in fuzzy logic, as an indication of decreasing strength of membership of the image in the set of images represented by the reference pattern. Using a total of 49 fuzzy-logic rules that formalize the relationships between these distance measures and light-spot intensity distributions of various degrees and kinds of misalignment, the control computer issues adjustment control signals to three motor drives that effect the x, y, and z adjustments of the spatial filter.

In a test of the system, the pinhole and lens were purposely misaligned, but the resulting spot was kept within the view of the video camera. With the motor speeds used, the system took about 15 seconds to restore alignment in typical cases. The results achieved by the system were judged "good" by a skilled technician accustomed to performing manual alignment of the laser beam.

*This work was done by M. J. Krasowski of **Lewis Research Center** and D. E. Dickens of the University of Dayton. For further information, **write in 7** on the TSP Request Card. LEW-15913*



In the **Laser-Beam-Alignment Controller**, images from the video camera are compared to reference patterns by the fuzzy-logic pattern comparator. The results are processed by the fuzzy-logic microcontroller, which sends control signals to the motor driver that adjusts the lens and pinhole in the spatial filter.

Programmable Iterative Optical Image and Data Processing

Programming would be effected by selective, timed amplification to compensate for repeated propagation losses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of iterative optical image and data processing would overcome the limitations now imposed by the loss of optical power after repeated passes through many optical elements — especially, beam splitters. The method was conceived for use in such optical-processing schemes as those that involve repeated comparisons, in a VanderLugt optical correlator, of reference images with each of many different versions of an input image generated by small increments of rotation and scaling, the purpose being to find a correlation or match between the input image and one of the reference images. The method would involve a selective, timed combination of optical wavefront phase conjugation and amplification to regenerate images in real time to compensate for losses in optical iteration loops; the timing would be such that the amplification would be turned on to regenerate the desired image, then turned off so as not to regenerate other, undesired images or spurious light propagating through the loops from unwanted reflections.

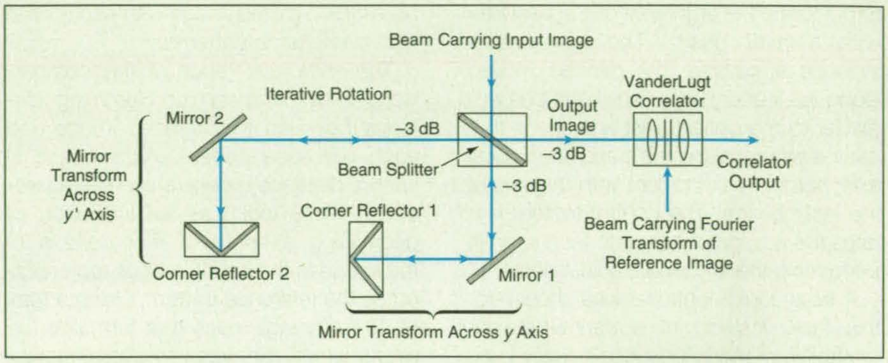


Figure 1. A **Basic Iterative Rotation Processor** is a conceptual optical processor in which rotated versions of an input image would be generated in rapid succession by multiple reflections and presented to an optical correlator. Multiple-pass optical losses make this processor impractical.

Figure 1 schematically illustrates an iterative rotation processor of the type described above, but without amplification according to the proposed method. In principle, the input image could be rotated iteratively, in small increments, through a full circle by repeated passes through two suitably aligned mirror transform modules. In practice, amplification would be needed to overcome the optical loss on each pass, thereby retaining enough optical power to query all angles of interest.

The top part of Figure 2 schematically illustrates two alternative regeneration schemes, while the bottom part of Figure 2 shows the configuration of a rotation processor containing regenerator units according to this method. In either scheme, the affected beam of light would be reflected into one end of a multimode optical fiber that would be long enough (typically ≤ 1 km) to introduce enough delay (several tens of microseconds) to facilitate timing control for switching amplification on and off (with typical switching times of the order of 1 μs and perhaps eventually less). Such delays (denoted τ1 and τ2 in Figure 2) would also be chosen much longer than the delay, τ0 along the free-space segments of the optical path.

In one of these schemes, both amplification and wavefront phase conjugation would be effected by four-wave mixing at the second-mentioned end of the optical fiber. In the other scheme, a two-wave-mixing phase conjugator and an optical-fiber light amplifier would be used; the optical fiber would serve as both the amplifier and the delay line. Propagation of an optical image launched into the fiber at point P would scramble the phases of the image data emerging at point Q. To remove the phase scrambling from the image, one can use wavefront phase conjugation at the point-Q-end of the fiber to generate a "time-reversed" wavefront, which upon propagating back through the fiber, would reemerge unscrambled at point P.

This work was done by Deborah J. Jackson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 86*** *on the TSP Request Card.*

NPO-19394

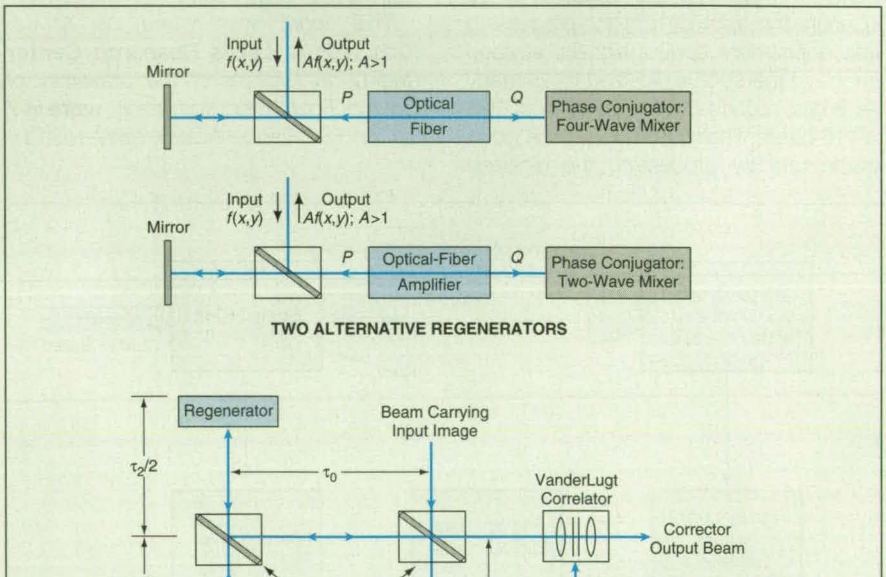


Figure 2. **Image Regenerators** according to the proposed method would compensate selectively for optical losses in this iterative rotation processor.

Polaradiometric Pyrometer

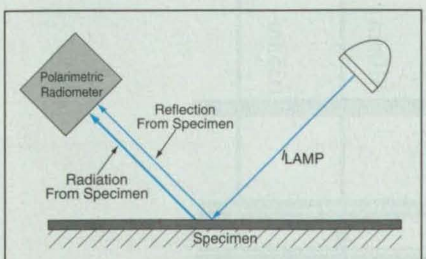
It is not necessary to determine the emissivities of the specimen.

NASA's Jet Propulsion Laboratory, Pasadena, California

The polaradiometric pyrometer is a conceptual pyrometer that would provide measurements from which one could calculate the temperature of a specimen, without having to measure or account explicitly for the polarization-dependent emissivities and reflectivities of the specimen. The polaradiometric pyrometer would include a polarimetric photometer or radiometer and a lamp that emits light of spectral intensity I_{LAMP} at wavelength λ. I_{LAMP} would be both measurable and controllable. The instruments would be arranged so that lamp light reflected from the specimen would enter the polarimetric photometer along with thermal radiation emitted by the specimen (see figure).

The principle of operation of the polaradiometric pyrometer is based partly on the simple equations for the relationships among the emissivities, the reflectivities, and the intensities of the various polarization components of light emitted by, and light reflected from, the specimen. A straightforward derivation that starts from these equations leads to a simple criterion for determining the spectral intensity, I_b, of radiation emitted by the specimen at wavelength λ: The effects of the emissivities and reflectivities would balance each other in such a way that when $I_b = I_{LAMP}$, the light that entered the polarimetric photometer would be unpolarized (that is, the intensity of entering light polarized in the plane of incidence would equal the intensity of entering light polarized parallel to the plane of incidence). Thus, to determine I_b without having to measure the polarization-dependent emissivities or reflectivities of the specimen, it would suffice to adjust I_{LAMP} until the desired unpolarized condition was obtained. One would then measure I_{LAMP}.

Then, using $I_b = I_{LAMP}$ and assuming that the specimen emits black-body radiation, the absolute temperature, T, of the specimen could be computed by use of Planck's radiation law. The customary form of Planck's radiation law can be manipulated easily to obtain $T = hc/\lambda k \ln[(2hc^2/I_{LAMP}\lambda^5) + 1]$, where h is Planck's constant, k is Boltzmann's constant, and c is the speed of light in a vacuum.



The **Polaradiometric Pyrometer** would provide measurements of spectral intensities in two perpendicular polarizations. When the brightness of the lamp was set so that the two measured intensities were equal, the measurements could be used to compute the temperature of the specimen.

This work was done by Ali A. Abtahi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 13*** *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 20]. Refer to NPO-19064.

Tunable Blue, Green, Orange, and Red Upconversion Fiber Lasers

An upconversion fluoride fiber laser codoped with praseodymium and ytterbium produces coherent radiation at several wavelengths.

Los Alamos National Laboratory, Los Alamos, New Mexico

For applications in optical data storage, full-color displays, color printing, and biomedical instrumentation, there has been strong interest in the development of all-solid-state lasers that generate visible output wavelengths. One of the most promising approaches to this problem makes use of frequency upconversion in insulating solids.

Frequency upconversion is a process in which the energy resident in two or more infrared pump photons populates a high-lying energy level of a laser-active ion. One-photon transitions to low-lying levels then yield visible light. Many upconversion lasers based on doped optical fibers have produced output wavelengths ranging from the near-infrared to the ultraviolet. But the greatest advantage offered by the optical fiber geometry is that room-temperature operation is much easier to obtain than in the bulk-gain media more conventionally employed.

The visible upconversion laser described here offers many unique characteristics that are attractive for many applications. For instance, the laser can be pumped by a single GaAlAs laser diode, and it produces tunable multicolor visible output at room temperature. To the knowledge of the researchers, their 300-mW output power obtained at 635 nm is the highest yet reported for room-temperature operation of an upconversion laser. The combination of a laser diode pump and an optical fiber gain medium makes possible extremely compact packages suitable for a diversity of real-world applications.

The experiments used two fiber-laser cavity configurations. In the first, dielectric mirrors are butted against the fiber ends. One of these serves as a high reflector, the other as the output coupler. For the sake of convenience, and to test pump wavelength tunability, a tunable Ti:Al_2O_3 laser is used as a surrogate for a diode-laser pump. A 20X microscope objective focuses the pump light through the high reflector onto the fiber end. The second configuration is similar to the first, except that a collimating ball lens and an intracavity prism interposed between the output coupler and fiber end provide wavelength discrimination sharper than that provided by the mirror coatings. The prism also makes possible fine tuning of the output wavelength.

The laser-active medium is a ZBLAN® single-mode fiber doped with 3000 ppm by weight of Pr^{3+} and 20,000 ppm by weight of Yb^{3+}. Its core and cladding diameters are 3 micrometers and 125 micrometers respectively. The fiber has a numerical aperture of 0.3 and a cutoff wavelength of 1.17 micrometers. A variety of fiber lengths ranging from 20 cm to 10 m were used in order to investigate laser operation.

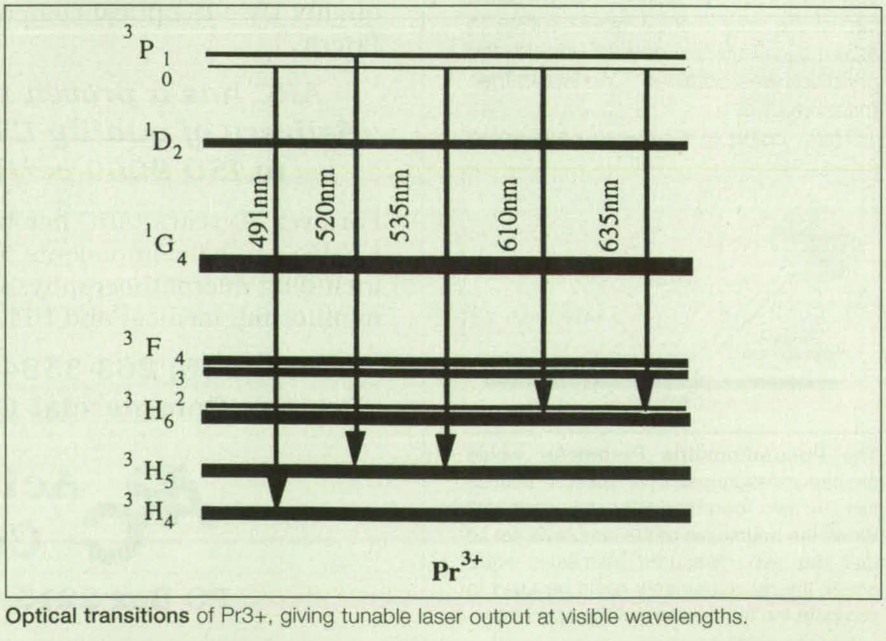
laser wavelength (nm)	635	615	520	491
threshold(mW)	42	29	21	60
slope efficiency	52%	11.5%	12.4%	3%
maximum output (launched power)	300 mW (760 mW)	44 mW* (430 mW)	20 mW (200 mW)	4 mW (200 mW)
cavity configuration	1	2	1	1
fiber length	60	60	42	26
output coupling (% transmission)	96	5	3	3
tuning range*	635-637	605-622	517-540	491-493

*cavity configuration 2.

Table: Summary of **Upconversion Fiber Laser Performance**

For a fixed pump wavelength of 860 nm, the performance of representative upconversion fiber lasers is summarized in the table. The threshold pump powers and slope efficiencies given in the table are determined with respect to the launched pump power, a quantity estimated in the experiments to be about 40% of the pump power incident on the input microscope objective. It should be emphasized that the performance shown in the table is by no means optimized.

By using the second cavity configuration, and with about 60 mW launched pump power at 860 nm, the experiments achieved tunable laser operation at 491-493 nm (Pr^{3+}:$^3P_0 \rightarrow ^3H_4$), 517-540 nm (Pr^{3+}:$^3P_1$, $^3P_0 \rightarrow ^3H_5$), 605-622 nm (Pr^{3+}:$^3P_0 \rightarrow ^3H_6$), and 635-637 nm ($P^{r3}+$:$^3P_0 \rightarrow ^3F_2$). These laser transitions are shown schematically in the figure. Laser operation is obtained for pump wavelengths falling anywhere in the range of 780-885 nm. This wide excitation range is ideal for diode laser pumping, since the exact diode output wave-



Optical transitions of Pr3+, giving tunable laser output at visible wavelengths.

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length is not critical for optimal laser performance. Two pumping processes, one identified as stepwise excited-state absorption and the other as a "photon-avalanche" process, are responsible for filling the $Pr^{3}+$ $^{3}P_0$ or $^{3}P_1$ upper laser levels.

This work was done by Ping Xie and T.R. Gosnell at Los Alamos National Laboratory. For further information, contact Dr. Xie, CST-2, Mail Stop E535, **Los Alamos National Laboratory**, *Los Alamos, NM 87544. Inquiries concerning rights for commercial use of this technology should be addressed to the Industrial Partnership Office, Los Alamos National Laboratory, Mail Stop K571, Los Alamos, NM 87545; (505) 665-9090. Refer to LAD-94-041.*

Portable, 1-Watt Green Diode-Pumped Solid-State Laser

A folded resonator design yields an optical-to-optical conversion efficiency exceeding 12 percent.

Air Force Phillips Laboratory, Kirtland AFB, New Mexico

A demonstrated intracavity-frequency-doubled diode-pumped solid-state laser achieved an optical-to-optical conversion efficiency exceeding 12 percent from an 808-nm beam into the rod crystal to 532 nm out of the resonator. The folded-resonator design used a single end-pumped Nd:YAG rod. Different diode pump arrays were optically coupled to the rod using either lenses or optical fibers. The rod was held to approximately 25° C and the arrays to whatever temperature was required to maintain the 808-nm pump wavelength. A newly designed temperature feedback control loop allowed constant monitoring and control of the laser diode's temperature.

