WHAT'S NEW AT TECHNOLOGY 2006 — PAGE 24

October 1996

Vol. 20 No. 10

NASA Tech Briefs

The Design/Engineering Technology Digest

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Instrumentation Software News.

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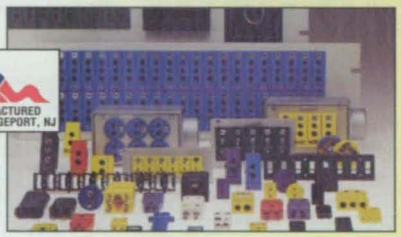

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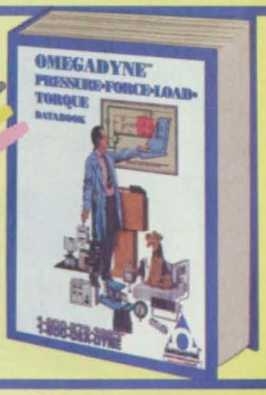

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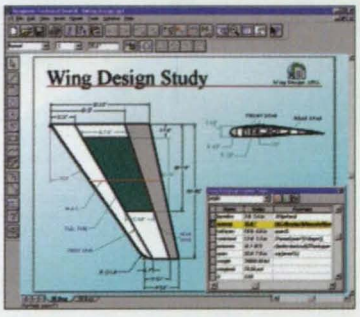

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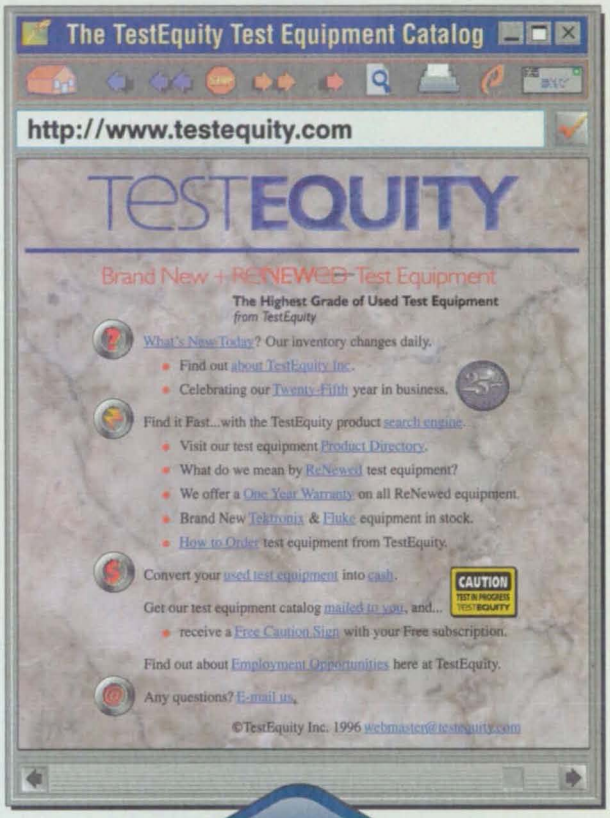

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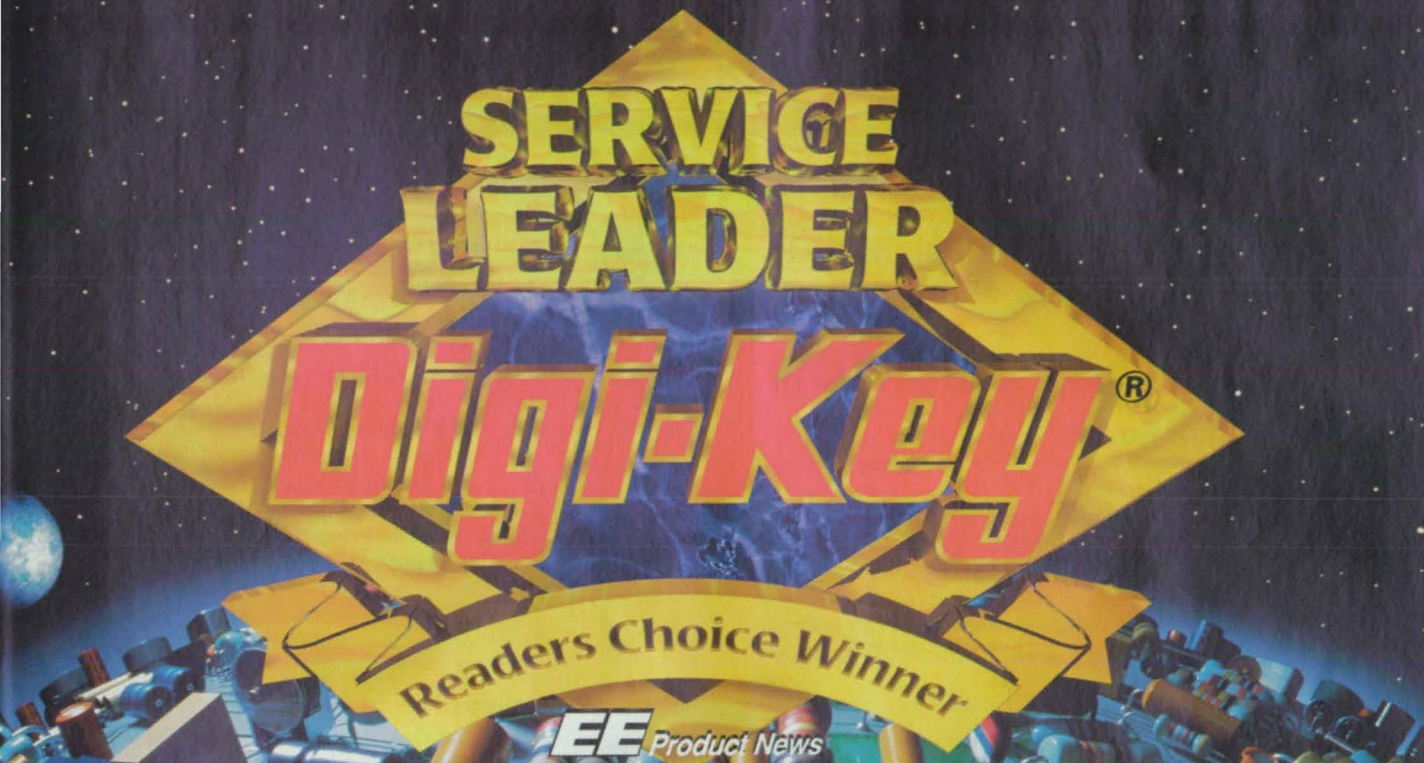

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October 1996
Volume 20 Number 10

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NASA Tech Briefs

Official Publication of the National Aeronautics and Space Administration

FEATURES

TECHNICAL SECTION

(continued on page 8)

NASA's Goddard Space Flight Center has designed a 3D roller-locking sprag that is more compact, stronger, lighter, more efficient, and more durable than conventional 2D sprags. The 3D version allows two directions of motion or no motion at all, dramatically improving the performance of roller-locking devices and eliminating the need for ratcheting. The innovation will be displayed at Technology 2006 (Oct. 29-31). For more information on the 3D sprag, as well as other new technologies at the show, see the feature beginning on page 24.

(Photo courtesy of Goddard Space Flight Center)

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A design team led by Dr. Neal Frink at Langley Research Center developed Tetrahedral Unstructured Software Systems (TetrUSS), an aerodynamic analysis and design system used for low-speed through supersonic aerodynamics in aircraft such as the B747. TetrUSS was named co-winner – with Jet Propulsion Laboratory's LinkWinds – of NASA's 1996 Software of the Year. For more information on both winners, see page 28.