Figure 1 shows the resonator. A single rod 1 cm long by 0.8 cm in diameter was used as an active mirror in an inverse Z resonator configuration. Resonator mode volume in the Nd:YAG was approximately 10 mm^3. The rod was HR-coated at 1064 nm and AR-coated at 808 nm on the rear (pump) surface, and AR-coated at 1064 nm on the front surface. The end mirrors (M1 and M3) of the resonator were both HR-coated at 1064 nm; the end mirror in the frequency-doubling leg (M3) was also HR-coated at 532 nm. The output coupler (M2) was HR-coated at 1064 nm on one surface and AR-coated at 532 nm on both surfaces.

The inverse Z resonator design allows implementation of a two-rod configuration, as shown in Figure 2, where mirror M1 is replaced by a second Nd:YAG crystal. Pumping of each rod with a high-power laser diode results in scaling to higher powers while alleviating gain-media thermal loading. Previous experiments have explored similar multiple-rod (two or more) configurations. Three Nd:YAG rods were used in a Z resonator with each pumped by a 3-W SDL 2481-P1 diode. The resulting output was 2.2 W at 1064 nm in the TEM_{00} mode. The Air Force has a patent pending on this multiple-rod design in both Germany and the United States.

The frequency-doubling crystal used in recent experiments by scientists at PL/LIDA's Semiconductor Laser Technology Branch was a single piece of potassium titanyl phosphate (KTP) 3 mm X 3 mm X 10 mm. The KTP was mounted in holder that allowed X-Y-Z translation, moderate X-Y tilt, and 360° rotation about the resonator (Z) axis. For these experiments, the KTP temperature was not monitored or stabilized. Future experiments at higher optical power will require temperature stabilization of the KTP crystals.

The initial experiments used a beam-shaping train, consisting of three cylindrical lenses and one spherical lens, to focus an SDL 3550-S 15-W CW laser diode array into the Nd:YAG crystal. Losses in the lens train were approximately 26 percent, and 11 W of pump power were incident on the Nd:YAG rod surface; the incident pump beam was elliptical and approximately 1 mm X 2 mm in cross section. The resonator, when optimized, emitted 1.05 W of 532-nm radiation with a moderately elliptical beam shape.

The later experiments used an SDL 3550-P5 fiber-coupled diode array that was first collimated with a Melles Griot 8-mm lens and then focused into the Nd:YAG rod with a 31.7-mm spherical lens. Both lenses were AR-coated at 830 nm. Losses in the fiber were approximately 33 percent, and 10 W of pump power were incident on the rod surface. The pump beam was circular, and approximately 1 mm in cross section. When optimized, the resonator emitted 1.25 W of 532-nm radiation in the TEM_{00} mode.

A prototype of the laser has been packaged into a volume of less than one cubic foot using off-the-shelf power supplies. An LMS-7008 Lambda constant current power supply delivered the 20 A necessary to drive the fiber-coupled diode. No liquid coolant was required; all cooling was accomplished using solid-state thermoelectric technology. A Kepco FAW 15-10K power supply capable of delivering 10 A was used to drive two TE coolers, one of them to cool the diode to 25°C, and the second to cool the YAG rod.

The resonator design was modified to a V resonator with the fiber of the laser diode butt-coupled to the YAG rod; this was done to simplify the final design and to take up less space. The two power supplies, 15-W laser diode with TE cooler and heat sink, YAG rod with TE cooler and heat sink, KTP crystal, resonator mirrors and mounts were all installed in a Pelco camera box that was 6.2 X 8.8 X 26 in. The laser's entire packaged weight was approximately 35 lbs.

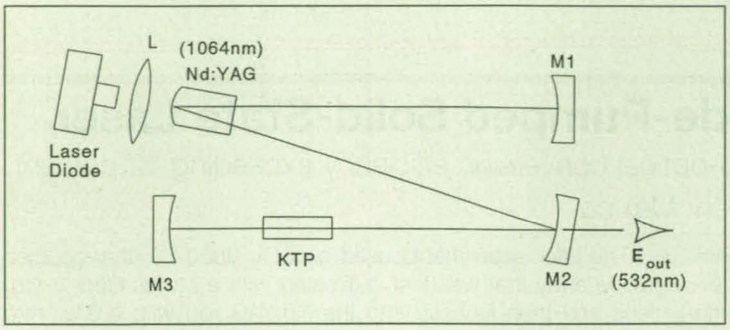

Figure 1. **Inverse Z Resonator** with intracavity frequency doubler.

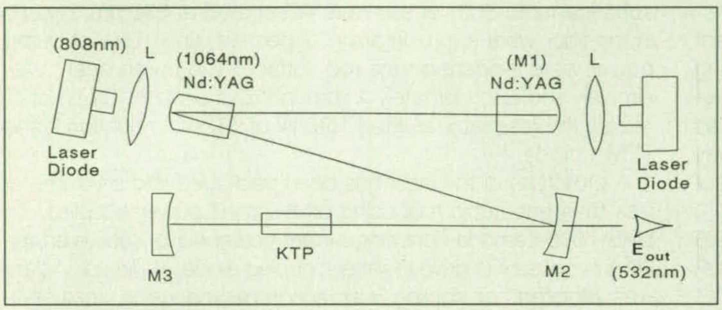

Figure 2. **Inverse Z Resonator with Multiple Nd:YAG Crystals** and intracavity frequency doubler.

The novel temperature control circuit maintained the temperature of the diode and the rod at approximately 25°C. The laser was operated at 50 percent duty cycle (16 Hz) for a specialized field test and produced approximately 1.0 W average power of green radiation. The packaged prototype, in conjunction with TE coolers, is air-cooled and requires single-phase 115 VAC prime power. No other external connections are required. The design is such that it can be scaled to higher powers.

This work was done by Peter S. Durkin and Stephen G. Post of the Semiconductor Laser Applications Branch of **U.S. Air Force Phillips Laboratory**, *Kirtland Air Force Base, PL/LIDA, 3550 Aberdeen, SE, New Mexico 87117-5776, a participating member of the Alliance for Photonic Technology. For further information, contact Mr. Post: (505) 846-4758; FAX (505) 856-4313.*

Alternatively, inquiries concerning this device may be directed to the Alliance for Photonic Technology, 851 University Blvd. SE, Bldg. 1, Suite 200, Albuquerque, NM 87106-4339; (505) 272-7001.

X-Ray Measurements of Displacements in Hostile Environments

Measurements could be made through smoke, flames, and solid layers.

Lewis Research Center, Cleveland, Ohio

A developmental method of noncontact extensometry of objects in hot or otherwise hostile environments is based on focusing and scanning of x rays. The principal advantage is expected to be the ability to make measurements through stratified and/or flowing gases, smoke, and flames, as well as through solid layers of x-ray-transparent materials.

The use of x rays as a medium of measurement overcomes the obvious disadvantages of contact measurement techniques in hostile environments. Furthermore, while radiation at optical wavelengths can be severely refracted by stratified and/or flowing gases and can be severely attenuated by smoke, x rays penetrate smoke easily and are hardly refracted.

The x rays chosen for use in this method are at the low end of the hard-x-ray spectrum; this choice represents a compromise between the need for the penetrating ability and low refractivity of higher-energy photons and the need to minimize the radiation hazard posed by high-energy photons. The most commonly available sources of this kind of radiation are x-ray-diffraction tubes that either contain copper filaments and emit radiation at a characteristic wavelength of 1.5 Å or else contain molybdenum filaments and emit at a wavelength of 0.7 Å.

Figure 1 schematically illustrates the basic principle of the method. By use of Bragg reflection from a suitably ground and bent crystal, the x rays from a typical line or point source are focused into

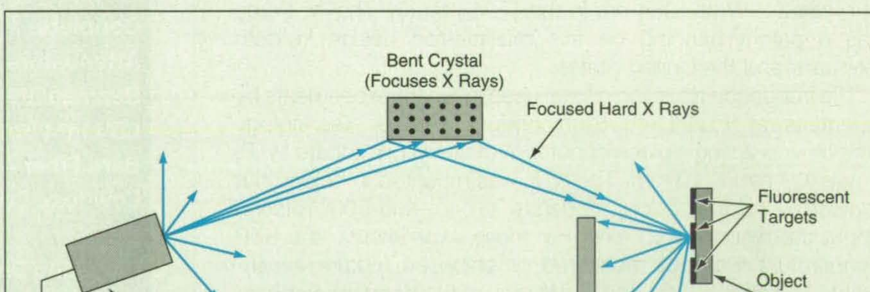

Figure 1. A **Beam of Hard X Rays** focused to a line is scanned across an object to be measured. The beam induces x-ray fluorescence in targets attached to or embedded in the object, and the level of fluorescence is measured as a function of scan angle.


TECHNOLOGY
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a narrow and intense line image that can be scanned across the object to be measured. Targets that fluoresce secondary x rays when illuminated by the hard-x-ray line image are attached to or embedded in the object. Fluorescent photons are detected in a large plastic scintillator placed as close as possible to the object without exposing the scintillator to the harsh environment of the object. Light from the scintillator is funneled into a photomultiplier tube, the output of which is sent to a high-speed amplifier and a computer-controlled counting unit.

The photon-counting rate increases or decreases, respectively, as the incident x-ray beam crosses an edge while being scanned onto or off a fluorescent target. Thus, the position of an edge of the target can be determined from the photon-counting rate as a function of the beam-pointing or scan angle by use of the known scanning geometry. Moreover, any displacement of the edge perpendicular to the axis of the incident x-ray beam since a previous scan can be determined by comparing the data on photon-counting rate vs. beam-pointing angle from the two scans (see Figure 2). This provides the basis for determining the macroscopic displacements (or macroscopic strains computed from differential displacements) that have occurred between scans.

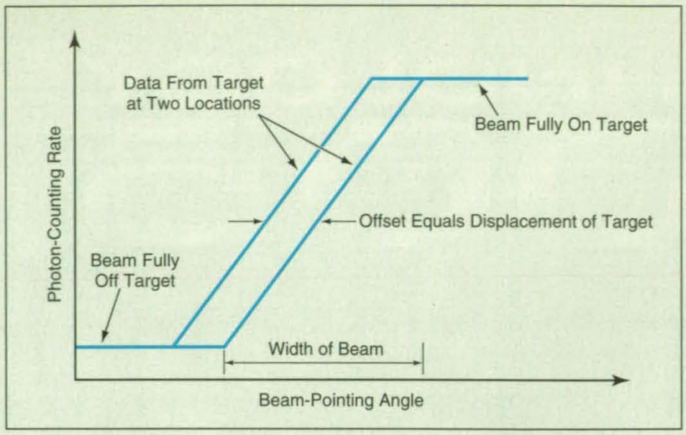


Figure 2. These **Simplified Theoretical Curves** represent data that might be acquired in two scans across the same target edge at different positions. The lateral offset between the curves indicates the amount of lateral displacement of the edge that occurred during the time between the scans.

This work was done by Gustave C. Fralick of **Lewis Research Center** *and Howard A. Canistraro, Eric H. Jordan, and Douglas M. Pease of the University of Connecticut. For further information,* ***write in 4*** *on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to the University of Connecticut. Inquiries concerning licenses for its commercial development should be addressed to

University of Connecticut
Storrs, CT 06268

Refer to LEW-15905, volume and number of this LASER Tech Briefs issue, and the page number.

Four-Spot Time-of-Flight Laser Anemometer for Turbomachinery

This apparatus measures flow velocity in a centrifugal compressor.

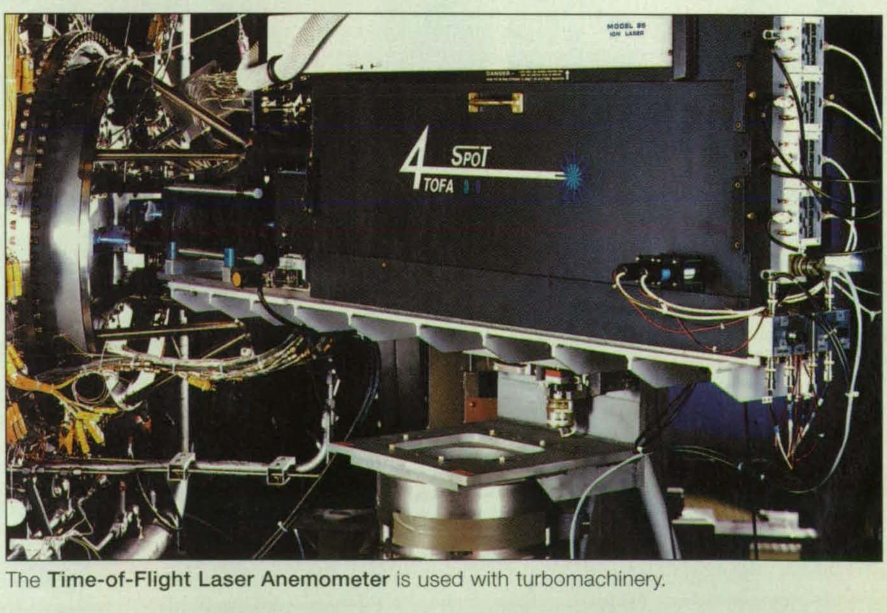
Lewis Research Center, Cleveland, Ohio

A two-color, four-spot time-of-flight laser anemometer has been designed especially for measuring flow velocity within the narrow confines of a small centrifugal compressor. This, or a similar apparatus, is generally well suited for measuring fast (typical speeds 160 to 700 m/s), highly turbulent gas flows in turbomachinery. Other potential applications include measurement of gas flows in pipelines and in flows from explosions.

As its name suggests, this apparatus measures the times of flight of small "seed" particles entrained in the flow between laser-light spots. The component of velocity along the line between the spots can then be computed as the distance between the spots divided by the time of flight. The design of this apparatus incorporates those features of two older laser-anemometer designs that are particularly desirable for measuring the highly turbulent flows in the narrow passages of turbomachines. The features in question are (1) the large acceptance angles of fringe anemometers (attractive for use in turbulent flows) and (2) the small illuminated probe volumes and the consequent spatial selectivity and sensitivity to small particles of time-of-flight anemometers (suitable for measurements near walls).

The two-color, four-spot laser anemometer nominally measures a single component of velocity along a line between the two pairs of overlapping elliptical spots (see figure). Actually, it measures velocities within an acceptance angle (about ±30°) defined by the spot geometry. The spots in each pair differ in both color and in polarization: The use of two colors increases the light flux in the measurement volume and enables better discrimination against cross-talk in the associated photodetection equipment described below. The polarizations of the two color spots in each pair are made orthogonal to each other to enhance discrimination further.

The spots are generated from the 514-nm (green) and 488-nm (blue) spectral lines of an argon-ion laser. Achromatic cylindrical lenses form the green and blue beams into the desired elliptical shape. A Pellin-Broca prism symmetrically dispers-



The **Time-of-Flight Laser Anemometer** is used with turbomachinery.

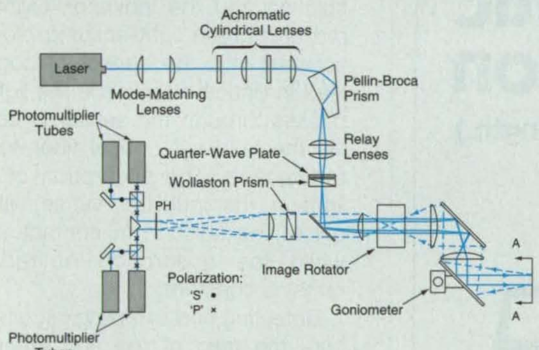
es the green and blue beams. The pairs of orthogonally polarized, overlapping spots are then generated by a quarter-wave plate followed by a Wollaston prism.

The light scattered from particles that traverse the spots is separated by color, collected by a lens, discriminated further by polarization, and directed onto four photomultiplier tubes, such that the output of each tube indicates the light scattered from one of the four spots. The overlap between the spots in each pair is chosen so that the light scattered from the transit of a given particle across all four spots results in two pairs of electronic pulses, the pulses in each pair overlapping by half the duration of one pulse. The overlapping pulses are subtracted electronically to obtain two bipolar pulses. The time between the zero crossings of the two bipolar pulses nominally equals the time of flight of the particle between the centroids of the pairs of spots. The fixed overlap of the spots results in a set of pulses that are optimally delayed, independently of velocity.

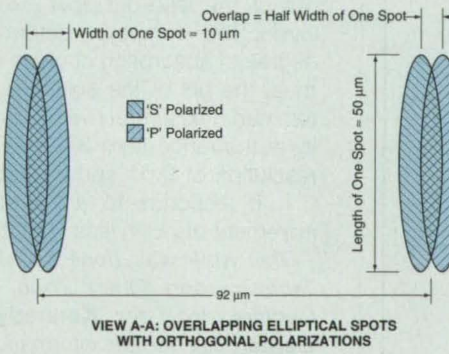
To obtain two-dimensional velocity information, the measurement volume is rotated to a selected number of orientations by use of a mirrored Dove-prism image rotator. At each orientation, measurements are taken and processed into a probability-density function of velocity. Then the probability-density functions from the various orientations are used to compute the magnitude and angle of an average velocity vector.

This work was done by Mark P. Wernet of **Lewis Research Center** *and Gary J. Skoch of the U. S. Army Aviation Systems Command. Further information may be found in NASA TM-105717 [N92-29105/TB], "A 4-Spot Time-of-Flight Anemometer for Small Centrifugal Compressor Velocity Measurements".*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15867



SCHEMATIC DIAGRAM OF APPARATUS



VIEW A-A: OVERLAPPING ELLIPTICAL SPOTS WITH ORTHOGONAL POLARIZATIONS

This **Two-Color, Four-Spot Laser Anemometer** measures a single component of velocity along a line between the two pairs of spots. The novel design of this apparatus enhances the capability to measure turbulent flow within a turbomachine.

pH Optrode Instrumentation

pH-sensitive chromophoric reagents are immobilized in porous optical fibers.

John F. Kennedy Space Center, Florida

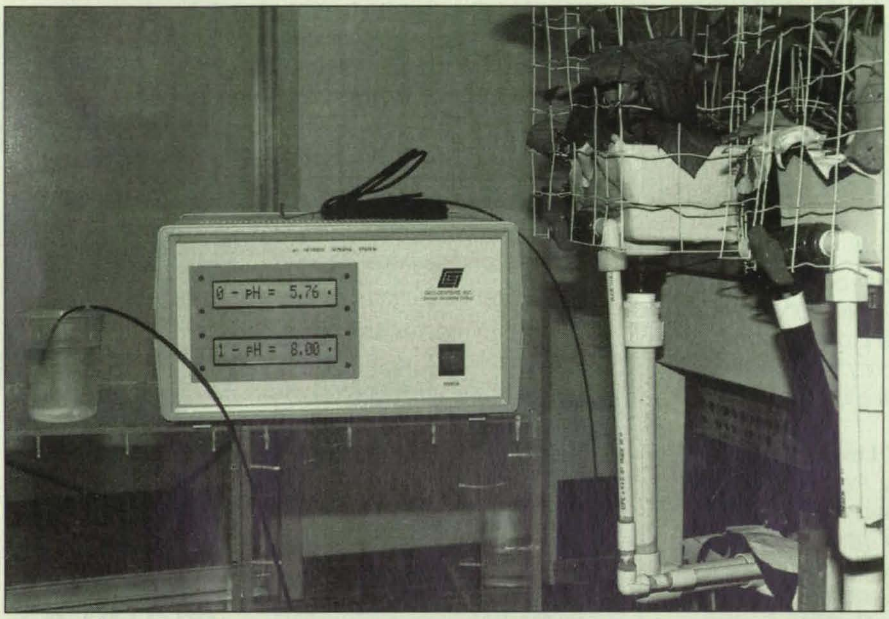
An optoelectronic instrumentation system measures the acidity or alkalinity (in units of pH) of an aqueous nutrient solution. The system includes one or more optrodes, which are optical-fiber chemical sensors that are, in a sense, analogous to electrodes but are not subject to some of the spurious effects that distort readings taken by pH electrodes. The concept of optrodes was also described in "Ethylene-Vapor Optrodes" (KSC-11579), Laser Tech Briefs, Vol. 1, No. 1 (September 1993), page 55.

The basic sensing unit in this system is a porous optical fiber, about 0.5 cm long and 250 mm in diameter, in which a pH-sensitive chromophoric reagent ("the indicator" for short) is immobilized. The indicator is bonded into the network of molecules in the fiber by mixing it into the monomeric solution that is subsequently polymerized to make the fiber. The monomeric solution also contains a solvent, which is evaporated from the fiber after polymerization to leave behind a network of interconnected pores. The fiber thus fabricated is mounted in a sensor head (see figure) and connected via lead-in and lead-out plastic optical fibers to optoelectronic interface equipment. A desktop computer connected to the interface equipment controls the system and processes the sensory data.

In operation, the sensing head is immersed in the solution, which enters the pores. The large surface area of the pores promotes contact between the solution and the indicator. Light from red and green light-emitting diodes is coupled into the sensor through the lead-in optical fiber, while the light that passes through the sensor is coupled via the lead-out optical fiber to photodetectors. The absorption of green light in the indicator varies with the pH of the solution in contact with it, while the absorption of red light remains constant.

Detecting and sampling circuits measure the ratio of red and green light going into the lead-in fiber and coming out of the lead-out fiber. From these levels, the computer determines the degree of absorption of green light and, thus, the pH of the solution. The system can measure pH with full reversibility in the range from 3.5 to 8.0, with a resolution of 0.01 and an accuracy of 0.1. It responds to a full-range step increment of pH in less than 1 min.

This work was done by Mary Beth Tabacco and Quan Zhou of Geo-Centers, Inc., for **Kennedy Space Center**. *For further information,* ***write in 181*** *on the TSP Request Card.*
KSC-11623



The **pH Optrode Sensor Head**, with lead-in and lead-out optical fibers, is convenient for monitoring solutions located away from supporting electronic equipment.

Increasing Range of Apparent Depth in a Stereoscopic Display

Light from the display screen is collimated.

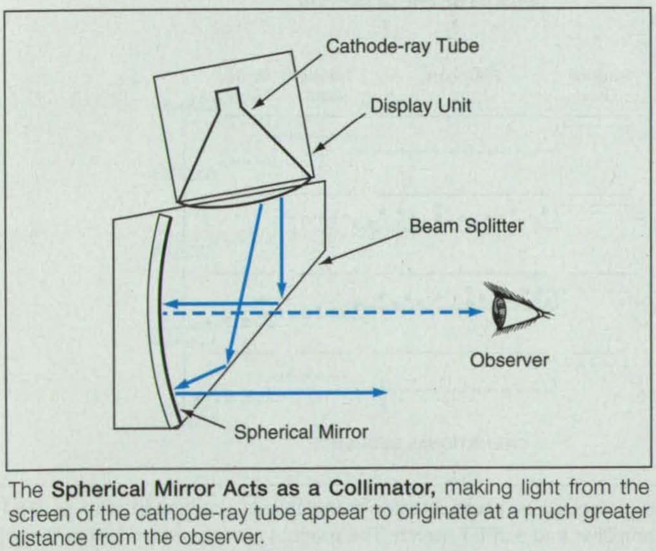
Langley Research Center, Hampton, Virginia

An optical configuration has been conceived for increasing the range of apparent depth provided by a stereoscopic display system, without imposing a concomitant reduction in the field of view. As in some other stereoscopic systems, the observer wears shuttered goggles synchronized with alternating left- and right-eye views on a display. However, instead of looking directly at the display screen, the observer looks at the screen via reflection in a mirror that collimates the light emitted by the screen.

This configuration is based on a finding, from psychophysical experiments, that the range of apparent depth in stereopsis increases with the distance between the screen and the viewer. Unfortunately, increasing the distance also narrows the field of view. Collimation can provide an optical effect equivalent to that of an increase in distance, without narrowing the field of view. This depth increase occurs apparently because collimation moves the accommodation distance of the eyes to infinity instead of the typical distance of about a meter between the eyes and a display screen, while still allowing the lines of sight of the eyes to converge on closer objects. Thus, a stereoscopic display system that includes collimation provides depth cues over the full range of stereoscopic vision.

A preliminary experiment to test the configuration was performed on the apparatus shown schematically in the figure. This apparatus was constructed by adding a stereoscopic display unit to a spherical mirror (the collimator) and beam splitter subassembly from an aircraft cockpit simulator windowing system. The apparatus was improvised hastily, without enough time to optimize the optical configuration. Nevertheless, the results of the experiment demonstrated hundredfold increases in the range of perceived depths, enabling the observer to perceive objects at distances as small as a few inches or as large as several hundred feet.

This work was done by Anthony M. Busquets, Russell V. Parrish, and Steven P. Williams of **Langley Research Center**. *For further information,* ***write in 37*** *on the TSP Request Card.*
LAR-14531



The **Spherical Mirror Acts as a Collimator,** making light from the screen of the cathode-ray tube appear to originate at a much greater distance from the observer.

Monolithic Active-Pixel Infrared Sensors

The sizes of instruments could be reduced because large cooling systems would not be needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

Monolithic arrays of active-pixel junction field-effect (JFET) devices made from InGaAs have been proposed for use as imaging sensors that would be sensitive to light in the visible and short-wavelength infrared parts of the electromagnetic spectrum. Each pixel of such an array would comprise a photodetector monolithically integrated with a JFET output-amplifier circuit of the source-follower type — a structure similar to that of a charge-coupled device (CCD).

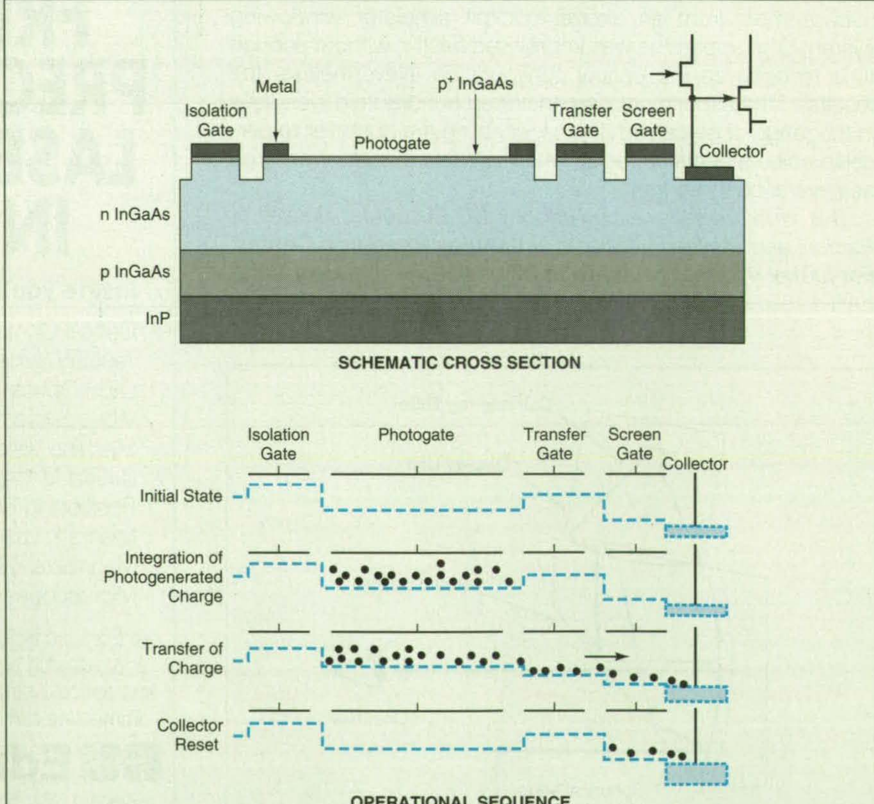
The figure illustrates schematically the structure and operation of an element of the array. The isolation gate would electrically isolate this element from adjacent pixels. The photogate would be the optically active region of the device, wherein electrons from optically excited electron/hole pairs would be stored temporarily during integration periods. For readout, a change in the potential applied to the transfer gate would allow the charge accumulated under the photogate to flow to the low-capacitance collector, which would be connected to the gate of the source-follower JFET. The screen gate would suppress capacitive feedthrough from the transfer gate to the collector. The source follower would buffer the output signal and provide it to a column bus selected by a switching signal applied to another JFET.

Each active pixel device would exhibit low readout-node capacitance like that of a CCD array but without the charge-transfer difficulties inherent in a CCD. The array would feature front illumination for enhanced response to shorter wavelengths. In comparison with older infrared-imaging devices, these devices would offer the advantages of substantial reductions of readout noise, with consequent elimination of the need for large, power-consuming mechanical coolers. The reduction in the cooling requirement would simplify development of miniature instruments for visible and infrared wavelengths. Readout circuitry could be less complex while providing random access to any element of an array.

In addition, monolithic arrays of these devices would offer several advantages over hybrid arrays. The size of an array would no longer be limited by considerations of differential thermal expansion between the array and a silicon readout-circuit chip. All of the processing needed to mate the array with the readout circuitry would be eliminated. Monolithic InGaAs sensor arrays with sizes comparable to those of silicon CCDs would be feasible. The cost of a monolithic InGaAs sensor array should be substantially less than that of an equivalent hybrid array containing HgCdTe photodetectors.

This work was done by Eric R. Fossum, Thomas J. Cunningham, Timothy N. Krabach, and Craig O. Staller of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 254*** *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 20]. Refer to NPO-18978.



Each **Active Pixel** would include a photodetector monolithically integrated with a JFET source-follower output amplifier and a JFET switch. The readout process would be like that of a single-pixel CCD.

Fiber-Optic Photoelastic Device Senses Pressure of Hot Gas

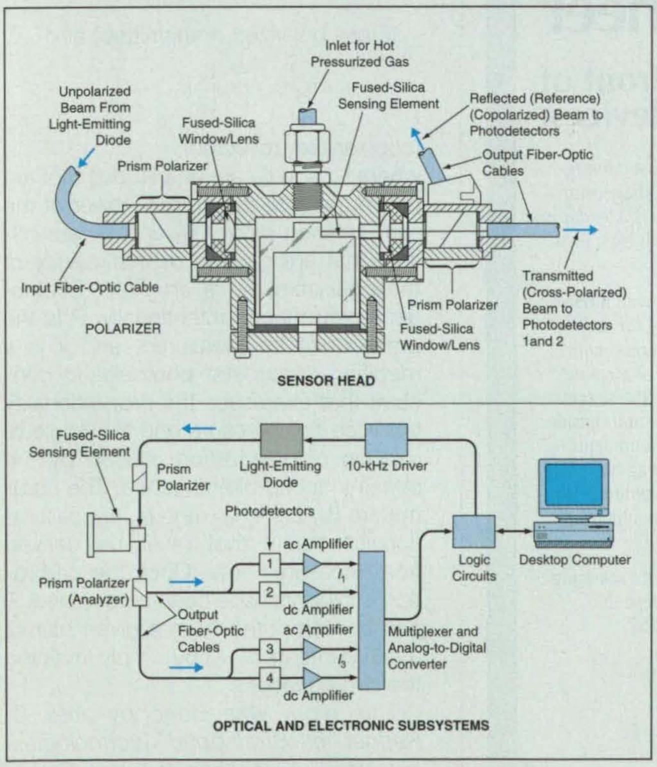
This is a prototype of pressure sensors for aircraft engines.

Lewis Research Center, Cleveland, Ohio

The figure illustrates an experimental fiber-optic/photoelastic device for measuring gas pressures up to 600 psi (about 4 MPa) at operating temperatures as high as 1,100 °C. This device is a prototype of a gas-pressure sensor for an aircraft engine. It can be mounted in the engine at or near the desired measurement point, where it can respond to both the time-varying and the steady components of pressure. In contrast, older pressure sensors based on strain-gauge transducers cannot withstand typical engine temperatures and must therefore be mounted in cooler surroundings and connected to the measurement points via long tubes, which distort the time-varying components of the pressure signals.

The photoelastic sensing element resembles an inverted cup and is made of fused silica. In the manner in which it is mounted in the sensor head and stressed by the pressure to be measured, the element is approximately functionally equivalent to a thick diaphragm. By virtue of the photoelastic effect, the sensing element becomes birefringent to a degree proportional to the stress. To measure the stress-induced birefringence and thus the pressure, a small projecting portion of the sensing element with polished surfaces is interrogated with polarized light.

The source of light is a light-emitting diode, which is pulsed at a rate of 10 kHz and emits at a wavelength of 840 nm. An input fiber-optic cable carries the light to a crystal prism



The **Pressure on the Fused-Silica Sensing Element** gives rise to birefringence via the photoelastic effect. The polarization of light is changed by the birefringence; the change in polarization can be measured and used to infer the pressure that causes it.

polarizer in the sensor head. The polarized light is admitted to the pressurized volume and collimated by a fused-silica window/lens. The collimated polarized light passes through the protruding portion of the sensing element, then through another fused-silica window/lens, then through another crystal prism polarizer. This second prism polarizer splits the outgoing light into two beams: (1) a transmitted beam, in which the polarization is perpendicular to that of the original polarization, and (2) a reflected (also called "reference") beam, in which the polarization is parallel to the original polarization. Each of these beams is focused onto the end of a fiber-optic cable, which carries it to photodetectors.