Photo courtesy of Langley Research Center

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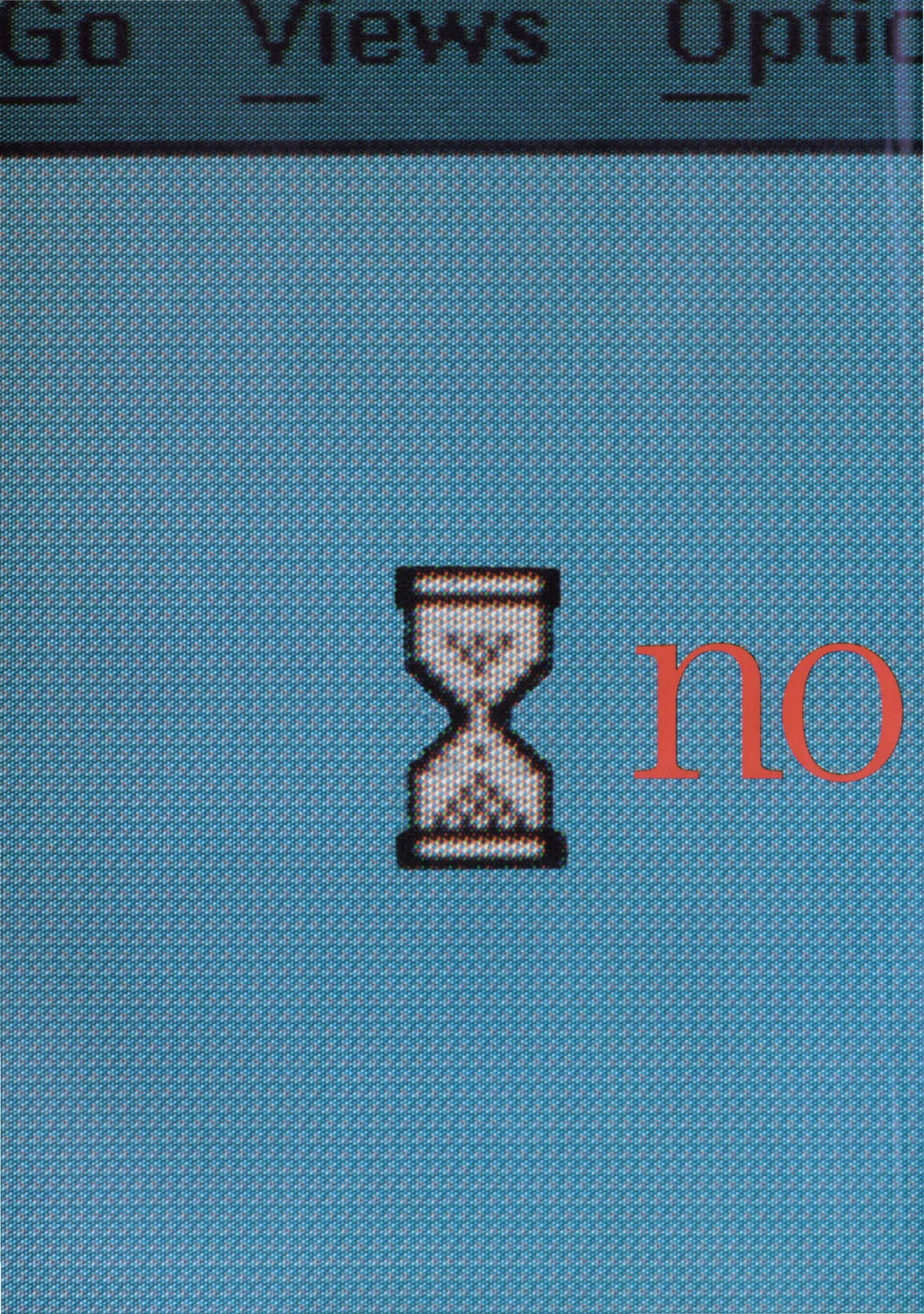
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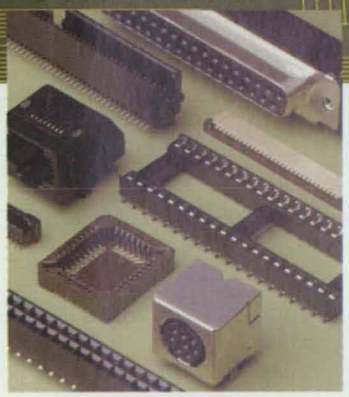
How to stay out of the rough in surface mount technology.



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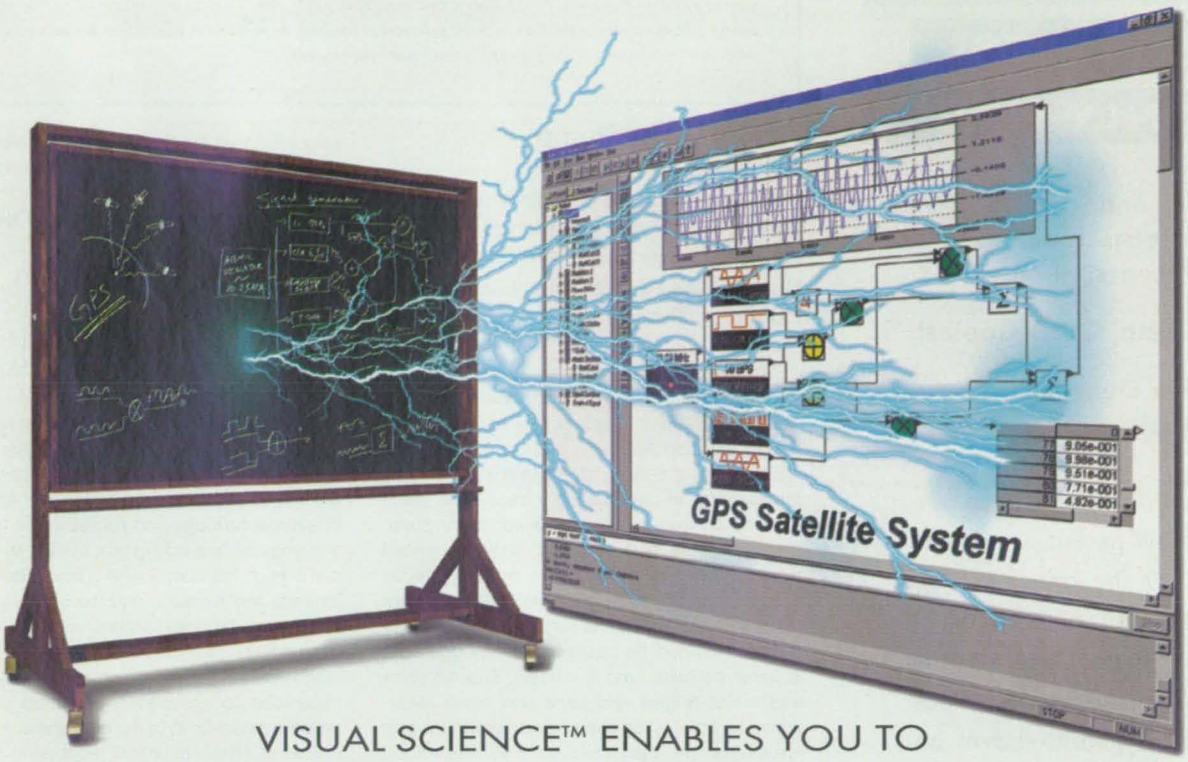

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NASA PATENTS

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:

Rotary Blood Pump

(U.S. Patent No. 5,527,159)

Inventors: Richard J. Bozeman Jr., James W. Akkerman, Gregory S. Aber, George A. Van Damm, James W. Bacak, Paul A. Svejkovsky, and Robert J. Benkowski, Johnson Space Center

Because rotary pumps can be made relatively cheaply and are less complex than other types, they find increasing use for ventricular assist, cardiopulmonary bypass procedures, and through-the-skin cardiopulmonary support applications in emergency cases. But there remains a need for an improved rotary pump that is reliable and compact, requires limited through-the-skin insertions, and produces fewer blood damage problems. The present pump includes a housing for a flow straightener, a rotor mounted on bearings with inducer and impeller portions, and a diffuser. The entrance and outlet angles and axial and radial clearances of the blades associated with the pump structures are optimized to minimize blood damage while maintaining pump efficiency. The rotor bearing chamber is filled with cross-linked blood or other biocompatible material, and a microcomputer-controlled back-EMF integrated circuit regulates rotor operation.

For More Information Write In No. 775

Dual-Latching Solenoid-Actuated Valve Assembly

(U.S. Patent No. 5,529,281)

Inventors: Myron J. Brudnicki and Jefferson Y. Yang, Marshall Space Flight Center

The invention is a tube-type high-pressure slide valve that can be actuated electrically by a solenoid, or manually by a toggle lever. In either case the tube is latched open or closed by means of permanent magnets. A slidable tube mounted within a cylindrical housing is equipped with a surrounding armature between its ends, with permanent magnets attached to the armature's outer radial surface. The housing contains a pair of concentric solenoidal electromagnetic windings, and a pair of pole pieces at either end to provide a gap between them and the armature's surfaces. In electrical operation, application of a current to the solenoid winding nearest the larger of the gaps, depending upon the valve's position, sets up a flux across that gap, opposing the magnet's flux in the smaller gap, that results in a greater force across the large gap, drawing the armature from the smaller to the larger gap. As the larger becomes the smaller, the current is removed and the tube is latched in its new position by the attraction between the pole pieces and the permanent magnet. One end of the housing has a valve seat mounted for contact with the tube when it is positioned axially in that direction, thus closing the valve.

For More Information Write In No. 777

Ampoule Failure System

(U.S. Patent No. 5,529,015)

Inventors: Dale A. Watring and Martin L. Johnson, Marshall Space Flight Center

In many crystal-growth furnaces, charge samples of toxic semiconductor materials such as gallium arsenide and mercury cadmium telluride are sealed in an ampoule, which is in turn sealed in a metal cartridge and placed in the furnace. If the ampoule fails during processing, the material can breach the container in a few minutes, contaminate the furnace, and cause loss of data, which can be very expensive in the case of microgravity experiments. Failure in a confined area with limited ventilation can spread vapors hazardous to personnel. The ampoule failure probe located close to the containment cartridge creates a timely chemical reaction in the presence of the toxic material, causing a step increase in resistance. A communicating electrical circuit connected to an external data acquisition system responds to the resistance increase, triggering automatic furnace shutdown.

For More Information Write In No. 776

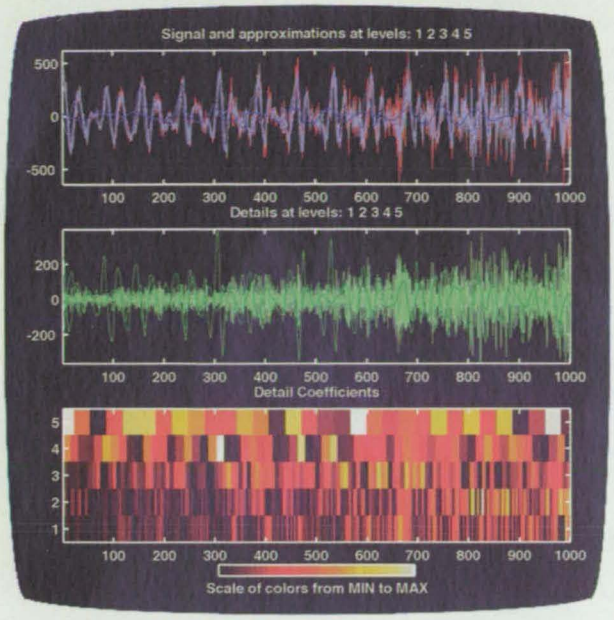
Means for Positioning and Repositioning Scanning Instruments

(U.S. Patent No. 5,531,093)

Inventors: Michael E. Polites and Dean C. Alhorn, Marshall Space Flight Center

Rotating unbalanced mass (RUM) devices are a new and power-efficient way to generate scan patterns using gimballed payloads such as x-ray telescopes and other scientific instruments. In the present device, the scanning instrument has first and second RUMs supported on respective drive shafts and spaced from the center-of-mass of the instrument. They rotate 180° out of phase with each other, with their planes of rotation parallel to each other and at a constant angular velocity. The centrifugal forces caused by such rotation create time-varying and relatively large-amplitude high-frequency operating or nominal reaction forces and torques, which act on the instrument to move its line-of-sight in a predetermined repetitive scan pattern. Sensors are used to obtain elevation and cross-elevation departure angles from the center of a desired scan. These are converted to a RUM-cycle angular velocity component, which is superimposed on the RUMs' nominal velocity, causing the speed to increase and decrease during each revolution to drive the instrument toward the desired scan center.