The outputs of the photodetectors are amplified, processed to obtain ac and dc components, digitized, multiplexed, and processed by a desktop computer. By use of pulsed operation and separation of ac and dc components, it is possible to correct for dc background signals that are independent of the desired sensor signals.

In principle, the outputs I_1 and I_3 of photodetectors 1 and 3 are the ac components that represent the intensities of the cross-polarized (transmitted) and copolarized (reflected) beams, respectively. These are given by

$$I_1 = I_{O1}\left[B_1 + \left\{\sin\left[\frac{\pi}{\lambda}(\delta_O + kP)\right]\right\}^2\right]$$

(cross polarized, transmitted) and

$$I_3 = I_{O3}\left[B_3 + \left\{\cos\left[\frac{\pi}{\lambda}(\delta_O + kP)\right]\right\}^2\right]$$

(copolarized, reflected)
where I_{O1} and I_{O3} are amplitudes that are proportional to the output power of the light-emitting diode, B_1 and B_3 are offsets that are caused by inefficiency of the polarizers, δ_O is an offset birefringence introduced intentionally, P is the pressure to be measured, and k is a modified composite photoelastic constant that expresses the proportionality between the pressure and the angle of rotation of polarization caused by the stress-induced birefringence. The parameters B_1, B_3, k, I_{O1}, and I_{O3} are calibration constants that must be derived from measurements. Once the calibration constants have been determined, P can be computed from a given pair of measurements (I_1, I_3) by simply inverting the two equations.

This work was done by Alex S. Redner of Strainoptic Technologies, Inc., and L. N. Wesson of Aurora Optics, Inc., for **Lewis Research Center**. *For further information,* ***write in 1*** *on the TSP Request Card. LEW-15433*

Complex-Amplitude Spatial Light Modulators

Each pixel would contain two modulating elements.

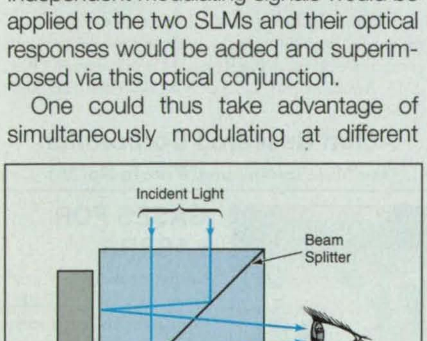
Lyndon B. Johnson Space Center, Houston, Texas

Spatial light modulators (SLMs) of a proposed type would provide independent control over both the phase and the amplitude of the electromagnetic field of the modulated light. In the polar representation of electromagnetic-field quantities that vary sinusoidally with time, this would be characterized as providing full control over the complex amplitude. The proposed SLMs would thus be useful in optical processing of information (e.g., by use of an optical correlator), in which it is essential to control complex amplitude as a function of time and of position in a correlation plane. In contrast, most practical SLMs now in use effect certain combinations of amplitude and phase in their modulations but cannot control amplitude and phase independently.

A typical conventional SLM either comprises a square array of electrically addressed modulating picture elements (pixels) or else is optically addressable at a continuum of locations. The action of the electrically addressed pixel or optically addressed spot is restricted to a characteristic string of locations (its operating curve); e.g., a curve of complex amplitude vs. applied voltage.

An SLM of the proposed type would comprise two conventional SLMs and a beam splitter arranged to place the virtual locations of the SLMs in optical conjunction: the SLMs would be positioned relative to the beam splitter so that an observer would perceive them to coincide at the location of the one in the direct line of sight through the beam splitter (see figure). Independent modulating signals would be applied to the two SLMs and their optical responses would be added and superimposed via this optical conjunction.

One could thus take advantage of simultaneously modulating at different points on the operating curves of the two SLMs. The two SLMs could have identical or different operating curves; for example, either could have a spiral curve or a straight curve at some angle with respect to the real axis. This approach would provide access to a two-dimensional range of complex amplitudes that are inaccessible when only one conventional SLM is used. By suitable design, this range would be made wide enough in both the real and imaginary dimensions to enable full complex-amplitude control over the light traveling toward the observer.



Two **Spatial Light Modulators** would be arranged with a beam splitter so that they appear to coincide and would be modulated independently to reach points of the complex-amplitude plane that are inaccessible via one spatial light modulator alone.

This work was done by Richard D. Juday of **Johnson Space Center**. *For further information,* ***write in 27*** *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 20]. Refer to MSC-22255.

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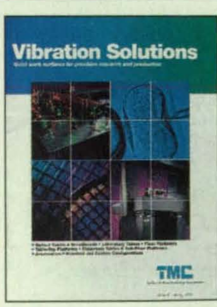

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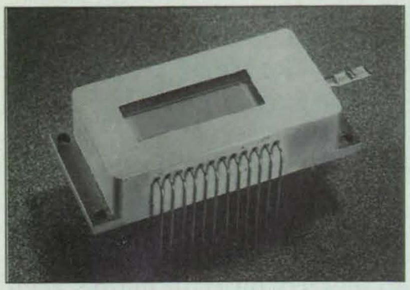


A Solution to CCD Thermal Management

The STA006A from Scientific Imaging Technologies Inc., Beaverton, OR, combines a CCD of 1080 x 314 24-micron pixels, a two-stage thermoelectric cooler, and a temperature monitor in a vacuum package. A fused silica window provides maximum optical response for spectroscopy and imaging applications. With a 16-bit dynamic range, the STA006A is capable of a CCD-to-package temperature differential of 70 °C.

For More Information Write In No. 740

Frame Grabber for the PCI Bus

Data Translation, Marlborough, MA, says that its DT3155 framegrabber for the PCI bus has special circuitry that assures high accuracy in a wide range of image processing applications. Because it operates on the high-speed PCI bus it can transfer images continuously in real time to the system's monitor for display or to its memory for storage. Compatible software includes Global Lab® Image, Glide, and Frame Grabber SDK™.

For More Information Write In No. 743

Photodiode Laser Power Meters

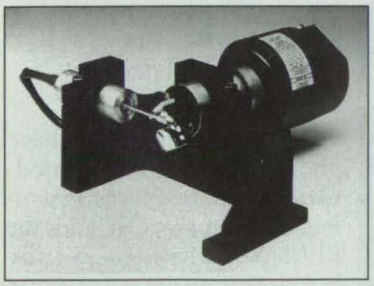
The Models PD300 and PD300-3W in the laser power meter series from Ophir Optronics, Peabody, MA, work in daylight. The company says that its patented dynamic background subtraction technology cancels 98% of background light even while illumination is changing. Four models are available all together: PD300 (350-1100 nm), PD300-UV (200-1100 nm), PD300-IR (800-1800 nm), and PD300-3W, which extends the PD300 power range of 0.1 nW-300 mW out to 3 W. SMA, ST, and FC fiber adapters are available for all models.

For More Information Write In No. 741

An "Ozone-Friendly" Chiller Recirculator

The CFT-75 cryogenic recirculator from NESLAB Instruments, Portsmouth, NH, has what the company calls an "ozone-friendly" patent-pending design. Called the Turbulator-75, the design increases cooling capacity by 20 percent without affecting cost. The unit is available with digital or analog control and a choice of circulating pumps. Applications include lasers, electron microscopes, GC/MS, turbomolecular pumps, and sputtering systems.

For More Information Write In No. 744



High-Speed CRS Scan Head

The modular X-Y scan head from General Scanning, Watertown, MA, has a counter-rotating scanner (CRS) at 4 or 8 kHz for high-frequency line scans and an M-series galvanometer for page scanning. A unique mirror configuration provides two-dimensional scanning from a single point to minimize distortion at the image plane. The small head, used for high-resolution imaging at video rates, is available with drivers and a pixel clock to linearize the line scan.

For More Information Write In No. 742

TE Temperature Control with Users' Choice

Complementing its line of laser diode and temperature control products is the LDT-5525 from ILX Lightwave, Bozeman, MT. This temperature controller provides up to 4 A current to a TE module and features direct temperature readout of thermistors and IC sensors. The instrument's hybrid smart-integrator algorithm ensures fast settling times and maintains temperature stability typically within several milli-Kelvin, the company says. The unit's user can choose either constant-current or constant-temperature modes.

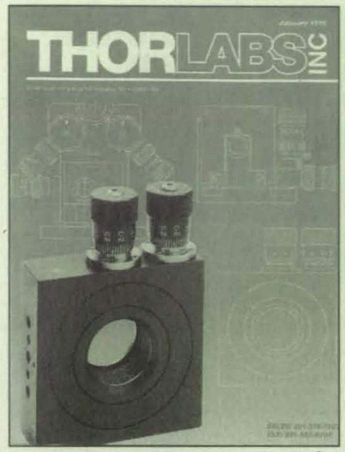
For More Information Write In No. 745

NEW LITERATURE

A Contour Projector with Telecentric Optics

A 6-page color brochure from Optical Gaging Products, Rochester, NY, describes the Top Bench benchtop contour projector, which incorporates AccuCentric™ telecentric optics so that the image is fully corrected, erect, and unreversed. With SmartCheck® Graphical Measurement Software for Microsoft Windows™, it is available in a semiautomatic version for manual systems and a full CNC version for motorized systems.

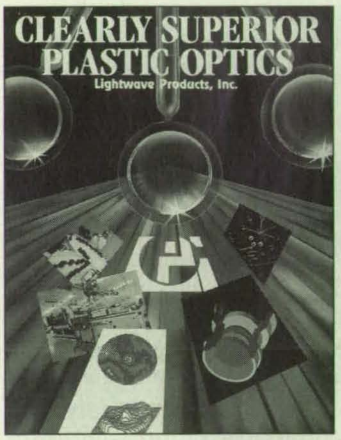
For More Information Write In No. 734



Broad Range of Optical Products from Stock

The 100-page 1995 catalog from Thorlabs Inc., Newton, NJ, features more than 300 new products, among them translating postholders, dielectric mirrors, optical rails, aspheric lenses, and single- and multimode optical fibers. The catalog groups a wide range of products by such categories as mounting components, fasteners and accessories, optoelectronics, laser diodes, aspheric lenses, and fiber optics.

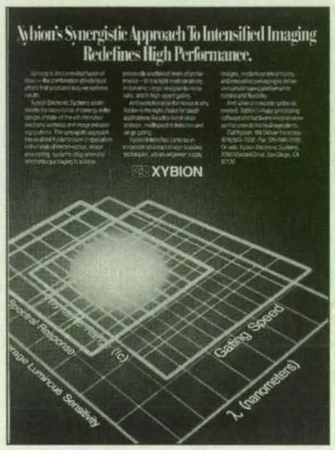
For More Information Write In No. 737



Plastic Optics Design and Production

The capabilities brochure from Lightwave Products Inc., Rochester, NY, outlines its advanced plastic molding techniques and optical technology. Combined, the company says, these produce extremely high-quality plastic optics with turnaround times much shorter than industry average. The firm can design and manufacture plastic spheres, aspheres, flats, and micro-optics for a wide variety of applications, and can use robotics to produce high volumes.

For More Information Write In No. 735



Solutions to Image Capture and Processing

Xybion Electronic Systems, San Diego, CA, offers a 28-page compendium of specification and information sheets on its product line of color and monochrome ISG and ISS Series CCD cameras, IRO Series intensified relay optics, video cameras, camera control units, and frame stores. Also featured is the GTP-100 global time and position system, combining a GPS receiver and an IRIG-B time code generator.

For More Information Write In No. 738

Color and Monochrome CCD Cameras

The Image Sensing Division, Itasca, IL, of Sony Corp. of America offers a 16-page full-color booklet describing its lines of color and monochrome CCD camera modules and accessories. Full technical performance data accompany descriptions of key features and application information about each unit. A final section deals with C-mount, NF-mount, and bayonet lenses, filters, adapters, power supplies, cables, connectors, and junction boxes.

For More Information Write In No. 736

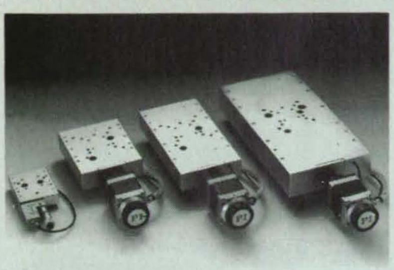
Photoelastic Polarization Modulator

To the more than a dozen basic photoelastic polarization modulator models, Hinds Instruments, Hillsboro, OR, adds the PEM-90™, with a sensitivity in polarization measurement to the order of 10^{-6}. A 10-page brochure describes principles and modes of operation of photoelastic modulators, the PEM-90's design features, and how to select a system. An application note in the form of a checklist is included. Modulators will measure circular and linear dichroism, birefringence, optical rotation, ellipsometry, and polarimetry.

For More Information Write In No. 739

NEWS FROM: Polytec PI

M-100 Series Linear Stages



- Low cost, high precision
- Sub-μm resolution
- 2 μm repeatability
- 18, 25, 50 and 100 mm travel
- Manual, DC & stepper motors
- PiezoMike™ option for nanometer resolution
- Compatible with PI positioning equipment & motor controllers

Applications examples:
Micropositioning, micromanufacturing

Write in No. 476

P-730 X-Y Piezo Stages

- Piezoelectric X-Y motion
- Monolithic flexure design
- 50 x 50 and 100 x 100 μm travel
- < 1 nm resolution
- Capacitive & LVDT sensors
- Fast scanning

Applications examples:
Near field scanning microscopy, atomic force microscopy, mask & wafer alignment.

Write in No. 479

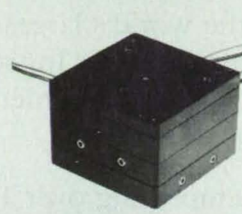
Catalog Supplement Now Available!

The Classic PI Products for Micropositioning Catalog is still available, but now a new supplement is yours for the asking. This new PI publication features the cost-effective M-125/150 linear positioners, M-500 stages, motor controllers, new low cost controllers and amplifiers for low voltage PZT actuators and other innovative motion products.

Write in No. 480

P-762 Multi-Axis Alignment System

- Piezoelectric X, Y, Z, Θ, ϕ, motion
- 100 μm/1.7 mrad travel per axis
- Compact: 80 x 80 x 55 mm

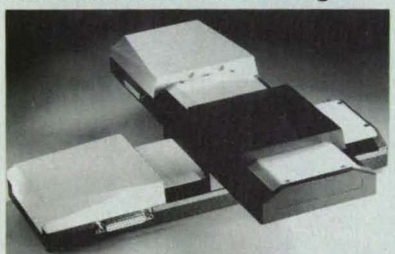


- Wire EDM cut flexures
- Integrated displacement sensors for < 40 nm/1 μrad resolution
- < 20 ms step response
- X, X-Y, Z and tip/tilt versions

Applications examples:
Fiber alignment, integrated optics

Write in No. 481

M-500 Motorized Linear Stages

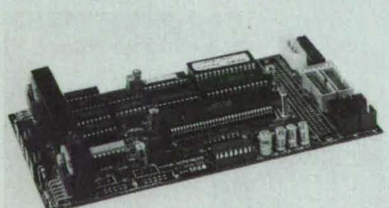


- Superior, compact design
- Precision ground ball screws
- 100 kg (220 lb.) load capacity
- Sub-μm resolution
- Up to 150 mm/sec velocity
- 100, 200 & 300 mm travel
- DC servo & stepper motors
- Optional integrated glass scale for < 1μm bi-directional repeatability
- Compatible with PI positioning equipment & motor controllers

Applications examples:
Micropositioning, micromanufacturing

Write in No. 477

C-808 Servo Motor Controller Board



- Low cost, stand alone controller
- 2 independent axes
- On-board linear power amplifiers (25W) with 16 bit D/A converters
- RS-232 interface
- I/O lines for flexible automation
- Programmable power supply mode

Wide range of DC motor controllers 2 to 16 axes, rack mount & PC plug-in versions, software also available.

Applications examples:
Micropositioning, flexible automation

Write in No. 478

LightLine... Fiberpositioner
Hitting your target— Exactly!