For More Information Write In No. 778



This image from the MATLAB Wavelet Toolbox shows a five-level decomposition of a voice signal. Wavelet analysis is producing breakthroughs in the development of communications signal processing algorithms. Data courtesy of U. S. Robotics Mobile Communications Corp.

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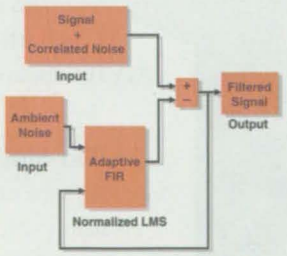

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For More Information Write In No. 605

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 14).

Active-Pixel Image Sensor Integrated With Readout Circuits

This sensor includes not only the photosensors but also the timing, control, and readout circuits, all integrated on one chip. It offers an alternative to charge-coupled devices (CCDs), which are more expensive to produce and present greater difficulty in integrating control and signal-processing functions.
(See page 38.)

Dual-Mode Chemical Sensors

Sensors are being developed that can identify chemical species and their concentrations optically. One mode would identify the chemical and the other would identify its concentration.
(See page 46.)

Phase-Locking a Gyrotron Using a Quasi-Optical Circulator

After successfully demonstrating coherent operation, gyrotrons, which have been used to heat plasmas, may become available for high-power applications in communication and radar systems.
(See page 58.)

Regenerative Single-Unit Fuel Cells

Featuring solid ionomer membranes, prototypes of a class of efficient fuel cells have been built and tested. These can serve as either fuel cells or electrolysis cells and may become key building blocks for future electric-power-generating/energy-storage systems.
(See page 74.)

Modified Intermetallic Has High Temperature Potential

By substituting molybdenum largely for the chromium in chromium silicide, one obtains an alloy with increased resistance to oxidation, erosion, and creep. Possible applications include blades and vanes in turbine engines and chemically inert extrusion dies in the food, glass, and polymer-processing industries.
(See page 78.)

Tetrahedral Lander Would Protect Against Impact

A proposed soft-landing device is designed as an alternative to a parachute to cushion and protect a person or object dropping to Earth. The lander has a capsule, inflatable legs, and sails for safe impact. Landing would be safer, for example, in forested and rocky areas where parachute ropes can become entangled.
(See page 88.)

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For More Information Write In No. 552

Notebook

Our Chief Editor, Linda Bell, faced an impossible mission this month.

Her task: Write an article entitled "What's New At Technology 2006." While I think you'll agree she did a terrific job in highlighting some of the cutting-edge technologies that will be presented and displayed in the Anaheim Convention Center from October 29-31, no single story could possibly convey the many exciting new features at this year's show.

For starters, there will be more than twice as many exhibits to visit. Technology 2006 will be colocated this year with TeleCon XVI, the largest trade show on teleconferencing and videoconferencing, and TeleMed II, the premier conference on telemedicine technology and applications. Combined, the three events will house over 150,000 square feet of exhibits, open free of charge to all registrants.

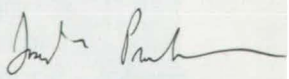
Technology 2006 and TeleCon will hold a joint plenary session on Tuesday, Oct. 29. The high-powered lineup of speakers includes Daniel Goldin, Administrator of NASA, and James Barksdale, the President and CEO of Netscape Communications. Netscape, of course, produces the dominant Internet browser — a fact Microsoft would dearly like to change. Their "epic battle," as *Time* magazine put it in its Sept. 16 cover story, will profoundly affect how we use computers and access information. This plenary is not to be missed!

Also new this year: A poster presentation showcase in the exhibit hall on Oct. 29 (starting with a networking breakfast at 9:00 am), where you can talk one-on-one with government and industry pathsetters about licensable inventions and new products in a wide array of fields; exhibit hall demonstrations and an Oct. 30 plenary on agricultural technologies for transfer; and short courses on Oct. 31 covering such topics as East-West technology alliances, patents and licensing, commercialization strategies, and financial planning. (For the first time, you can earn Continuing Professional Development Hours by attending Technology 2006 sessions and short courses.)

What's more, if you are one of the first 5000 confirmed registrants, NASA will give you a free CD-ROM (valued at $250) containing over 20 years of the agency's technical reports and patents, as well as hundreds of unpublished NASA software programs.

The list of new features goes on, but one thing hasn't changed: This NASA-sponsored conference remains your best, one-stop source for finding engineering solutions and new product ideas to grow your business, and for meeting the government and industry experts who can help you bring ideas to market. If you haven't registered yet, you can still do so using the form on page 121.

I hope you enjoy Linda's article (beginning on page 24), and look forward to seeing you in Anaheim.



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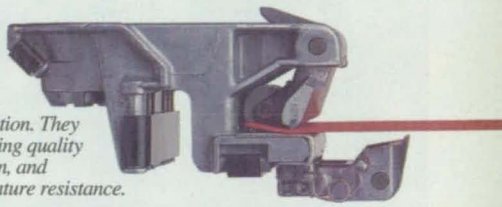

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For More Information Write In No. 530

WHAT'S NEW AT TECHNOLOGY 2006

Technology 2006 (October 29-31) at the Anaheim, CA Convention Center, will showcase commercially promising inventions and processes developed by the country's leading commercial and government technologists. Here are some highlights.

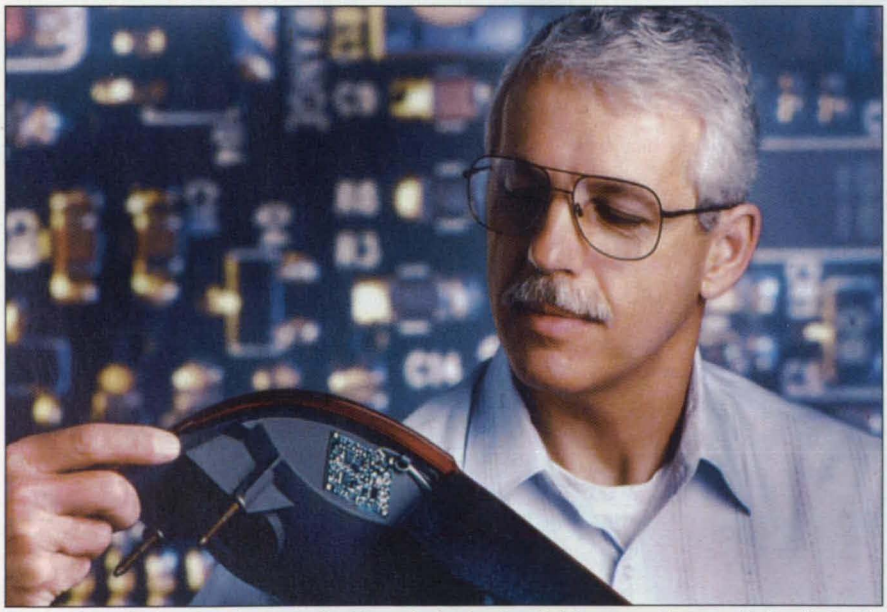
Miniature Radar

An inexpensive miniaturized radar system developed at Lawrence Livermore National Labs (LLNL) may become the most successful technology ever privatized by a federal lab, with a potential market for the product estimated at between $100 million and $150 million. The system already has generated $1 million in licensing fees: 15 companies already have licensed the technology and 12 more are negotiating to commercialize it. Interest in the technology has proved extraordinary – so much so that LLNL has ordered hundreds of prototype versions and will distribute them at a cost of $3000 to $5000 to companies to evaluate the system.

The micropower impulse radar was developed by engineer Tom McEwan as part of a device designed to measure the one billion pulses of light emitted from LLNL's Nova laser in a single second. The system he developed is the size of a cigarette box, and consists of about $10 worth of parts. The same measurement had been made previously using $40,000 worth of equipment.

Titan Technologies of Edmonton, AL, Canada, was the first to bring to market a product using the technology when they introduced storage-tank fluid sensors incorporating the system. The new radar allowed Titan to reduce its devices from the size of an apple crate to the size of a softball, and to sell them for one-third the cost of a comparable device. The Federal Highway Administration is preparing to use the radar for highway inspections and the Army Corps of Engineers has contracted with LLNL to use the system for search and rescue radar. Other applications include a monitoring device to check the heartbeats of infants to guard against Sudden Infant Death Syndrome (SIDS), robot guide sensors, automatic on/off switches for bathroom hand dryers, hand-held tools, automobile back-up warning systems, and home security.