LightLine means:

- State-of-the-art positioning system for fibers, waveguides, LED's, etc.
- Fully automated closed loop search for "hot spot"
- Powerful software with 3D graphics
- Flexibility due to digital control by 32 bit RISC microprocessor
- Patented PiezoWalk™ drive for **6 x 6 x 6 mm** travel/**10 nanometer** resolution
- Absolute measuring, integrated, displacement sensors with 10 nm resolution
- Three linear axes, three tilt axes
- 25 years of **Polytec PI** experience in designing micropositioning systems

Polytec PI

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Costa Mesa, CA 92626
Tel: + 714 850 1835 FAX: + 714 850 1831

23 Midstate Dr., Suite 104
Auburn, MA 01501
Tel: + 508 832 3456 FAX: + 508 832 0506

For More Information Write In No. 482


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Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Electronic Systems

Study of Performance of Second-Order Digital Data-Aided Loop

A report presents an evaluation of the performance of a second-order digital data-aided loop (DAL). A DAL is a suppressed-carrier data-communication radio-receiver subsystem that uses power in the sidebands (corresponding to the data modulation) to enhance tracking of the carrier or subcarrier frequency. A digital DAL is said to be of second order when the z-transform transfer function of a filter in the loop is of the form $F(z) = A_1 + A_2/(z-1)$. The report begins with a description of a digital DAL and of the results of a previous study of a second-order analog DAL. To enable utilization of the results of that study, the Laplace-transform transfer function of the corresponding digital DAL is derived. Both the exact z-transform transfer function of the analog loop filter and a linear-interpolation method are used in approximating the Laplace transform of the transfer function of the second-order digital filter. A mathematical model of the tracking phase jitter of the second-order digital DAL is derived by use of this approximation. Next, the effect of the tracking phase jitter on the bit-error-rate performance is investigated by computer simulation, using design parameters for deep-space communication systems.

This work was done by Tien M. Nguyen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Performance Evaluation of the Second Order Data-Aided Loop,"* ***write in 96*** *on the TSP Request Card*

NPO-19058

Mechanics

Computed Aeroelastic Motions of Wings in Transonic Flows

A report describes computational simulations of aeroelastic motions of delta and swept wings in transonic flows. The results of the simulations are compared with experimental data in some cases. This is one of many studies directed toward understanding the aerodynamic behavior and enhancing the maneuverability of fighter airplanes equipped with such wings.These studies also have implications for gas pumps and turbines, in which flows near the tips of vanes and blades can reach supersonic speeds.

The flow of air about a wing is represented in this study by the thin-layer version of the Navier-Stokes equations in strong-conservation-law form. The equations of aeroelastic motion of the wing are obtained by use of the Rayleigh–Ritz method, in which the aeroelastic displacements as functions of time are expressed as functions of a finite set of assumed vibrational modes, and the contribution of each mode to the total motion is found by solving Lagrange's equations. The equations of flow are coupled with the equations of structures via an aerodynamic-force vector in the equations of aeroelasticity, which are solved by use of the linear-acceleration method. The equations of flow are solved via a time-accurate, implicit finite-difference numerical-integration scheme, using computational grids that conform to and move with, the aeroelastically deformed wing surface.

Computations are performed for elastic and rigid versions of swept fighter wings in steady motion. Rigid versions of these wings are forced to oscillate about fixed angles of attack. Both rigid and flexible versions of these wings are forced to pitch upward (ramp motion) from a 0° angle of attack at various rates. The computations for rigid wings illustrate the behaviors of moving shock waves in the presence of leading-edge vortices, and the results of these computations agree well with those of experiments. The ramp-motion computations illustrate shock/vortex interactions. They also illustrate the effects of flexibility and rate of increase of pitch in flows with vortices.

This work was done by Guru P. Guruswamy of **Ames Research Center** *and Shigeru Obayashi of MCAT Institute. To obtain a copy of the report, "Transonic Aeroelastic Computations on Wings Using Navier-Stokes Equations,"* ***write in 48*** *on the TSP Request Card.*

ARC-13191

Computer Programs

Multirepressor Control Systems for Efficient Promoter Regulation

A report presents a numerical-simulation study, based on molecular-level mathematical models, to evaluate the effectiveness of eight different configurations of repressor synthesis control of cloned-product-gene expression initiated from a promoter/operator genetic sequence. In this study, both single- and dual-repressor situations were considered, using genetically structured molecules for the lac and IPR promoter/operator in example calculations. The results of the numerical simulations suggest that the most effective control of cloned-gene expression would be achieved by use of a cross-regulation configuration carried on a multicopy plasmid. For a range of vector copy numbers, this system would retain control of the promoter under the uninduced condition and provide the highest overall transcription rate in the induced condition.

This work was done by James E. Bailey and Wilfred Chen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Multirepressor Control Systems for Promoter Regulation,"* ***write in 20*** *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

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18652, volume and number of this NASA Tech Briefs issue, and the page number.

NPO-18652

Physical Sciences

Structure/Permeability Relationships of Polyimide Membranes

A report describes an experimental study of the permeabilities, by each of five gases, of membranes made of four different polyimides. The study was conducted to gain understanding of the effects of molecular structures of the membranes on permeabilities and to assess the potential for exploitation of selective permeability in gas-separation processes. The gases used in the experiments were H_2, O_2, N_2, CO_2, and CH_4. Each of the four polyimide membranes was made from (a) the dianhydride monomer 2,2-bis(3,4-dicarboxyphenyl) hexafluoropropane dianhydride ("6FDA" for short) and (b) one of the following four diamine monomers: meta-phenylenediamine ("*m*-PDA"), 2,4-diaminotoluene ("2,4-DATr"), 2,6-diaminotoluene ("2,6-DATr"), and 3,5-diaminobenzotrifluoride ("3,5-DBTF"). The permeabilities were measured at a temperature of 35 °C, at pressures from 1.4 to 8.2 atm (0.14 to 0.83 MPa). The coefficients of permeability (P) of all of the membranes by the various gases were found to decrease in the order $P(H_2) > P(CO_2) > P(O_2) > P(N_2) > P(CH_4)$. In the case of each membrane/gas combination, P was either generally independent of, or else decreased slightly with, increasing differential pressure across the membrane. Permeabilities of three of the membranes were found to increase, and their selectivities to some gas pairs to decrease, in the order P(6FDA/*m*-PDA) < P(6FDA/2,4-DATr) < P(6FDA-2,6/DATr); this appears to be due to increasing mean interchain distances in these polymers. The permeability of 6FDA-3,5/DBTF is higher, and its selectivity lower, than expected from its mean interchain distances, possibly because of a higher segmental mobility. This study demonstrates the potential usefulness of these four polyimides as membrane materials for two gas-separating processes (CO_2 and CH_4, O_2 and N_2). The selectivities of these polyimides to the two gas pairs are higher than those of other polyimides with comparable permeabilities. The polyimides were also found to be more permeable to N_2 than CH_4, whereas most other glassy polymers are more permeable to CH_4.

This work was done by A. K. St. Clair of **Langley Research Center** *and H. Yamamoto, Y. Mi, and S. A. Stern of Syracuse University. To obtain a copy of the report, "Structure/Permeability Relationships of Polyimide Membranes II,"* ***write in 61*** *on the TSP Request Card.*
LAR-14600

Mathematics and Information Sciences

Human Factors in Aircraft Automation

A report presents a survey of the state of the art in human factors in the automation of aircraft operation. In particular, it presents an examination of aircraft automation and its effects on flight crews in relation to human error and aircraft accidents. The use of artificial intelligence in future automation will not replace the need for experienced pilots. While automation makes an aircraft easier to fly, it brings boredom to the human operators, potentially resulting in complacency and errors. It was found that redundancy is needed in automated controls critical to flight. Automation can assist flying, but humans must remain in control. Automation should be used to provide options and data for use by humans to make decisions.

This work was done by Charles Billings of **Ames Research Center**. *To obtain a copy of the report, "Human-Centered Aircraft Automation: A Concept and Guidelines,"* ***write in 77*** *on the TSP Request Card.*
ARC-13243

Mechanics

Upwind-Differencing Computations of Incompressible Flows

A report discusses the application of an upwind-differencing numerical-integration scheme in conjunction with the method of pseudocompressibility to computations of flows of incompressible fluids, with emphasis on steady-state flows. In the artificial-compressibility formulation, a term proportional to the derivative of pressure with respect to pseudotime is added to the equation of continuity, the constant of proportionality being the reciprocal of an arbitrary pseudocompressibility parameter. The equation of continuity is combined with the equations of conservation of momentum, forming a hyperbolic system of equations, complete with artificial pressure waves of finite speed. The equations can be integrated numerically by marching (iterating) in pseudotime to a steady-state (with respect to pseudotime) solution.

If the flow is time dependent, then one performs such iterations in pseudotime at each physical time step. Any of a large number of compressible-flow algorithms can be used to compute the flows in the pseudotime iterations. The computed flow field satisfies the original incompressible equations once the pseudotime iterations have converged.

The present study is part of a continuing effort to find an efficient method of solution of the Navier-Stokes equations of three-dimensional flow of an incompressible fluid. For the sake of relative ease and reduction of computational requirements, only two-dimensional flows are considered, with the expectation that extensions to three dimensions can be performed in subsequent studies.

The Navier-Stokes equations are formulated in generalized two-dimensional curvilinear coordinates. The convective terms are upwind-differenced on the computational coordinate grid via a flux-difference-split approach that yields uniformly high accuracy at points throughout the interior of the grid. This approach eliminates the need for explicitly added artificial-dissipation terms to suppress numerical instabilities. The viscous fluxes are treated by use of central differences that are accurate to second order.

An implicit line-relaxation scheme that is applicable to both steady and unsteady flows is used to solve the resulting system of finite-difference equations. Implicit boundary conditions based on the method of characteristics are formulated for all boundaries and incorporated into the computer code, making it possible to use large pseudotime steps and thereby converge on the solution in a relatively small number of iterations.

Three test cases are presented: driven flow in a square cavity, flow over a backward-facing step, and flow around a circular cylinder. The flows computed for these cases agreed well with flows computed and/or measured in previous studies.

This work was done by Stuart Rogers and Dochan Kwak of **Ames Research Center**. *To obtain a copy of the report, "An upwind differencing scheme for the incompressible Navier-Stokes equations,"* ***write in 58*** *on the TSP*

Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 20]. Refer to ARC-13190.

Materials

Hyperelastic Behavior of Solid Rocket Propellants

A one-page report discusses a study of the uniaxial stress-vs.-strain relationships of typical highly-filled HTPB solid rocket-propellant materials. A typical stress-vs.-strain plot from measurements taken at a constant strain rate shows a region of linear viscoelasticity at low strain, followed by a region of hyperelasticity as strain increases. In the region of hyperelasticity there is a point of inflection where the plot swings upward, showing an increasing modulus. At a higher strain level there is a second point of inflection where the curve turns downward, indicating a decreasing modulus.

This work was done by Rodney Beyer and Phillip Graham of Atlantic Research Corp. for **Marshall Space Flight Center.** *To obtain a copy of the report, "Hyperelastic Behavior for HTPB Propellant,"* ***write in 95*** *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 20]. Refer to MFS-28880.

Materials

Nickel Aluminide Alloys Made by Rapid Solidification

A collection of reports describe experimental metallurgical studies of nickel aluminide alloys made by a rapid-solidification powder-metallurgy process. The process incorporates ultrafine dispersions of hard, stable refractory compounds and rare-earth oxides into the alloys. The experimental studies included a detailed study of the microstructures of nickel aluminides containing various dispersoids based on HfC, TiB_2, and Er_2O_3. The effects of the dispersoids on the high-temperature mechanical properties (flow stress, and compressive and tensile creep) of the alloys were investigated.

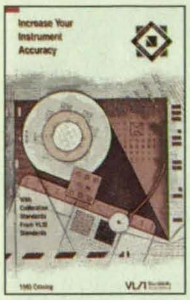
Results indicate specific additives can result in improved strength and ductility.

This work was done by Ranjan Ray of Marko Materials, Inc., for **Lewis Research Center**. *To obtain copies of the reports, "Fine Grained B2 Nickel Aluminide Alloys With Improved Formability Made Via Rapid Solidification Technology," "Dispersion Strengthened Nickel Aluminide (NiAl) Alloys via Advanced Melt Spinning Technology," "Dispersoids in Rapidly Solidified B2 Nickel Aluminides," "Influence of Grain Size on the Creep Behavior of HfC-Dispersed NiAl," "1000–1300 K slow strain rate properties of NiAl containing dispersed TiB_2 and HfB_2," "Carbide-dispersion-strengthened B2 NiAl," and "Does a Threshold Stress for Creep Exist in HfC-Dispersed NiAl?"* ***write in 65*** *on the TSP Request Card.*
LEW-15546

continued on page 100

LITERATURE SPOTLIGHT

Free catalogs and literature for NASA Tech Briefs' readers. To order, write in the corresponding number on the Readers Information Request Form (page 85).

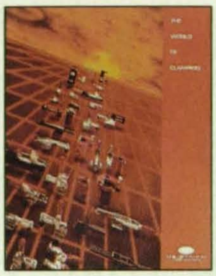


CALIBRATION STANDARDS CATALOG

Free 1995 catalog of metrology calibration standards for surface contamination, critical dimensions, film thickness, surface profiling, characterization and more. Important for ISO 9000 certification. From VLSI Standards, 3087 North First St., San Jose, CA 95134; Tel: 408-428-1800; Fax: 408-428-9555.

VLSI Standards

For More Information Write In No. 300

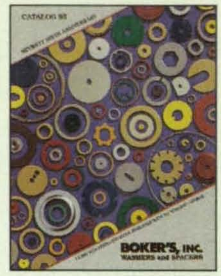


DE-STA-CO

The World of Clamping Catalog 894 describes and illustrates toggle and special clamps with vertical and horizontal hold-down, straightline, latch, and squeeze action. Spacing products, hydraulic devices, and CAD database are covered along with applications. De-Sta-Co, Box 2800, Troy, MI 48007; Tel: 810-589-2008; 800-245-2759.

De-Sta-Co

For More Information Write In No. 301

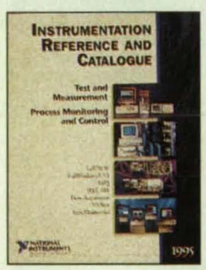


WASHERS AND SPACERS

NEW FOR '95! Boker's free 32-page Catalog 95 offers 12,000 non-standard sizes with no tooling charges. Outside diameters of 0.080" to 2.631", a wide variety of inside diameters and thicknesses, and 2,000 material variations create millions of possibilities. Materials include low carbon, cold rolled strip and sheet steel; five types of spring steel; stainless steel; aluminum; brass; copper; nickel silver; and such nonmetallic materials as Delrin®, Teflon®, Mylar®, and nylon. Metric sizes also. Tel: 1-800-927-4377; Fax: 612-729-8910.

Boker's Inc.

For More Information Write In No. 302



FREE INSTRUMENTATION REFERENCE AND CATALOG

National Instruments is providing a 1995 catalog detailing computer-based data acquisition, instrument control and data analysis products. Includes information on exciting new products and technologies such as Plug and Play boards, Power Macintosh software, Test Executives, SPC and SQL add-ons, HP-UX instrument control, PCMCIA interfaces and VXI*plug&play*. There is also information on customer education classes. Tel: 512-794-0100; 800-433-3488 (US and Canada); Fax: 512-794-8411.

National Instruments

For More Information Write In No. 303

COMPACT ULTRASONIC THICKNESS GAUGE

The T-Mike ES brings the latest technological dimension to StressTel's product line. Features: High Speed Scanning; LED Alarm lights; Differential Function; Data Send; amber colored aircraft-style display; Auto Probe Zero; Size is 2.5" X 4.5" X 1.25"; weighs 11 oz. with batteries; extended battery life; and 2 year warranty. StressTel offers a complete line of ultrasonic nondestructive testing equipment. Tel: 408-438-6300; Fax: 408-438-7917.

StressTel Corporation

For More Information Write In No. 304

RUGGED MINIATURE SWITCH

The new Series 70 is an environmentally rugged line of lighted and unlighted switches. Ready for wet, dusty or oily duty, the Series 70 is ideal for a variety of control and instrumentation requirements. Available with DPDT Momentary or Alternate switch actions. Mounts on 0.700" centers with 0.880" behind the panel space. Lighted pushbuttons use T-1 LED or Incandescent MFB lamps for a wide variety of display types, colors, and lighting styles. StacoSwitch, Inc., Costa Mesa, CA 92626. Tel: 714-549-3041; Fax: 714-549-0930.

StacoSwitch, Inc.

For More Information Write In No. 305

NEW CLUTCHES AND BRAKES CATALOG

describes highly-engineered, electromagnetic products used in a broad range of sophisticated rotary motion control applications, from office automation and robotics to aerospace. Our passion for quality and attention to details will meet or exceed your highest expectations. Tel: 716-631-9800; Fax: 716-631-9368.

Deltran Division, American Precision Industries

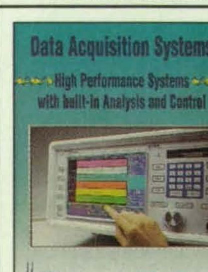
For More Information Write In No. 306

PRECISION MOTION CONTROL

API's 1995/96 172-page step motor systems catalog, featuring the new Intelligent Drive series, is a complete source for motion control technical, application and product data. Definitions, comparison charts, and diagrams simplify the selection/application process. American Precision Industries, Motion Technologies Group, Controls Division, 4401 Genesee St., Buffalo, NY 14225; Tel: 716-631-9800; Fax: 716-631-0152.

American Precision Industries

For More Information Write In No. 307



High Speed DATA ACQUISITION SYSTEMS are designed to meet exacting measurement requirements. Components feature fast throughput and highly accurate digitizers (overall 0.1% accuracy with 100 ksps to 200 Msps, and 32 Megapoints/channel). Automatic setups, analysis and touch screen controls in PC-based software add excellent user interfaces for high speed dynamic measurements in the physical and material sciences. Hi-Techniques, Inc., 152 Owen Road, Madison, WI 53716; Tel: 608-221-7500; 800-248-1633.

Hi-Techniques, Inc.

For More Information Write In No. 308

NEW GUIDE TO SPRING DESIGN

Mid-West Spring's new Guide to Spring Design helps engineers/designers plan, design and specify springs. Brochure includes design formulae, materials property and Wahl curvature stress correction data. Compression, torsion and extension springs are discussed, along with materials data on high carbon spring steel, steel alloys, stainless steel, non-ferrous, and high temperature alloy wire and flat high-carbon spring steels. For a free copy contact Mid-West Spring Manufacturing Company, 1404 Joliet Road, Unit C, Romeoville, IL 60441; Tel: 800-619-0909; Fax: 708-739-3890.

Mid-West Spring Manufacturing Co.

For More Information Write In No. 310

OPTICALLY SUPERB STEREO-ZOOM MICROSCOPE

Priced 30-40% under comparable models, the Titan Stereo Zoom comes with 10X and 20X eyepieces and 2X objective, making it the only stereo zoom microscope to offer a zoom range of 7X to 160X without the need for costly extra optics. Binocular body is 360° rotatable and inclined 45° for comfortable viewing. TITAN TOOL SUPPLY CO., INC., 68 Comet Avenue, Buffalo, NY 14216; Tel: 716-873-9907; Fax: 716-873-9998.

Titan Tool Supply Co., Inc.

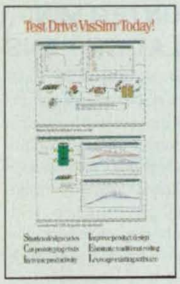
For More Information Write In No. 311

TIME AND FREQUENCY PRODUCTS

TrueTime's Precision Timing Products catalog features GPS-Synchronized Clocks in rackmount, portable, and board-level configurations. Includes illustrations and product specifications for our complete line of Synchronized Clocks, Time Code Products, and Remote Displays to fit a variety of time and frequency applications.

TrueTime, Inc.

For More Information Write In No. 312



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VisSim is the ideal environment for nonlinear dynamic simulation. The highly interactive visual Windows™ interface lets you develop complex models and test new ideas quickly and easily without writing a line of code. Call: 508-392-0100; Fax: 508-692-3102. FREE WORKING DEMO. Visual Solutions, Inc., 487 Groton Rd., Westford, MA 01886.

Visual Solutions, Inc.

For More Information Write In No. 313

GAS-FIRED VACUUM TEMPER FURNACE

Surface Combustion offers a 2-page "sell sheet" featuring its VacuDraw® High Performance Gas-Fired or Electrically Heated Tempering Furnace. The gas-fired version is the latest expansion to Surface's family of batch tempering furnaces that utilize the patented and successful Uni-DRAW® design. The furnaces are designed to perform tempering (drawing), annealing, stress relieving, low temperature brazing, and soldering. Tel: 419-891-7150; Fax: 419-891-7151.

Surface Combustion, Inc.

For More Information Write In No. 314

New DA95 catalog offers 288 different "ready to use" precision acme and precision ball screw drives. Screw drives come totally assembled with machined ends, precision end bearings and feature standard NEMA motor mounts and couplings. Complete linear slides featuring precision rail assemblies are offered in seven sizes with strokes to 135 inches. CAD files are available to speed designs. Contact: Greg Traeger, Sales Manager, Ball Screws & Actuators, San Jose, CA 95136. Tel: 800-882-8857.

Ball Screws & Actuators

For More Information Write In No. 315

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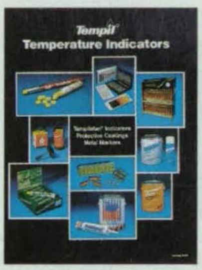
Precision Metalsmiths, Inc.

For More Information Write In No. 316



TEMPERATURE INDICATORS AND MONITORS

This most extensive line of temperature indicating products includes sticks, label monitors, indicating liquids and pellets for pre-heat/post-heat welding. The 8-page catalog discusses hand test kits, metal markets and protective coatings. Applications cover welding, metal-working, electronics, nuclear and machinery. Tempil Division, Tel: 908-757-8300; Fax: 908-757-9273.

Air Liquide America Corp.

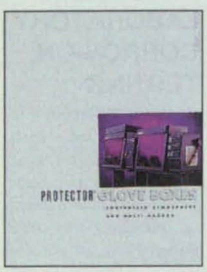
For More Information Write In No. 317

PRESSURE TRANSDUCERS/TRANSMITTERS

Taber pressure transducers/transmitters are outlined in a new brochure. They are available in low and high models in a variety of pressure ranges. Differential transducers provide high differential overload pressure and high line pressure capability. Oceanographic transducers are completely submersible, highly accurate pressure sensors. For more information contact: John Pinder. Tel: 800-333-5300.

Taber Industries

For More Information Write In No. 318



GET YOUR HANDS ON THE PROTECTOR® GLOVE BOXES CATALOG

Thumb through this 28-page, full-color catalog detailing Labconco's controlled atmosphere and multi-hazard glove boxes. Find complete information on built-in options including the automatic pressure controller with foot pedal and purge/fill controller. Call 800-732-0031.

Labconco

For More Information Write In No. 319

TOOLS, TOOL KITS, CASES & TEST EQUIPMENT

Installation/repair tools, tool kits, test equipment, telecom equipment, LAN testers & instrument/shipping cases are detailed in this 300+ page full-color catalog. Includes products for field service & depot repair. Indexed catalog features over 100 standard tool kits & complete information on "customizing" to meet specific customer requirements. Complete specs & prices are provided for all products. Tel: 800-866-5353; Fax: 800-234-8286.

Specialized Products Co.

For More Information Write In No. 320

MANUAL & MOTORIZED POSITIONING SYSTEMS

Daedal's new 300-page catalog provides specifications for cross roller and ball slides; center and side drive cross roller tables; closed and open frame motorized tables; rail tables; manual and motorized rotary tables; digital micrometer stages; single and multi-axis motion controllers; half-step, microstepping, and servo motor drives; and optical positioners and hardware.

Daedal Div., Parker Hannifin Corp.

Tel: 800-245-6903; Fax: 412-744-7626.

For More Information Write In No. 321

Find out how Datum Inc. Network Time Servers and Board Level Timing Modules can be used to synchronize your network and workstations to Global Positioning System, GPS, satellites and IRIG Time Code. TCP/IP and Novell Netware™ networks can be synchronized to within 1-10 milliseconds. VME, VXI, PC, SUN SBus™, QBus™ workstations can be synchronized to within 1 microsecond. Tel: 800-348-0648 or 408-578-4161; Fax: 408-578-4165.

Datum Inc. — Bancomm Division

For More Information Write In No. 322

RECIRCULATING CHILLERS

64-page catalog features a complete line of recirculating chillers for cooling water-cooled equipment. These chillers offer steady cooling with heat load removal up to 75 kW, spanning temperature ranges of +5 °C to +35 °C. Chillers feature: 1) ozone-friendly refrigeration-systems, 2) LED display, 3) operating status gauges, and 4) easy access to internal components. Also available is CFC-free Constant Temperature Equipment. Call toll-free at 1-800-258-0830.

NESLAB Instruments, Inc.

For More Information Write In No. 323

FREE LAMP CATALOG

This catalog features replacement lamps at discount prices for all types of equipment. Lamps for audio-visual, photographic, micrographic, and graphic arts equipment. 100% guaranteed brand names—toll-free ordering—no minimum order. All deliveries via Second-Day Air at NO extra cost. Also, lamps for medical and electronic instruments, microscopes and video use. Tel: 800-772-5267; Fax: 800-257-0760. PSC Lamps Inc., 435 W. Commercial St., E. Rochester, NY 14445.

PSC Lamps Inc.

For More Information Write In No. 324

LUMITEX... CREATORS OF WOVEN LIGHT

This eight-page color catalog describes new low-power, long-life light sources for use in portable and hand-held applications. Also included are new woven panel construction options for use in high-volume, price sensitive backing areas. Ideal for LCD backlighting, machine vision, and switch, keypad, and control panel applications. Lumitex, Inc., 8443 Dow Circle, Strongsville, OH 44136. Tel: 800-969-5483; Fax: 216-243-8402.

Lumitex, Inc.

For More Information Write In No. 325

ELECTRONIC HARDWARE CATALOG

Globe's Free 240-page catalog details their comprehensive line of electronic hardware including: handles, ferrules, jack screws, standoffs, spacers, captive panel screws, panel screw retainers, thumb screws, shoulder washers and many more. Available in American or Metric standards with over 40 protective finishes. Globe Electronic Hardware, 34-24 56th Street, Woodside, NY 11377. Tel: 800-221-1505; in NY 718-457-0303; Fax: 718-457-7493.

Globe Electronic Hardware

For More Information Write In No. 326

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Low-cost disposable applicators permit instantaneous selection from a variety of plating possibilities without preparation of solutions. Specially formulated plating compounds can be used anywhere; prototype development work, electronic instrument repair, contact repair, etc. Pens available: copper, tin, zinc, nickel, black nickel, silver, chrome-color, rhodium, palladium and gold (24, 18, and 14K). Tel: 908-526-8440. Fax: 908-526-8348.

Hunter Products, Inc.

For More Information Write In No. 327

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Select from over 2000 standard Retaining Rings, from 1/2" to 16" (12mm to 280mm) in both English & metric sizes and carbon or stainless steel. All in our 56 PAGE CATALOG No. RR-94. The catalog contains data for Materials, Shear, Bending, RPM, Installation Stress & Groove Design. SPECIAL RINGS ARE EASY TOO! Edgewinding, our NO-TOOLING-COST manufacturing process enables 2 week deliveries for nearly any special ring size. Smalley Steel Ring Co., 385 Gilman Ave., Wheeling, IL 60090; Tel: 708-537-7600; Fax: 708-537-7698.

Smalley Steel Ring Company

For More Information Write In No. 328

"OUT OF THIS WORLD" COMPUTER APPLICATIONS

For applications in hostile environments, Pro-Log industrial computers come in a wide variety of single boards, rack mounts and full systems. The company recently installed computers for telescope control at the South Pole for the National Science Foundation and multiprocessor systems for crystal-growing experiments on a NASA space shuttle Pro-Log offers Pentium, 486, 386 and 286 solutions.Tel: 800-252-3279; Fax: 408-646-3517. PRO210

Pro-Log Corporation

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Hardigg Cases offers over 225 standard rotationally molded transit cases, including a full line of 19" EIA rack mount cases, deck cases, and flangemount cases. Hardigg's expert engineering, manufacturing, and test facilities provide start to finish custom design capability. A complete list of standard cases allows for rapid delivery...as few as three working days! Take advantage of over forty years of experience...design a Hardigg case into your next project!

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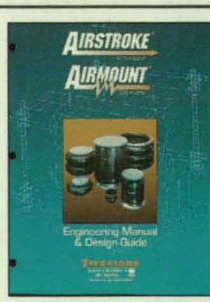
Radio Research Instrument Co., Inc.

For More Information Write In No. 331

FIRESTONE ENGINEERING MANUAL & DESIGN GUIDE AVAILABLE



The Firestone Engineering Manual & Design Guide for Airmount® isolators and Airstroke® actuators is a 101-page guide containing selection information and application tips. To receive a copy, write to: Firestone Industrial Products Company, 701 Congressional Blvd., Carmel, IN 46032, or call 800-888-0650.

Firestone Industrial Products Company

For More Information Write In No. 332

LABORATORY CORROSION TESTING

Corrosion laboratory provides testing of metals, alloys, composites, coatings. Capabilities include: bench-top, electrochemical, autoclave, stress corrosion cracking, erosion-corrosion, corrosion fatigue, and salt spray evaluations. Standardized or custom-designed testing is available. LaQUE CORROSION SERVICES, PO Box 656, Wrightsville Beach, NC 28480; Tel: 910-256-2271; Fax: 910-256-9816.

LaQue Corrosion Services

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JUN-AIR VACUUM PUMPS

The JUN-AIR oil-less compressors have proven outstanding performance for pressure duty and with slight modifications the oil-less compressors may be adapted for vacuum duty. The internal sealing systems require no form of lubricant, making vacuum pumps suitable for many applications. A number of non-explosive gasses may be evacuated down to maximum vacuum of 30 mbar. Humidity, temperature and filter size will also influence the performance. Tel: 708-215-9444; Fax: 708-215-9449.

JUN-AIR USA INC.

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Programs will create all fastener holes • hex nuts • bolts all screws (soc. hd., slotted, phillips) • washers (flat, lock, spring) • pins (dowel, split, cotter, spiral) • retaining rings & grooves • structural beams (all) • pipe fittings • springs (compression, extension, torsion) • thread inserts & holes. 1000's of parts. Bill of Materials programs **automate** the process of tracking and creating BOMs, including **creation of graphic BOM table** and **part labels,** works without CADDS Data Extract. Full 30 day **DEMO available.**

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Design Solutions Software Co.
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Parts Express International Inc.

For More Information Write In No. 336

1995 PCMCIA PRODUCTS CATALOG

The new PCMCIA-PC CARD standard has brought many new devices such as Video Capture, 16-bit Stereo, CD-ROM, Pager, and mini PC Card Camera Cards. ENVOY DATA has released its new catalog with these products plus many others like: Memory, I/O (serial, parallel, SCSI, A/D, etc.) with Industrial Card and Drives, Multimedia, Industrial, and Engineering tools for PCMCIA applications. Tel: 602-892-0954; Fax: 602-892-0029. 953 E. Juanita Ave., #A, Mesa, AZ 85204.

Envoy Data Corporation

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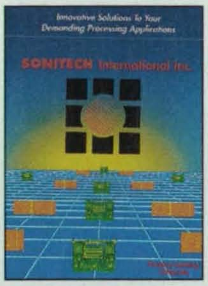

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Sonitech International

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SUNX SENSORS GENERAL CATALOG

SUNX brochure featuring photoelectric, fiber optic, laser beam, pressure/vacuum, ultra-small, proximity, ultraviolet beam, ultrasonic, and linear array sensors. Also, featuring visual color inspection system, rotary shaft encoders, optical identification system, analog output sensors, light curtain sensors, and wafer address sensors. SUNX Sensors, 1207 Maple Street, West Des Moines, IA 50265; Tel: 800-280-6933; Fax: 515-225-0063.

SUNX Sensors

For More Information Write In No. 339

MECHANICAL COMPONENTS

PIC Design's new Catalog 43 is bigger than ever--288 pages including new Modular Framing Elements, Linear Motion Systems & Positioning Tables and expanded lines of Lead Screws & Nuts, Belts & Pulleys, Ball Slides, Shoulder Screws, Bearings, Shafting, Couplings and much more. PO Box 1004, Middlebury, CT 06762. Tel: 800-243-6125; Fax: 203-758-8271.

PIC Design

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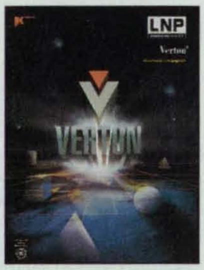

VERTON® STRUCTURAL COMPOSITES...

This brochure highlights the performance advantages of Verton Structural Composites in market segments such as automotive, small engines, boating/marine, and sports/leisure. These unique injection moldable composites are ideally suited to replace metals while providing both cost and weight savings. LNP Engineering Plastics, 475 Creamery Way, Exton, PA 19341; Tel: 800-532-2LNP.

LNP Engineering Plastics

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New Training series. 2 videos and 10 Comparison Charts describing over 40 revisions for the new ASME Y14.5M-1994 Geometric Tolerancing standard. A quick, economical way to update your department. From the noted author and authority, Alex Krulikowski, the Doctor of Dimensioning. Dept. 5B. Tel: 313-728-0909; Fax: 313-728-1260.