AERES, a San Jose-based company, has developed a new approach to ground-penetrating radar using impulse radar. The first application of the technology was an airborne system for detecting underground bunkers. The design can be altered to provide high depth capability for large targets, or high resolution for smaller targets near the surface. This supports requirements in land mine searches and explosive ordnance disposal for the military. AERES has developed both aircraft and ground-based systems designed for civilian applications as well as military. Underground utility mapping, such as locating pipes and cables; highway and bridge under-surface inspection; and geological and archeological surveying are examples of the possible civilian applications.



Tom McEwan displays the micropower impulse radar he developed at Lawrence Livermore National Lab. The radar is inserted into a car's taillight, where it would serve as a back-up warning system. The invention has been licensed to Amerigon of Burbank, CA for several automotive applications.

Telemedicine Breakthroughs

Technology 2006 is being held concurrently with the TeleCon XVI show on teleconferencing, videoconferencing, and collaborative systems, as well as Telemed II, the annual telemedicine and telehealth conference and exposition. These three conferences will present a NASA-sponsored workshop showcasing breakthroughs in telemedicine technologies, including NASA's advances in the fields of image compression, satellite communications, virtual reality and visualization tools, Internet tools, and biomedical sensors. The workshop's goal is to create NASA/industry partnerships in order to commercialize these technologies and help companies improve their competitive edge.

One focus is the Advanced Communication Technology Satellite (ACTS), the first all-digital, gigabit-capacity communications satellite. Operating in the Ka-band frequency band (30 and 20 GHz), the satellite uses dynamic hopping beams and advanced on-board switching channels, reuse of bandwidth, and small user Earth stations that interconnect. Developed by NASA's Lewis Research Center, the satellite was launched in 1993 and has pioneered high-risk technology for new services and products such as image compression studies in telemammography and for medical consultations on a rural and global basis. Follow-on commercial systems will provide affordable, high-data-rate transmission of medical records, images, and live video.

Compression of medical images is perhaps the single most cost-effective tool to open telemedicine to practical, affordable, general use. NASA has developed a number of technologies in the compression field that are available for

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commercialization, including lossless image compression algorithms which can compress medical images at 10 to 20 times the speed of the state of the art.

Virtual reality and visualization are necessary tools for providing medical education and diagnosis. NASA has used combined 3D reconstruction and virtual environment technologies to train clinicians and help surgeons plan complex procedures in reconstructive and plastic surgery. NASA also has developed image processing and visualization technologies for patient diagnosis in areas such as dermatology and ovarian cancer.

NASA has explored the Internet as a tool for providing clinical consultation and education in a cost-effective way. NASA also has developed a prototype Internet access model allowing an entire local area network of computers to connect to the Internet using a standard, analog telephone line for an 80% lower cost rate over standard connectivity solutions.

Miniaturized, application-specific biosensors, biotelemetry, and non-invasive monitoring have become vital to telemedicine. NASA has developed advanced biomedical sensors and biotelemetry devices that can use narrow bandwidth, ranging from two-stage transmission systems to "tricorder" devices used in applications from fetal surgery to emergency trauma care.

The smallest of the ACTS communication satellites, the Ultra Small Aperture Terminal (USAT) features a space-saving 14-inch antenna. USAT is used for interactive distance learning and remote medical tele-imaging.

3D Roller-Locking Sprag

Many machines with rotating parts use brakes and clutches to stop or control the degree and direction of motion of the driven parts. Brakes and clutches are incorporated between concentric rotating shafts or races in which bearings are used in rotating machinery. One class of locking brake/clutch uses spherical balls or cylindrical rollers between an inner and outer race; another class uses a roller or sprag in which the cam shape is incorporated into the sprag, which rotates through a small angle to engage the cam surfaces against the concentric cylindrical surfaces of the inner and outer races.

The 3D roller-locking sprag, developed at NASA Goddard, has no gears, allowing continuous motion in two directions, or no motion at all. It is expected to eliminate the need for ratcheting techniques in devices ranging from car transmissions to simple hand tools.

Two-dimensional sprags have been used in a variety of devices for many decades. NASA's Goddard Space Flight Center has developed a 3D roller-locking sprag that is more compact, stronger, lighter, more efficient, and more durable. In the 3D design, the concentric, cylindrical surface of the inner and outer races of the brake/clutch are replaced with grooves into which the tapered periphery of the 3D roller-locking sprag fit. This geometry creates four points of locking contact: two between the outer taper of the 3D sprag and the outer grooved race, and two between the inner taper of the 3D sprag and the inner grooved race. This geometry doubles the number of points of contact of conventional, ball-based roller-locking brakes/clutches, increasing the locking efficiency and reducing the level of sprag-to race contact stresses. The 3D sprag allows two directions of motion or no motion at all. Since there are no gears, continuous motion is possible.

The 3D sprag can dramatically improve the performance of roller-locking devices, open new applications, and eliminate the need for ratcheting techniques. Roller-locking sprags are used throughout everyday life, in devices ranging from automobile transmissions to starter motors and simple hand tools.

All-Plastic Battery

Researchers at the U.S. Air Force's Rome Laboratory and Johns Hopkins University have developed an all-plastic battery using polymers instead of conventional electrode materials. All-plastic power cells could be a safer, more flexible substitute for use in electronic devices and other commercial applications. In addition, all-polymer cells reduce toxic waste disposal, negate environmental concerns, and can meet EPA and FAA requirements.

Applications include powering GPS receivers, communication transceivers, remote sensors, backup power systems, cellular phones, pagers, computing products, and other portable equipment. Potential larger applications include remote monitoring stations, highway communication signs, and electric vehicles.

The Johns Hopkins scientists are among the first to create a potentially practical battery in which both of the electrodes and the electrolyte are made of polymers. Fluoro-substituted thiophenes polymers have been developed with potential differences of up to 2.9 volts, and with potential specific energy densities of 30-75 watt hours/kg.

All-plastic batteries can be recharged hundreds of times and operate under extreme hot and cold temperature conditions without serious performance degradation. The finished cell can be as thin as a business card and malleable, allowing battery manufacturers to cut a cell to a specific space or make the battery the actual case of the device to be powered.

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New digital operating environments require a new generation of transducer that is more flexible than current cone speaker, antenna, microphone, or sensor technologies. Patriot Advanced Technologies has addressed these requirements in developing an Advanced Membrane Transducer (AMT) that can perform multiple roles in a thin-film, flexible geometry. The membrane is capable of direct digital interface with computer systems, network applications such as the Internet, flight and transportation systems, phased array systems, wireless communications, multimedia, medical electronics, and other commercial, military, and consumer applications such as television, stereo, and computer speakers.

Similar to the way video software and hardware allow high definition television to be created by controlling display pixels, the transducer allows computers and other systems to address and manipulate independently addressable Sound Pixels™/Antenna Polygons™ to produce high-resolution audio and RF. The advantages of using a sound surface consisting of hundreds or thousands of sound pixels, compared with a pair of conventional speakers with single output voice coils and a conventional antenna with a fixed pole length and frequency, are numerous.

From digital speakers 3 mm thick that act simultaneously as antennas and microphones, to sound-generating plant-growth devices, to medical monitoring devices, the AMT technology can be adapted to reduce costs in manufacturing, installation, and repair, while providing high-quality sound and communications capabilities.

Low-Cost Fabrication and Joining Techniques

Silicon carbide-based fiber-reinforced composites are used in aeronautical, energy, electronics, nuclear, and transportation applications such as jet engines, nose cones, heat exchangers, gas filters, and radiant heater tubes. The two types of commercially available fiber reinforced silicon carbide matrix composites are produced either by chemical vapor infiltration (CVI) or by polymer impregnation and pyrolysis (PIP) – both very expensive.

NASA's Software of the Year

NASA's 1996 Software of the Year Awards will be presented in a special ceremony during the Technology 2006 Awards Dinner. Chosen by NASA's Inventions and Contributions Board, the awards are given to individuals who develop software that enhances NASA's mission and assists U.S. industry in maintaining world-class technology status.

1996 Co-Winners:

Tetrahedral Unstructured Software Systems (TetrUSS), developed by NASA's Langley Research Center, Hampton, VA (headed by Dr. Neal Frink)

TetrUSS aerodynamics analysis and design software, developed at NASA Langley, enables fluid mechanics analysis for low-speed through supersonic aircraft such as the B747 shown here.

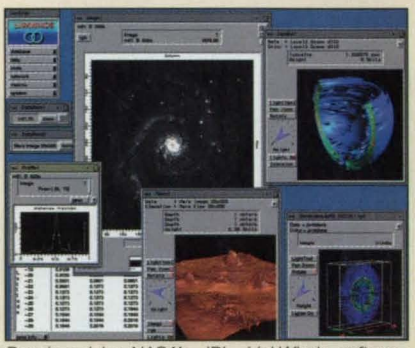
TetrUSS is an unstructured-grid aerodynamic analysis and design system for inviscid and viscous flow, incorporating a graphical user interface, surface and volume grid generation, an unstructured-grid upwind flow solver, and a graphical post processing tool. Used widely throughout U.S. industry, government, and universities, it was designed for low-speed through supersonic aerodynamics in spacecraft, rotorcraft, automotive, turbomachinery, and medical analysis and design.

The software's primary innovation is the method by which it generates the solution grid for the fluid mechanics problem it is solving. The unique methodology and graphical user interface reduce computational time, while a user-friendly menu enables quick, accurate set-up for its tetrahedral grid generation and the display of complex geometric grids and plots of results of its internal flow solver.

Linked Windows Interactive Data System (LinkWinds), developed by NASA's Jet Propulsion Laboratory, Pasadena, CA (headed by Dr. Allan S. Jacobson)

LinkWinds, a visual data exploration system for examination of geophysical and climatological data retrieved from satellite remote sensing, rapidly and interactively investigates large multivariate and multidisciplinary data sets to detect trends, correlations, and anomalies. The software grew out of JPL research to apply computer graphics to access, display, explore, and analyze science data.

LinkWinds applies a unique data-linking paradigm, resulting in a system that functions like a graphical spreadsheet. It provides an intuitive user interface on top of the traditional graphical user interface, and consists of an expanding suite of non-domain-specific applications. The program currently runs on Silicon Graphics and Sun workstations; an updated Sun and Linux version will be released soon for PCs.



Developed by NASA's JPL, LinkWinds software applies computer graphics to access, display, explore, and analyze geophysical and climatological data.

First Runner-Up:

Virtual Environment Vehicle Interface (VEVI), developed by Ames Research Center's Intelligent Mechanisms Group, Moffett Field, CA

VEVI is a modular operator interface for direct teleoperation and supervisory control of robotic vehicles. It uses real-time interactive 3D graphics and position/orientation sensors to produce generic video control capabilities, and has been used to control wheeled, air bearing, and underwater vehicles in a variety of environments.

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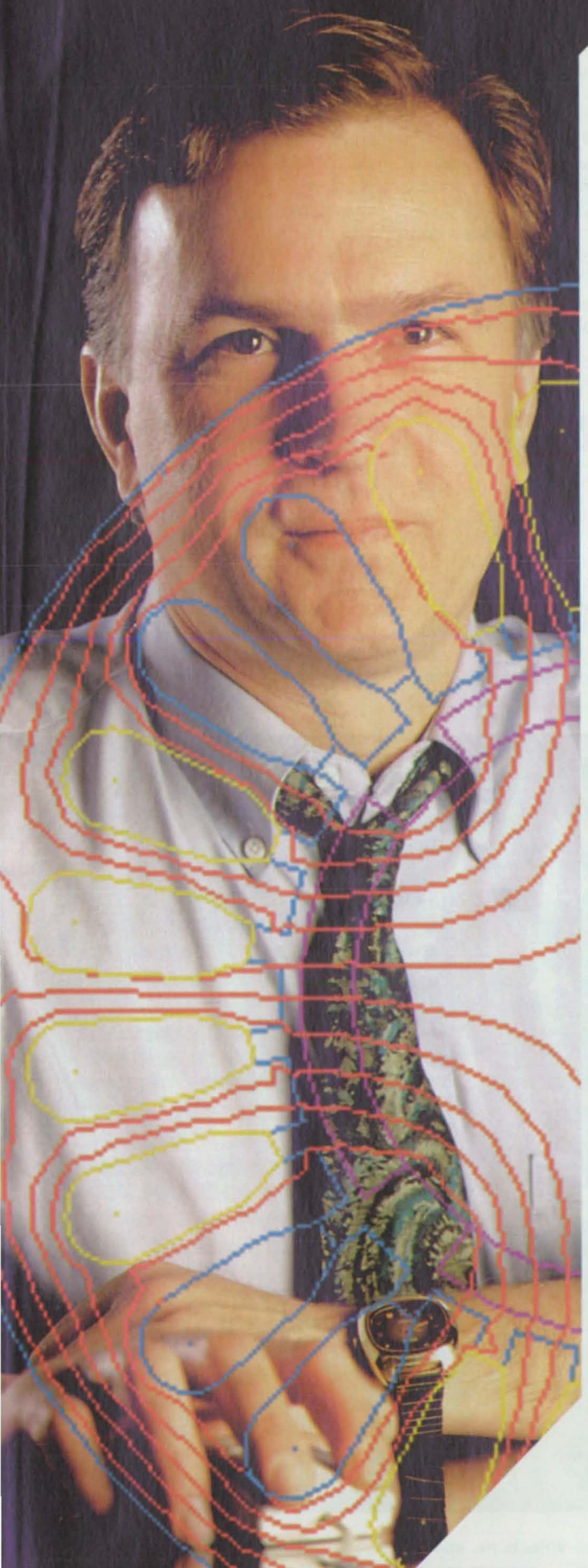

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For More Information Write In No. 607

Research at NASA Lewis has produced a low-cost approach to fabrication and joining of composites with 3D architectures, such as silicon carbide-based fiber-reinforced composites.

Research at NASA's Lewis Research Center has resulted in a lower-cost approach that reduces fabrication times significantly. The products produced by this process are nearly fully dense, with good control of the microstructure, second phases, and mechanical properties. The process involves production of a fiber preform, followed by infiltration with a resin mixture. After pyrolysis, the mixture converts to a porous carbonaceous matrix which subsequently is infiltrated with liquid silicon or refractory metal-silicon alloys.

The process is suitable for various types of fiber reinforcements, such as carbon, alumina, and silicon carbide. It has been used to fabricate composites with 3D architectures. A number of key properties, such as strength, creep, and environmental and thermal shock resistance of composites, can be tailored.

Lewis also has created a way to join carbon and silicon carbide fiber-reinforced composites of various shapes and sizes. The process can yield joints with tailorable microstructure and thermomechanical properties suitable for high-temperature applications.

GPS Positioning System Delivers High Accuracy

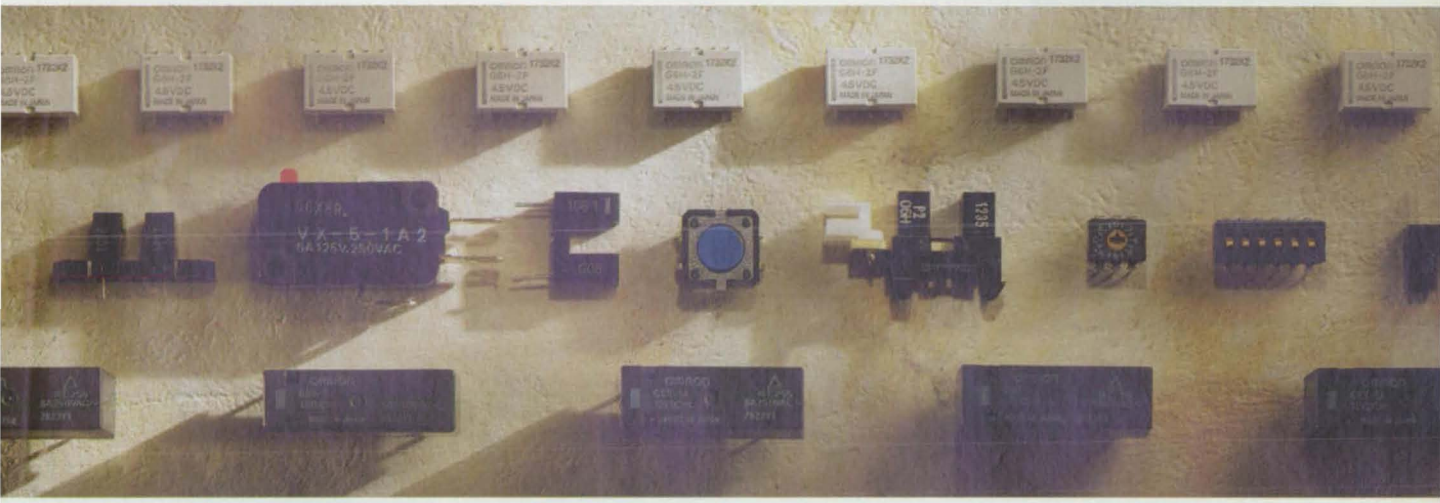
A system for real-time differential GPS (DGPS) positioning will deliver submeter accuracy to Earth satellites and ground-based users worldwide. Developed at NASA's Jet Propulsion Laboratory, the system could improve real-time position accuracy to a few decimeters for single-frequency users and 10 centimeters or better for dual frequency users. In addition to high accuracy, the system provides nearly complete separation of GPS orbit and clock corrections and continuous determination of interfrequency delay biases for all GPS satellites and reference receivers.

Key features include: the use of dynamic orbit estimation, which depends on high-accuracy satellite force models, signal models, geophysical models, and geometric models, in a Kalman filter formulation; use of real-time stochastic estimation to minimize orbit and clock errors arising from quasi-random variations in atmospheric propagation relays and solar radiation pressure; simultaneous processing of smoothed pseudorange and continuous carrier phase data; and use of the stable solar-magnetic reference frame, rather than an Earth-fixed frame, in computing the ionospheric corrections.

System operation will begin in January 1997. Early tests show approximate user differential range errors of less than 20 cm throughout the coverage area, with a North American reference network only. More comprehensive tests with additional global reference sites will be conducted.

For more information on Technology 2006, see pages 119-121, or call George DeFeis at 212-490-3999.

If You Think Omron Only Makes Relays, Read Between Our Lines.



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WHAT'S NEW ON DISPLAY AT TECHNOLOGY 2006

Technology 2006 features more than 60,000 square feet of exhibit space showcasing the latest technologies, products, and services. Here are a few of the new products you'll see on display.

Booth 923

FARO Technologies, Lake Mary, FL, will demonstrate AnthroCAM Version 1.32 **geometric measurement and reverse engineering software**, which was designed for use with FaroArm® measurement arms for 3D measurements in medical, diagnostic, and surgical applications. The 3D CAD-based software provides basic features measurement, CAD-to-part inspection, and reverse engineering capabilities. Enhancements include on- and off-line parts programming, a tubing feature for pipefitting through obstacles, geometrical dimensioning and tolerancing, and improved scanning that includes lock planes and lock cylinders. Users can collect individual points or streams of data in real time; the software surfaces the data points and exports models in a variety of formats, including DWG, DXF, and ASCII.