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"HANDS-ON" ADVANCED COMPOSITE WORKSHOPS—SINCE 1983

The brochure describes 13 different "hands-on" workshops in advanced composite materials technology. These workshops cover fabrication, repair, manufacturing, tooling, blueprint reading, adhesive bonding, ultrasonic inspection of composites, and 4 engineering workshops. Emphasis is placed on prepreg carbon and aramid fiber materials and processes, utilizing vacuum bagging and high-temperature curing methods in the oven and autoclave. Three workshops are Canadian DOT approved. REFRESHER WORKSHOPS OFFERED. For a free brochure, call 1-800-638-8441; Fax: 702-827-6599.

Abaris Training Resources

For More Information Write In No. 345

MOTION SYSTEMS AND CONTROLS

Compumotor and Digiplan have combined their motion control products into one 408-page catalog. The Engineering Reference section covers motor, drive, & feedback technologies with illustrated examples, how-to section and glossary of terminology. Second section covers Brushless Servo motors, amplifiers, controls and support software. Third section features Microstepping, Ministepping, & Linear Step Motor Systems, indexers, & encoders. Tel: 800-358-9070; Fax: 800-328-8087. COM201.

Parker Hannifin Corporation
Compumotor Division
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ADJUSTABLE SPEED DRIVES FOR APPLICATIONS TO 300 HORSEPOWER

Covering AC adjustable drives and DC controls, a new 224-page Danfoss catalog provides an overview of the VLT 2000 & 3000 Series of AC drives (spanning 1/2 to 300 HP); AC controls, Cycletrol Series DC controls; VariSpeed DC adjustable speed controls; and RDS-20 DC adjustable speed controls. Tel: 800-432-6367; Fax: 815-398-2869.

Danfoss Electronic Drives
Division of Danfoss, Inc.
For More Information Write In No. 347

AUTOMATION CONTROLS & COMPONENTS

New Automation Controls & Components Selector Guide provides overview of pneumatic and electronic industrial automation components and controls available from Festo. Over 90 product categories in 24-page brochure, covering control systems, PLCs, Fieldbus manifolds, sensors, pneumatic cylinders, valves and accessories. Education/Training programs in automation control technologies described. Contact: Festo Corporation, 395 Moreland Road, Hauppauge, NY 11788; Tel: 516-435-0800.

Festo Corporation
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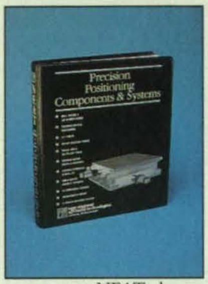

POSITIONING/ MOTION CONTROL CATALOG

NEW, detailed 160 page catalog covers NEAT's expanding line of precision positioning and motion control components and systems. Featured are single axis, X-Y, multi-axis, rotary, high vacuum, air bearing, and microscope stages. NEAT also provides a complementary line of stepping and servometer drives and controls. NEAT specializes in providing modified, custom, and turnkey SOLUTIONS to a wide range of positioning and motion control applications. Please contact our Sales Engineers at 800-227-1066, or send E-mail to neat@tiac.net for more information.

New England Affiliated Technologies
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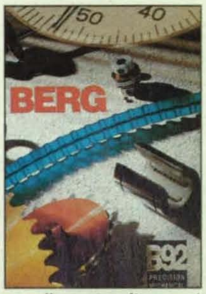

B92 CATALOG RELEASE

The latest catalog from W.M. Berg, Inc., coincides with Berg's silver anniversary. Founded in 1967, Berg has grown to become a recognized industrial leader of miniature precision mechanical components. A significant number of new items are added as well as expanding previous product lines. Featuring 50,000 standard components, 80% of which we are able to ship from stock within 24 hours. Available in metric version too: M92. Tel: 516-596-1700; Fax: 516-599-3274.

W.M. Berg
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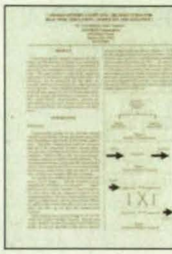

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The SCRAMNet™ Network, a real-time communications system based on a replicated shared-memory concept, is optimized for the high-speed transfer of data among computers. Applications include simulation, telemetry and data acquisition. Call for this FREE white paper. SYSTRAN Corp.; Sales Tel: 800-252-5601; Tel: 800-252-5601; Fax: 513-258-2729; E-mail: info@systran.com.

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Arconium is a producer and refiner of Indium to 7N purity... Indium Plus™, as recognized by the US Bureau of Mines. New applications for this shiny, semi-precious, non-ferrous metal, are being discovered every day. Indium products can help with coating, semiconductor crystal formation, sealing, conducting, light filtering, plating, soldering and more. Arconium, 50 Sims Avenue, Providence, RI 02909; Tel: 401-456-0800; Fax: 401-421-2419; Toll Free: 800-343-0282.

Arconium
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ELECTRO-MAGNETIC DESIGN SOFTWARE

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Vector Fields Inc.
1700 North Farnsworth Avenue
Aurora, IL 60505
Tel: 708-851-1734 Fax: 708-851-2106
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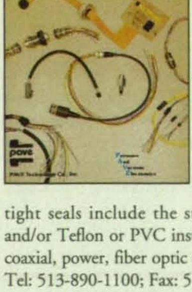

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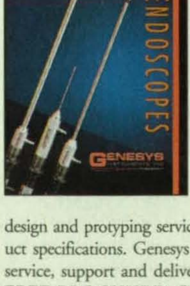
PAVE Technology Co.
2751 Thunderhawk Court,Dayton, Ohio 45414-3445 USA
For More Information Write In No. 355



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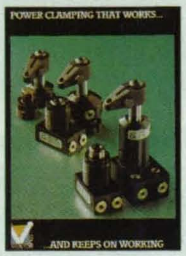
Active isolation, compact lightweight Desktops, and floor mounted systems. Perfect for all types of instrument/microscope mounting, manufacturing inspection stations, and research and development applications. Options include active feedback isolation, passive or manual leveling. Specializing in custom solutions for particular vibration problems. Herzan, 22681 Via Santa Maria, Mission Viejo, CA 92691; Tel: 714-859-7409; Fax: 714-472-8601.

Herzan

For More Information Write In No. 358



CLAMPS FOR CNC MACHINING

Vektek manufactures and markets a complete line of hydraulic clamping devices designed for use in metal cutting operations. The VektorFlo line of power workholding includes swing clamps, work supports, threaded and block style cylinders. These products are used on machining jigs and fixtures to improve clamping time and clamp force consistency. Contact Vektek factory direct sales at 800-992-0236.

Vektek, Inc.

For More Information Write In No. 359

THERMACAM™ FPA IR CAMERA

ThermaCAM™, a palm-sized focal plane array (FPA) infrared (IR) camera, combines state-of-the-art focal plane array technology with full infrared temperature measurement capabilities. ThermaCAM weighs less than six pounds complete with battery, color viewfinder and interchangeable lenses; it offers ultra-high resolution, 12 bit dynamic range, on-board digital signal processing and PCMCIA storage. Inframetrics, Inc., 16 Esquire Road, N. Billerica, MA 01862; Tel: 508-670-5555; Fax: 508-667-2702.

Inframetrics, Inc.

For More Information Write In No. 360

1995 ROGAN KNOB CATALOG

The complete lineup of Rogan knobs and dials--including a range of new offerings--is featured in their new fully illustrated catalog. New products included in this edition are several new Pure Touch Knobs™ such as clamping knobs in an expanded range of sizes, the all new five-lobe clamping knob and raised bar pointer knob. ROGAN CORPORATION, 3455 Woodhead Drive, Northbrook, IL 60062; Tel: 800-423-1543; Fax: 708-498-2334.

Rogan Corporation

For More Information Write In No. 361

NEW 6 1/2-DIGIT MULTIMETER UNDER $1,000

Introducing the Model 2000 multifunction DMM that's ten times faster at full resolution than other 6 1/2 digit meters. It is designed to excel in production applications where throughput and repeatability are essential. An option slot in the back allows users to plug in a ten-channel scanner card. Keithley Instruments, Inc., 28775 Aurora Road, Cleveland, Ohio 44139; Tel: 800-552-1115; Fax: 216-248-6168.

Keithley Instruments, Inc.

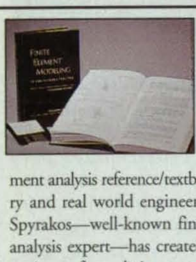
For More Information Write In No. 362

CRYOGENIC AND VACUUM MAGNETIC SHIELDS

Magnetic Shield Corporation offers a design guide as a detailed introduction to shield design considerations in vacuum and cryogenic applications. Performance of NETIC and CO-NETIC alloys at low temperature is discussed, including charts, graphs, and shielding formulas. Magnetic Shield Corp., Perfection MICA Company, 740 North Thomas Dr., Bensenville, Illinois 60106; Tel: 708-766-7800.

Magnetic Shield Corporation

For More Information Write In No. 363

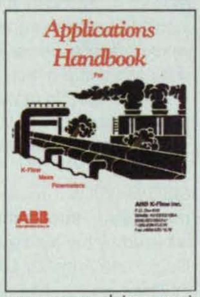


NEW BOOK HELPS YOU USE FEA IN THE "REAL WORLD"

A comprehensive finite element analysis reference/textbook offers a unique blend of theory and real world engineering examples. Dr. Constantine Spyrakos—well-known finite element stress and vibration analysis expert—has created a reference for all mechanical engineers from designers to "gurus." This richly illustrated, hardcover book includes a disk with every example problem. Subjects include: FEA basics, element types, modeling, types of analysis and interpretation of results.

APD

For More Information Write In No. 364



MASS FLOW METER APPLICATIONS HANDBOOK

The new handbook consists of a series of K-Flow application solutions. The "Application Handbook" illustrates the flow process configuration and ABB K-Flow flowmeter/transmitter systems used in a variety of process applications. Applications covered include Mass (Liquid, Gas, Multi-Component), Density (SG, API, Brix), %Solids, %Liquids, PID, Ratio Blending, Batching, Proportioning, etc.

ABB K-Flow

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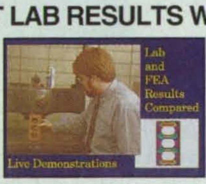
DCC Corporation

For More Information Write In No. 366

NEW VIDEO SHOWS HOW TO PREDICT LAB RESULTS WITH FEA



Finite Element Analysis In Action! is a new kind of instructional video for engineers. Live lab and computer demonstrations show how to better use any FEA software. A case study of brittle fracture--which can happen to almost any material, even steel--provides real-world examples. Two lab experiments and two FEA anaylses are conducted and the results compared. Demonstrates specific modeling and analysis techniques for predicting lab results with FEA.

APD

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Dolan-Jenner Industries

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ELECTROMAGNETICS

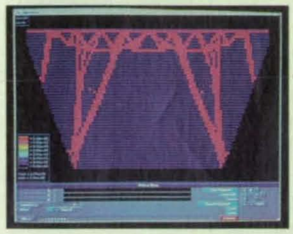
Electromagnetic field simulation software for electromechanical designers. Visualize field patterns and flux paths. Solve for force, torque, inductance and other electrical parameters on your desktop computer. Call for information on Maxwell EM. Ansoft Corporation; Tel: 412-261-3200; Fax: 412-471-9427.

Ansoft Corporation

For More Information Write In No. 369

New on the Market

Product of the Month



OptiStruct **optimization software** from Altair Computing Inc., Troy, MI, uses topology optimization to synthesize optimum design concepts or layouts based on a finite element model of package space, load cases, boundary conditions, and an estimate of available material. The layout, synthesized during conceptual design, when the greatest improvements are possible, is the stiffest, or least compliant, structure possible for the given conditions. The design can be further analyzed and refined using standard CAE tools. The software does not require an initial design as input, and runs on most UNIX workstations and supercomputers. It can be applied to existing designs for evaluation and improvement.

For More Information Write In No. 700

Alber Engineering, a division of Daytronic Corp., Miamisburg, OH, has introduced two **battery monitors**. The Model TBM Telecommunications Battery Monitor is suitable for low-voltage battery installations of one or two strings (up to 26 cells per string). The Model DBM Distributed Battery Monitor is intended for single-string industrial applications up to 400 cells, where standby power is critical. The units can test a battery under natural loads and provide readouts of all battery parameters.

For More Information Write In No. 701

MSC/MVISION Evaluator 2.0, a **materials information system** released by the MacNeal-Schwendler Corp., Los Angeles, CA, features an intuitive engineering user interface that simplifies consistent materials data access, and provides high-quality materials information required for predictive engineering. Users can search, select, and review complex materials property data, publish reports, and export to MSC/NASTRAN and other finite element analysis solvers.

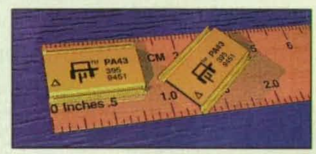
For More Information Write In No. 702

Harmonic Drive Technologies, Peabody, MA, is offering MSR **precision gearheads** that combine cup component gearing with a quick-connect coupling and NEMA 23 motor mounting interfaces. The wave generator assembly quick-connect coupling allows easy attachment of the gearhead to the shaft of common NEMA 23 or other servo or stepper motors. The gearheads are available in ratios of 50:1, 80:1, 100:1, and 160:1. Output torque ratings range from 68 to 680 in-lbs. They provide positional accuracy with low or zero backlash.

For More Information Write In No. 703

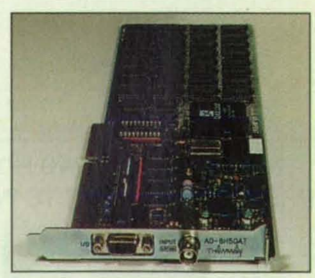
The Series 330 AC **gauging transducers** from Trans-Tek Inc., Ellington, CT, provide spring-loaded linear displacement measurements in ranges from ±0.005" to ±1.0". With a housing diameter of 3/8" and short overall lengths, the sensors can be used in tight spaces. They provide 20 microinch repeatability and mechanical frequency response times as high as 250 Hz.

For More Information Write In No. 704



Apex Microtechnology, Tucson, AZ, has announced the PA43 high-voltage monolithic **operational amplifier**. The high-performance monolithic op amp is available in a surface-mount package. Housed in a pinless, nonhermetic, dual in-line package, the PA43 handles 350 V rail-to-rail with a peak output current of 120 mA. The monolithic die is mounted to the amplifier's lid to facilitate heat dissipation.

For More Information Write In No. 705



The Thamway Model AD-8H50AT, a plug-in **analog-to-digital converter board** from Sci Tran Products, Allison Park, PA, provides 8-bit resolution, a 50 MSPS sampling rate, on-board buffer memory, ± 0.3% linearity, and ± 1/2 LSB accuracy. Reading digitized data from the buffer memory and controlling acquisition parameters are programmable with read/write instructions to the board's I/O port registers. The unit is priced starting at $2640 with 1 MB on-board memory.

For More Information Write In No. 706

New on the Market

BPM Technology Inc., Greenville, SC, has introduced the Personal Modeler which transforms solid modeling CAD designs into physical models that can be used for design verification, visualization, and evaluation. The **rapid modeling system** uses a drop-on-demand piezoelectric jetting system to jet microparticles of a nontoxic molten thermoplastic that freeze when they hit the object being built, becoming part of the object and forming it particle by particle.

For More Information Write In No. 707

NMB Technologies Inc., Chatsworth, CA, has released the 4715 KL all-plastic **axial cooling fan**. Though similar to other sizes in the KL series, the 4715 was designed for increased performance at a lighter weight. An aggressive clockwise fan impeller design results in increased airflow when installed in most systems.

For More Information Write In No. 708

Belt Technologies Inc., Agawam, MA, has developed a patent-pending **pulley system** that allows the user to track a belt by steering the pulley on the pulley shaft without moving the shaft, eliminating the need for steering mechanisms. The belt's tracking can be monitored and adjusted while in use by utilizing the appropriate drive and feedback hardware.

For More Information Write In No. 709

From Vickers Inc., Maumee, OH, comes the first **integrated motor pump (IMP)** for industrial applications. The fluid power unit is a combination of an oil-cooled electric motor mated with a variety of vane and piston pumps. Because air flow is not required for cooling, the entire unit can be enclosed completely in a sound-absorbing housing. The 60-HP IMP operates at sound levels under 71 dB through 3000 psi.

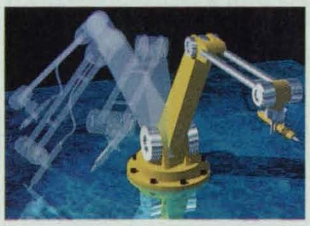
For More Information Write In No. 710

Available in spray, liquid, precision dispenser, wipes, and pen applicators, the ProGold **electrical contact cleaner** from Caig Laboratories, San Diego, CA, deoxidizes and cleans surface contamination, penetrates plated surfaces, and molecularly bonds to base metals. The cleaner also fills in gaps on surfaces, increasing effective contact area and distributing current more evenly over the contact surface. It can be used on all electrical connectors and contacts, as well as to protect bare copper boards and complete circuit boards in storage.

For More Information Write In No. 712

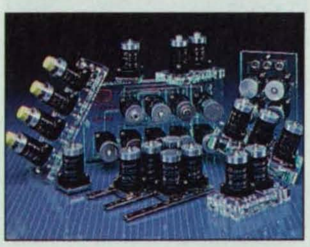
DALSA Inc., Waterloo, Ontario, has announced the CT-E2 multi-tap **TDI cameras** featuring a blue enhanced sensor. The Time Delay and Integration cameras are available with 2048, 1536, 1024, or 512 pixel lengths with eight, six, four, and two outputs, respectively. The CCD cameras use up to eight parallel outputs for fast throughput rates, and are suited for applications requiring high speed and low ambient light such as silicon wafer and electronic packaging inspection, web inspection, document scanning, and postal sorting. The camera sensors provide enhanced blue responsivity, resulting in images being detected at shorter wavelengths.

For More Information Write In No. 713



Dynamic Designer Motion and Dynamic Designer Motion Lite are two new **AutoCAD simulation design tools** from Design Technologies International Inc., Corralitos, CA. The tools integrate 3D dynamic motion simulation capabilities with AutoCAD for Windows. Both products operate on part models built from AutoCAD wireframe, surface, or solid geometry. Different joint types represent connections between parts. An interactive solution engine calculates dynamic motion and resulting displacement, velocity, accelerations, and reaction forces of each part and displays them in AutoCAD.

For More Information Write In No. 714



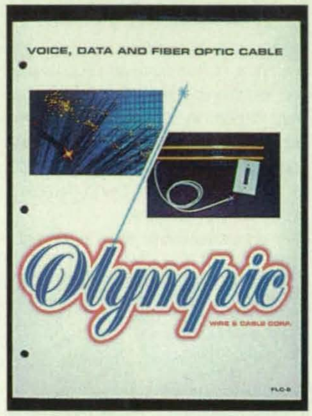
Clippard Instrument Laboratory Inc., Cincinnati, OH, is offering 25 models of **acrylic motion control circuit subplates** with standard circuits and ported 10-32 or 1/8 NPT. The subplates are pre-plumbed and allow modulars to be stacked. Circuit systems such as pneumatic/electronic interface, programmable sequencing, automatic oscillating circuits, and dedicated sub-routines can be constructed for various motion control operations, including on/off operations and routines that require interfacing of electronic programming with sensors.

For More Information Write In No. 715

New Literature

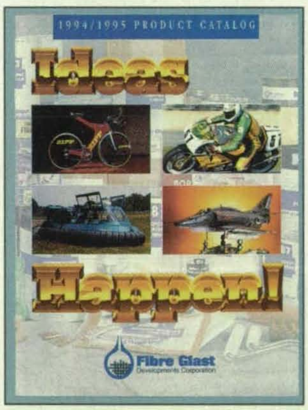
Tilton Engineered Components, Tilton, NH, offers a 12-page brochure describing **custom belts, roll covers, and urethane components.** Belt types included are Soft-Trak foam, instrumentation, stitched, round, silicone, composite, and cast urethane.

For More Information Write In No. 720



A 98-page catalog of **voice, data, and fiber-optic cables** has been released by Olympic Wire and Cable Corp., Fairfield, NJ. More than 200 items, including wires, cables, cords, connectors, tools, jacks, panels, and tubing, are described. The catalog contains dimensional diagrams, technical data, and a cross reference guide.

For More Information Write In No. 721



Fibre Glast Developments Corp., Dayton, OH, has introduced a 40-page catalog of **fiberglass materials**, including resins, gel coats, reinforcements, fillers, tools, pigments, colors, additives, safety equipment, spray equipment, and mixing and measuring devices. Books, videos, and pamphlets also are included.

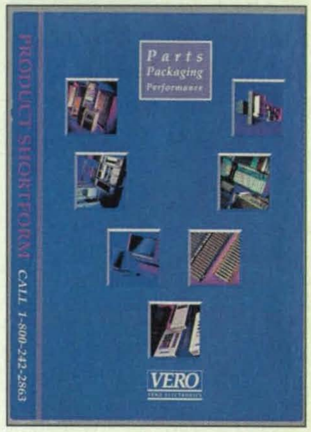
For More Information Write In No. 722

A 36-page catalog of **electronic test equipment and measurement tools** is available from Wavetek Corp., San Diego, CA. Featured are test and measurement tools used in the evaluation, design, production, and maintenance of electronic and electrical devices and systems.

For More Information Write In No. 723

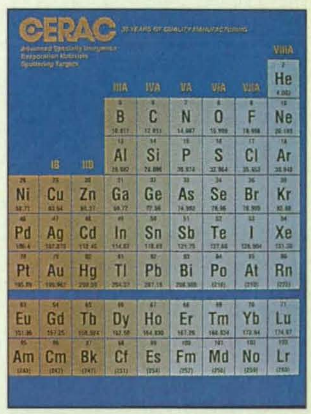
Industrial Devices Corp., Novato, CA, has released a 356-page catalog on its line of **linear actuators and control systems.** Products include rod-type electric cylinders with up to 2,400 lbs. of thrust and rodless actuators with thrust ratings up to 1,200 lbs. and travel lengths of 108 inches; DC servo, brushless servo, and microstepping drives; limit switch controls; analog position controls; programmable Smart Drives, and DeviceNet™ Smart Drives.

For More Information Write In No. 724



A line of **electronic packaging hardware** is described in an eight-page brochure from VERO Electronics Inc., Hamden, CT. Products included are electronic component housing and cable management cabinets, cardframes, custom front panels, desktop enclosures, instrument cases, prototyping boards, backplanes, microracks, power supplies, and the Speedwire System for displacement wiring.

For More Information Write In No. 725



The 390-page *Advanced Specialty Inorganics Catalog* from CERAC Inc., Milwaukee, WI, describes a line of **inorganic chemicals, metals, alloys, and ceramics**. The catalog features manufacturing capabilities, including evaporation materials and sputtering targets, and quality control processes such as analytical testing. An alphabetical listing provides quick chemical referencing.

For More Information Write In No. 726

New Literature

Fiber Options Inc., Bohemia, NY, has released a 38-page catalog describing broadcast and professional **video fiber-optic transmission products.** The products interface with broadcast and professional video, industrial and process control, machine vision, and CCTV systems.

For More Information Write In No. 727

An eight-page brochure from Barksdale Inc., Los Angeles, CA, describes the company's line of **pressure and temperature switches, pressure transducers, and control valves,** including a new line of 100 million cycle solid-state pressure switches. Standard models for each product group, and custom engineering capabilities are featured.

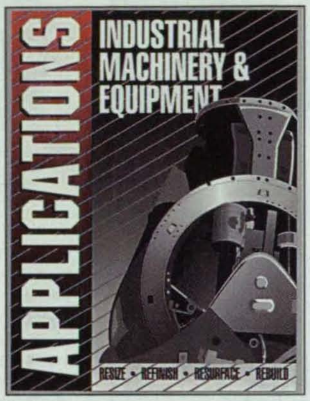
For More Information Write In No. 728

A 16-page catalog of **video imaging and optical products** is available from Marshall Electronics Inc., Culver City, CA. Included are industrial and scientific cameras, lenses, monitors, framegrabbers, receivers/transmitters, and related accessories.

For More Information Write In No. 729

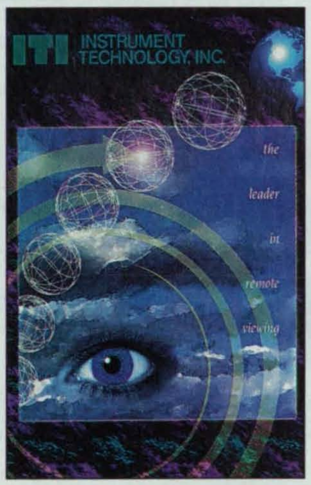
Conversion Devices Inc., Brockton, MA, has published Data-Pak, a literature package describing the Power-Pak™ family of high-density **distributed power modules**. Included are electrical and mechanical specifications of 77 power converter models, and application notes on optimizing distributed power networks

For More Information Write In No. 730



An application guide published by Sifco Selective Plating, Cleveland, OH, describes methods of **repairing industrial machinery and equipment.** Many in-house repairs to ways, spindles, bearing diameters on lathes and milling machines, hydraulic pistons and cylinders, pump bearing housings, and screw machine carrier bearings can be performed without disassembling or moving the equipment.

For More Information Write In No. 731



Instrument Technology Inc., Westfield, MA, is distributing a 24-page catalog containing technical data, specifications, and ordering information on its line of more than 1,500 **remote viewing instruments.** Among the products offered are rigid, miniature (micro), and extendable borescopes; flexible and semiflexible fiberscopes; videoscopes; and accessories.

For More Information Write In No. 732

The QA-3000 **accelerometer** is described in a brochure from Allied Signal Aerospace, Redmond, WA. The device is suited for precision inertial navigation systems with performance in the sub-nautical mile-per-hour range. A load-insensitive design allows user range scaling to fit any application.

For More Information Write In No. 733

continued from page 89

Physical Sciences

Assessment of C_{60} as a Propellant Material for Ion Thrusters

A report presents analyses and data to support the proposed use of C_{60} (buckminsterfullerene) as an alternative to Xe, which is currently the propellant material of choice for use in ion thrusters. The concept of using C_{60} for this purpose with the expectation of greater efficiency because of its greater molecular mass was described in "Electrostatic Propulsion Using C_{60} Molecules" (NPO-18526), *NASA Tech Briefs*, Vol. 17, No. 6 (June, 1993), page 89. However, the efficiency of an ion thruster is affected not only by the molecular mass of the propellant but also by the ionization cross section of the propellant molecules and by the effects of double and dissociative ionization. Accordingly, detailed estimates of the ionization cross section for electrons impacting on C_{60} and estimates of effects of multiple ionization and dissociative ionization were made via a combination of theoretical prediction and inference from experimental data.

This work was done by Don Rapp and Stephanie D. Leifer of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Effect of Use Of C_{60} as a Propellant in Ion Thrusters,"* ***write in 59*** *on the TSP Request Card.*
NPO-19100

ERRATA

In the "1995 Award Finalists" section of the April 1995 issue, under the subhead "Harsh Environment Strain Gauges" on p. 15, the sentence "Thomas Moore invented compensating strain gauges that are effective over a range of temperatures up to 370° C" should read, "Thomas Moore invented compensating strain gauges that are effective over a temperature range from 370° C to about 800° C."

On the NASA Patents page of the April 1995 issue (page 18), Raoul Tawel's invention, "Adaptive Neuron Model--An Architecture for the Rapid Learning of Nonlinear Topological Transformations," was attributed incorrectly to Langley Research Center. Mr. Tawel's work was conducted at Jet Propulsion Laboratory. We apologize for the errors.

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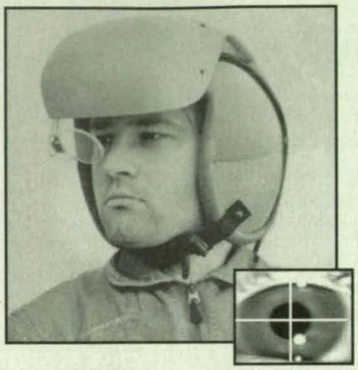

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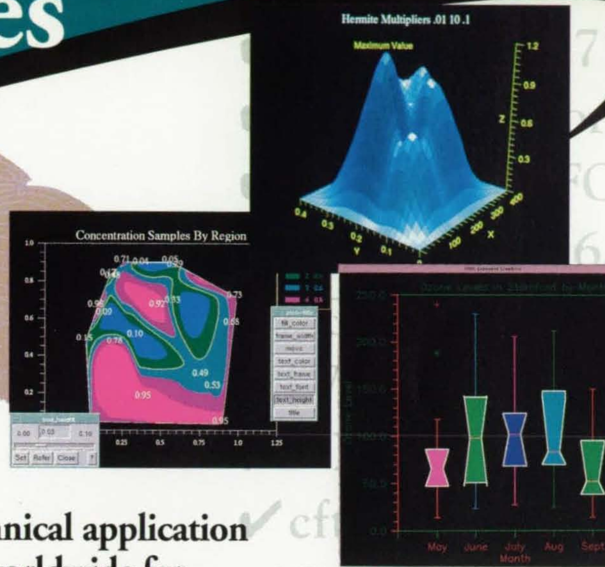

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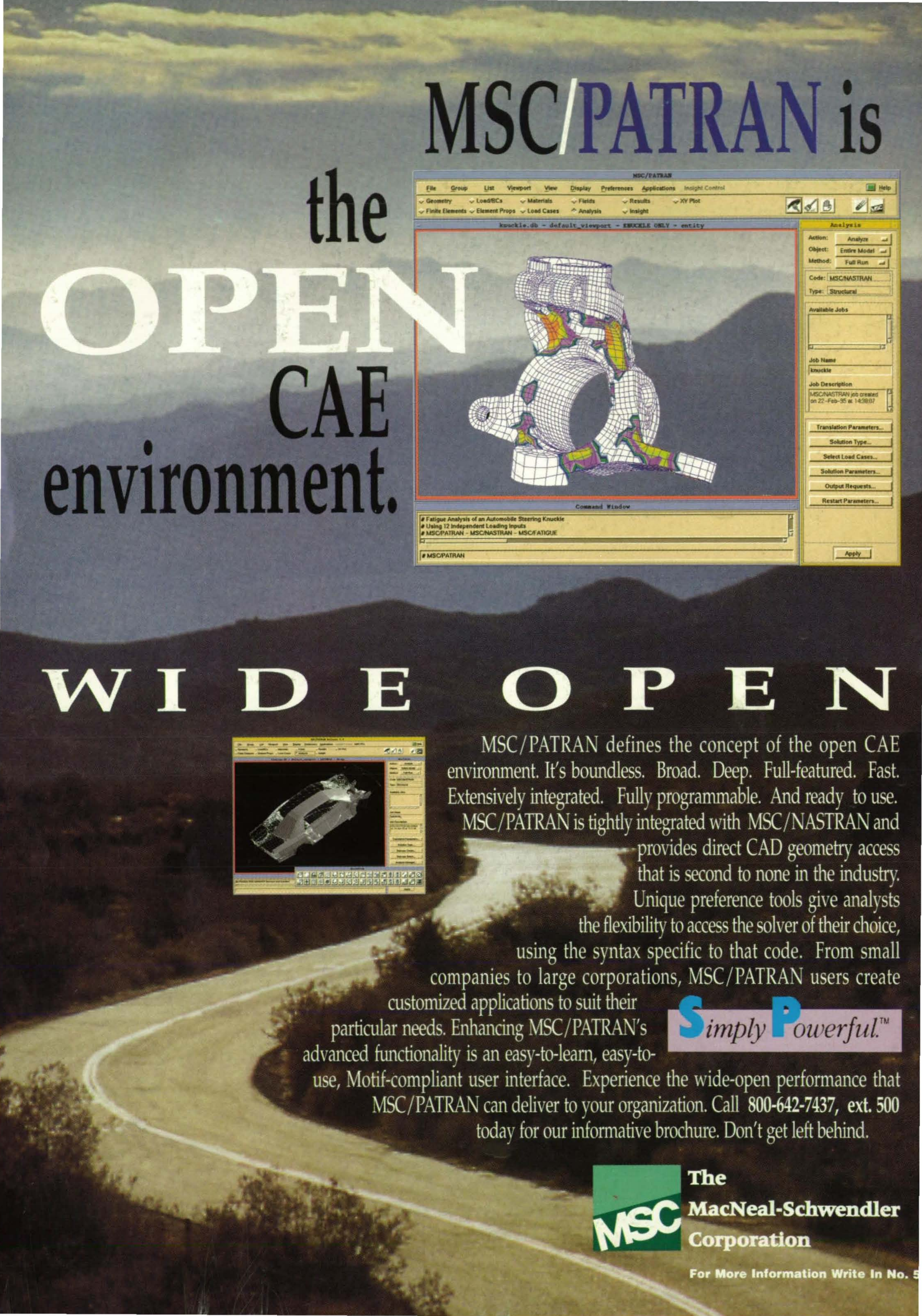
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