Booth 914

MagNet version 5.2 **electromagnetics analysis software** from Infolytica Corp., Montreal, Quebec, Canada, uses a neural network to determine optimum discretization of a problem geometry for solution. The software is "taught" through experience in problem-solving which parts of a device are expected to have large changes in electromagnetic fields, and bases its solution on the acquired "knowledge." The software includes a new force/torque calculation module for designers of motors, actuators, and similar devices, and an open boundary technique for far fields or stray fields. It is compatible with Windows 95, Windows NT, Windows 3.1, and UNIX.

Booth 132

The Point Ionizer™ **ionization device** from Crystal Mark, Glendale, CA, incorporates a balanced flow of positive and negative ions and an abrasive nozzle to reduce static charges generated from abrasive blasting. The device can be used to improve cleanliness on surfaces where static charges generate an electromagnetic field, causing the abrasive particles to cling to the substrate being blasted. It also is used when blasting coatings off of ESD-sensitive devices such as electronic components and printed circuit boards. It enables containment of electrostatic discharge below 20 volts.

Booth 320

Tiodize, Huntington Beach, CA, will exhibit Fiber/Lite **composite fastener products** and Tribo/Comp **composite bearing material**. Fiber/Lite fasteners are compression-molded and machined from materials such as 3D woven carbon, glass fiber, reinforcing epoxy, and polyimide resin in gang channel, rivet, insert, nut, pin, hinge, latch, and rod-end configurations. The fasteners have low water absorption and thermal expansion, and feature high tensile, shear, and fatigue strength. Tribo/Comp is a self-lubricating composite material with a low coefficient of friction and no creep at 30,000 psi/600° F loads. It is used for bearings, bushings, thrust washers, and wear pads.

Booth 927

Machida, Orangeburg, NY, will display **flexible borescopes** designed for a variety of visual inspection applications. The borescopes can accommodate most inspections when the elimination of tear-down is necessary. Also highlighted will be specialized turbine inspection kits, blending borescopes, scopes with channels, and working tools, video systems, light sources, and related accessories.

Booth 732

The Sisuner® **non-adhesive sealing system** from Tokue Rubber Industrial Co., Southfield, MI, consists of two separate springs molded into each side of the joining surface. The two springs – a U-spring and a flat spring – lock together after insertion to form an airtight seal that is water-resistant and flexible. There is no adhesive or glue used to seal the joint. Applications include replacement of damaged bellows and seals, absorption of vibration, and where bends and sharp angles are encountered. Spring size and material composition can be specified, and the system's springs can be molded into various materials such as rubber, synthetic resin, and polyethylene.

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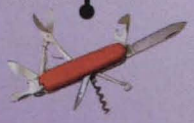

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Special Focus: Sensors

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Active-Pixel Image Sensor Integrated With Readout Circuits

A single chip performs most of the functions of a video camera.

NASA's Jet Propulsion Laboratory, Pasadena, California

A single-chip complementary metal oxide/semiconductor (CMOS) integrated circuit comprises an active-pixel image sensor with timing, control, and readout circuits. This chip performs the electronic functions of a video camera of 128 × 128 pixels with control of integration time, selection of a readout window (a subset of the full array of pixels), and frame activation. This chip offers an alternative to charge-coupled devices (CCDs). It is difficult to integrate control and signal-processing functions into CCDs, and fabrication of CCDs is expensive in comparison with fabrication of devices like the present one.

The chip features a 1.2-μm design rule implemented in an n-well CMOS process. The pixel pitch is 19.2 μm. The chip operates from a 5-V power supply. An externally-generated clock signal is needed to produce video output. Readout is implemented with a column-parallel architecture; the outputs of the pixels are multiplexed, one row at a time and then one column at a time through a single on-chip amplifier/buffer. Digital circuits employ common logic elements to control row and address decoders and delay counters. In addition to the clock and power, the required inputs to the chip are a single +5-V power supply, start command, and parallel data load commands for defining integration time and windowing parameters.

Figure 1 illustrates the major functional blocks. The analog outputs are VS_OUT (signal) and VR_OUT (reset), and the digital outputs are FRAME and READ. The inputs to the chip are asynchronous digital signals. To command the chip to read out from only a specified area of interest within the 128 × 128 array, the decoder counters are preset to start and stop at values that have been loaded into the chip via the 8-bit data bus. Alternatively, when the DEFAULT input line is used, all counters are set to read out from the full 128 × 128 array.

A programmable integration time is set by adjusting the delay between the end of one frame and the beginning of the next. This parameter is set by loading a 32-bit latch via the input data bus. A 32-bit counter operates from one-fourth the input clock frequency and is preset each frame from the latch; thus, very long integration times are achievable. The input clock signal can have any frequency up to about 10 MHz. The pixel readout rate is tied to one-fourth the clock rate. Thus, the frame rate is determined by the clock frequency, the window settings, and the integration time. A frame rate of 30 Hz can be achieved without difficulty.

The chip is idle when the RUN command is deactivated. It is recommended to set operating parameters while the chip is idle, but because of the asynchronous nature of operation of the chip, it is also possible to set the operating parameters at any time. When RUN is activated, the chip repeatedly reads out frames based on the parameters loaded in the control registers. When RUN is deactivated, the frame in progress runs to completion, then operation stops.

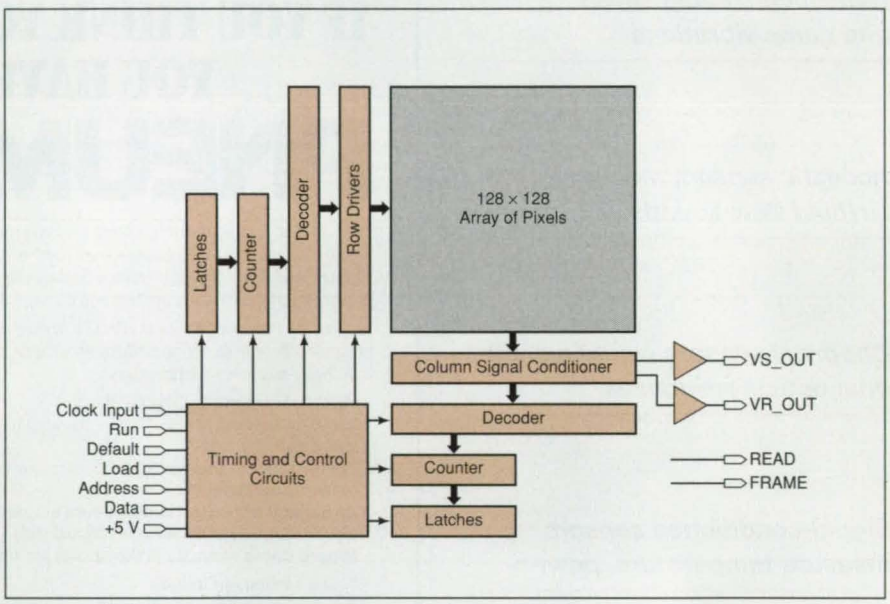

Figure 1. The **Active-Pixel Image Sensor** includes not only the photosensors but also the timing, control, and readout circuits, integrated on one chip.

The photosensor in each pixel is a photodiode. The pixels in this device are said to be active because each pixel also contains active components; namely, three transistors that are parts of the readout circuitry. Figure 2 illustrates one active pixel along with readout circuits external to the pixels. The pixel unit cell consists of the photodiode, a source-follower input transistor, a row-selection transistor, and a reset transistor, which controls lateral blooming through proper biasing of the reset gate.

At the bottom of each column of pixels, there is a load transistor VLN1 and two output branches to store the reset and signal levels. Each branch consists of a sample-and-hold capacitor (CS for the signal level; CR for the reset level) with a sampling switch (SHR and SHS for the reset and signal level, respectively), and a second source follower with a column-selection switch (COL). The reset and signal levels from each pixel are read out differentially, enabling correlated double sampling to suppress 1/f noise and fixed-pattern noise. These readout circuits are common to an entire column of pixels. The load transistors (VLP) of a second set of source followers and associated clamp circuits are common to the entire array.

The readout circuits perform correlated double sampling (CDS) to suppress pixel fixed-pattern noise and an improved version of double-delta sampling (DDS) to suppress column fixed-pattern noise. After a row has been selected for readout, the signal that is present on each column from each pixel in that row is sampled (SHS) onto the holding capacitor CS. Next, each pixel in the row is reset (RESET). This is followed by sampling the reset level (SHR) onto holding capacitor CR.

The pixels in the chosen row are then read out by reading out the columns in sequence. After a column has been selected, there is a settling time equivalent to one-half the column selection period. Then DDS is performed: Prior to DDS, reset and signal column outputs (Vcol_R and Vcol_S) contain their

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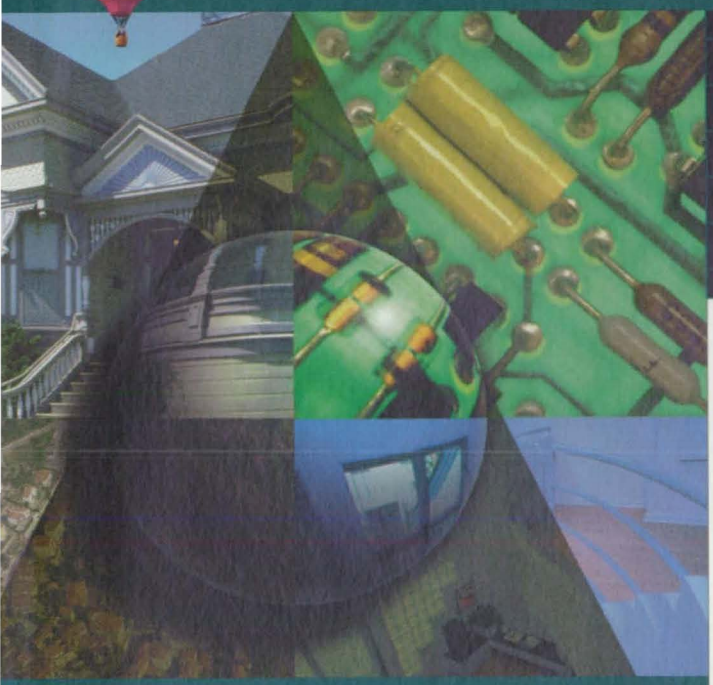

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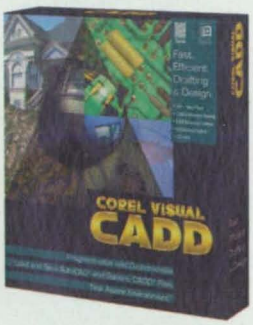

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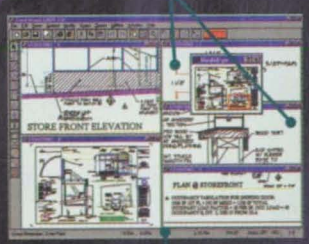

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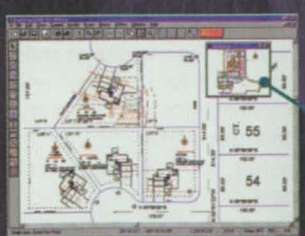

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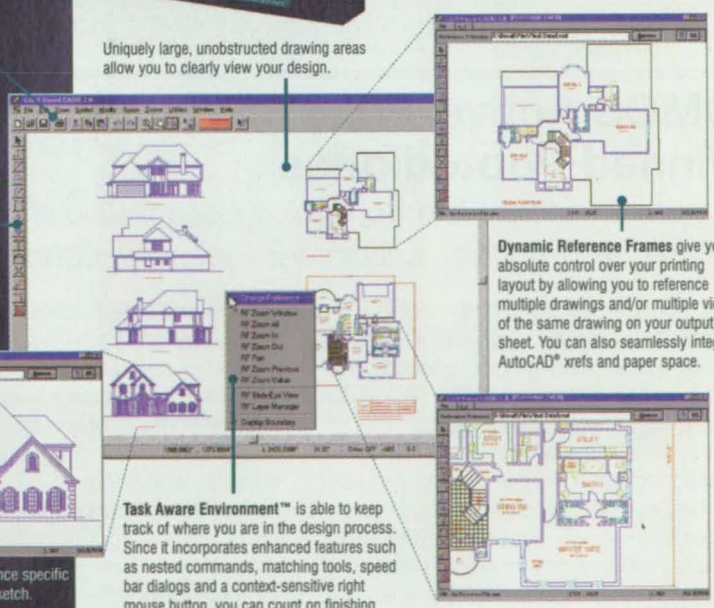

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respective values plus a source-follower voltage threshold component. Immediately after CLAMP is turned off, the DDS switch (the transistor labeled "DDS" in Figure 2) and two column-selection switches ($\overline{COL}$) on opposite sides are used to short CR and CS together. The result is a difference voltage coupled to the output drivers (VR_OUT and VS_OUT) that is free of the voltage threshold component.

This work was done by Robert Nixon, Eric Fossum, and Sabrina Kemeny of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 5*** *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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Refer to NPO-19582, volume and number of this NASA Tech Briefs *issue, and the page number.*

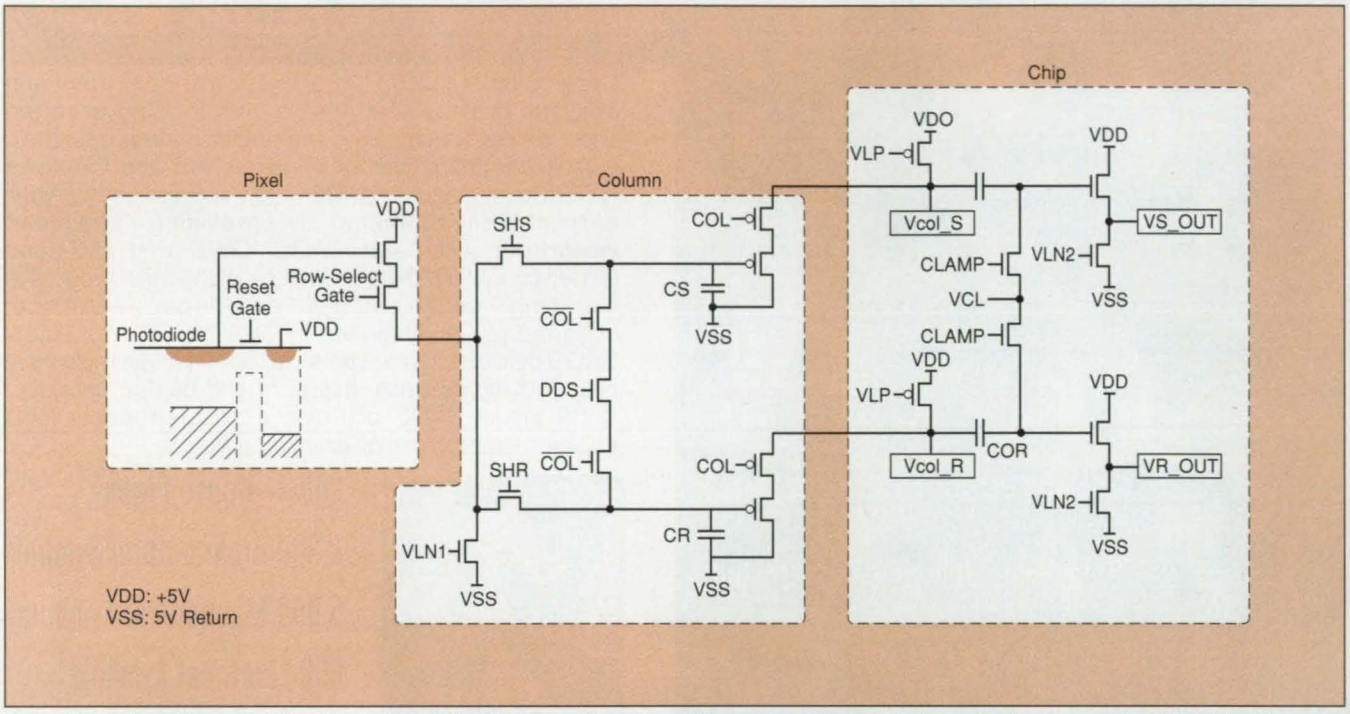

Figure 2. **Each Active Pixel Contains Part of the Readout Circuitry**, while some of the readout circuitry is common to all the pixels in a column and some serves all the columns on the chip.

CMOS Active-Pixel Image Sensor Containing Pinned Photodiodes

Lower dark current and higher blue response are anticipated.

NASA's Jet Propulsion Laboratory, Pasadena, California

A complementary metal oxide/semiconductor (CMOS) active-pixel image sensor containing pinned photodiodes has been built (but not yet tested) in an effort to improve on a silicon-based active-pixel image sensor that was developed previously and is now in use at NASA's Jet Propulsion Laboratory. The older sensor operates with high quantum efficiency except in the blue part of the spectrum, where the response is diminished by photogates made of polycrystalline silicon ("poly" for short). In addition, the dark current (1 nA/cm^2) of the older sensor is greater than desired. Accordingly, the present sensor was designed to incorporate pinned photodiodes as its photoelements because pinned photodiodes can be fabricated without overlying poly. Pinned photodiodes are characterized by no lag, low reset noise, low dark current, and high quantum efficiency.

The sensor contains an array of 256 × 256 pixels on an integrated-circuit chip with an overall size of 1.2 × 1.2 cm and with a 40-pin pad frame. All of the row and column circuitry is designed with a 40-μm pitch to match the pixel size. The circuitry operates at transistor/transistor-logic voltage levels from power supplies of 5, 2.5, and 1.25 Vdc. Row and column addressing of the pixels is accomplished via 8-input NAND gates (one such gate for the rows, the other for the columns). Each 8-input NAND gate contains eight n-channel transistors in series, implemented by use of overlaid poly-1/poly-2 gates, somewhat as in a charge-coupled device.

A column-control logic circuit generates a column-selection signal, which is used to control the serial readout of data and is used with a crowbar signal to perform an operation that reduces fixed pattern noise. Each column-readout circuit contains two sample-and-hold capacitors; one for the signal level and one for the reset level. The crowbar signal activates a crowbar switch, which is a transistor switch in each column-readout circuit that is used to selectively short-circuit the two sample-and-hold capacitors together to reduce the fixed pattern noise generated by threshold-voltage offsets in p-channel source followers in the readout circuitry.

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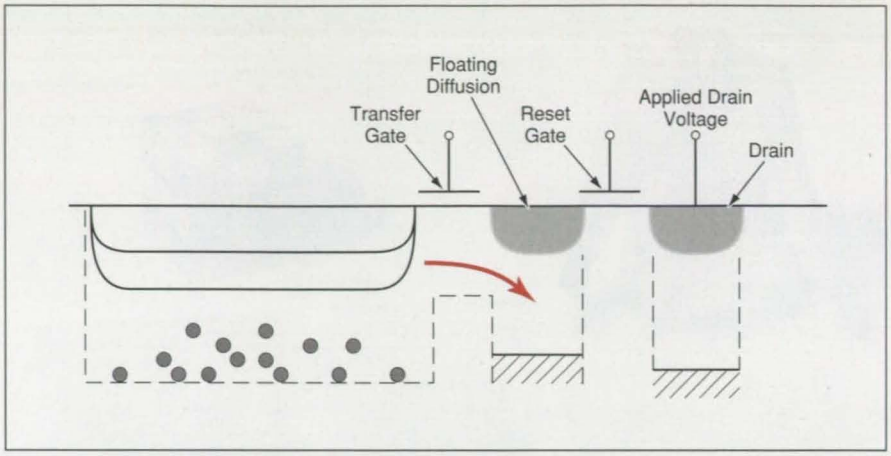
Both the signal and reset levels of each pixel are read out, providing for off-chip subtraction to reduce the noise from each pixel.

The figure illustrates the active-photosensor part of a pixel, with its pinned photodiode and integral transistors. It includes a transfer gate, a reset gate, and a floating diffusion node that connects to the input node of an n-channel source follower. A row-control logic circuit generates a row-selection signal plus the signals that are applied to the transfer and reset gates of each pixel in the selected row. The transfer gate is clocked to transfer the signal charge to the floating diffusion node. A frame-reset signal is also available; this signal is an inverted one that, when low, switches on the reset transistors in all pixels, putting all the floating diffusion nodes at the reset level but not emptying the signal charge from the pinned photodiodes.

The signals from the array of pixels are read out a row at a time. The reset and signal level from each pixel in the selected row is loaded in the sample-and-hold capacitors at the bottom of the column of that pixel. The levels from the columns are then read out serially.



A **Pinned Photodiode in Each Pixel** is expected to give higher blue response and lower dark noise than does a poly photogate in each pixel in an older device.

This work was done by Eric R. Fossum and Russell C. Gee of Caltech and Paul P. K. Lee, and Teh Hsuang Lee of Eastman Kodak Company for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 10*** *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:

Larry Gilbert, Director
Technology Transfer
California Institute of Technology
Mail Code 315 - 6
Pasadena, CA 91125
(818) 395-3288

Refer to NPO-19648, volume and number of this NASA Tech Briefs *issue, and the page number.*

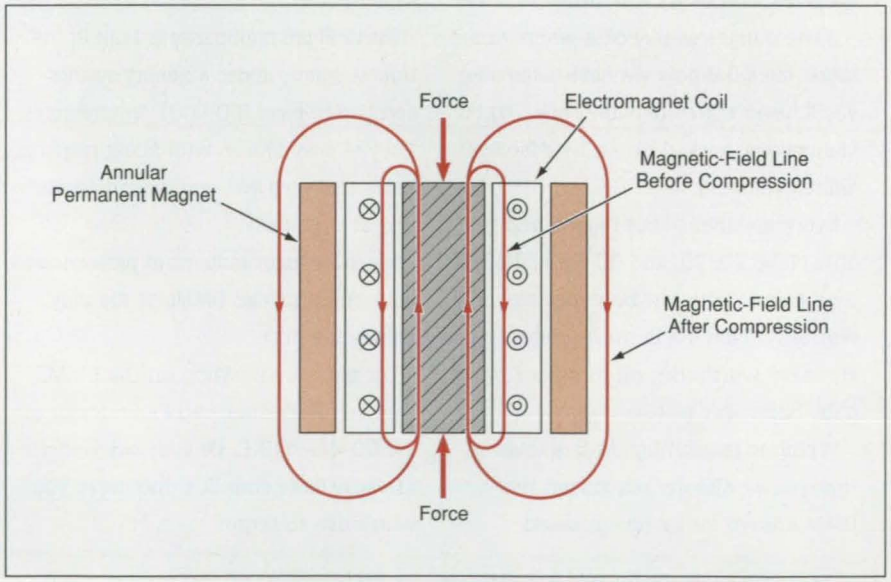
Magnetostrictive Transducers Would Sense and Damp Vibrations

These devices would incorporate a high-energy magnetostrictive material.

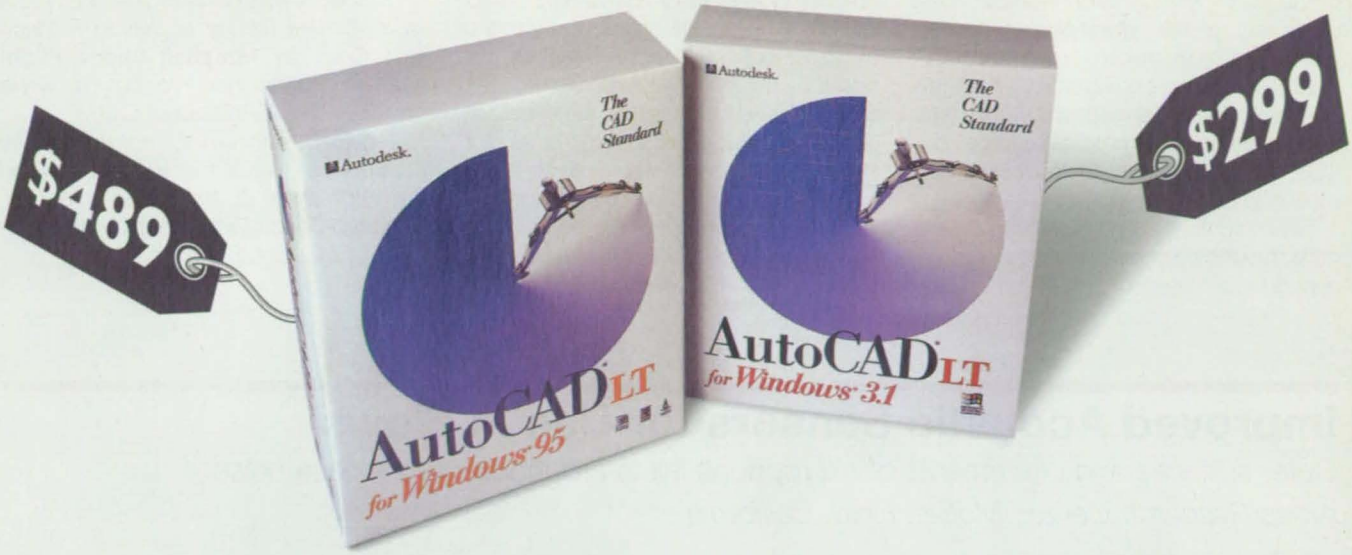
Marshall Space Flight Center, Alabama

Magnetostrictive transducers are being investigated for potential use in sensing and damping vibrations of structures. The magnetostrictive material to be used in these transducers is Terfenol-D (or equivalent). Previously, magnetostrictive transducers have been operated in a "forward" mode, in which electrical currents are applied to electromagnets that, in turn, apply magnetic fields to magnetostrictive components to generate large forces via the magnetostrictive effect. The advantage of Terfenol-D (or equivalent) is that it can also effect the "reverse" transduction from mechanical to electrical energy with equal efficiency.

In a typical application, a structure would contain one or more members made at least partly of the magnetostrictive material surrounded by an electromagnet coil and an annular permanent magnet (see figure). When a force (e.g., a vibrational force) was applied to the magnetostrictive material, a magnetic field would be generated by the magnetostrictive effect and intercepted by the coil. The ends of the coil could be connected to sensing circuitry for measurement of vibrations. The ends of the coil could also be connected to a suitable resistor or short circuit to damp the elec-



This **Magnetostrictive Transducer** could be used as a passive vibration damper, a vibration sensor, or a force actuator.



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tromagnetic energy and thereby passively damp the vibrations. (Alternatively, the transducer could also be operated as a conventional magnetostrictive force transducer by applying current to the coil to produce a force and thus, a desired distortion and vibrational motion in the member.)

Experiments were performed to determine the degree of passive damping produced by a magnetostrictive transducer containing Terfenol (or equivalent). Damping was found to be optimized by use of particular coil-shunt resistances, as predicted by theory. Other experiments were also performed to measure the sensitivity of the transducer as a velocity sensor. These experiments showed that the transducer put out large velocity-related voltages, both when it was used as a sensor only and when it was also used simultaneously in the "forward" actuator mode.

This work was done by Ralph C. Fenn and Michael Gerver of Satcon Technology Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 29*** *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; (205) 544-0021. Refer to MFS-26290.

Improved Acoustic Sensors for Use in Flows

Outer surfaces and placements of microphone inlets are modified to reduce noise.

Ames Research Center, Moffett Field, California

Figure 1 illustrates two sensors that measure sound waves in flows of air and other fluids at subsonic speeds; one is of an older design and one is of a newer, improved design that results in less measurement noise. Both include curved nose sections with smooth transitions to aft cylindrical sections. In both cases, the cylindrical sections contain microphones with side inlets covered by screens. The two designs differ mainly in the shapes of the nose sections and placements of microphone inlets relative to the nose-section/cylindrical-section transitions.

In the older design, the nose section features a sharp tip that can create flow instabilities when the longitudinal axis of the sensor lies at even a small angle from the direction of flow. Moreover, the screen and microphone inlet are located adjacent to the nose/cylinder transition, in an area of unfavorable pressure gradient, where the pressure is very sensitive to fluctuations in the freestream flow such as those fluctuations caused by freestream turbulence. The microphone responds to these fluctuations in the same way in which it responds to the pressure fluctuations from sound waves that one seeks to measure; as a result, the microphone output includes noise contributed by flow instabilities.

In the newer design, the nose features a rounded tip; the nose section is ellipsoidal, with its major axis collinear with the longitudinal axis of the cylindrical section, its minor axis coincident with the diameter of the cylindrical section, and an eccentricity of about 4. Unlike the sharp tip in the older design, this rounded tip does not readily excite instabilities when mounted at small angles to a smooth flow or when the direction of flow fluctuates with turbulence. The surfaces of the nose section and the adjacent cylindrical section are made as smooth as possible to further reduce the incidence of instabilities.

In the newer design, the microphone inlet is located between 3 and 4 cylinder diameters downstream of the nose/ cylinder transition. This location is chosen because it is downstream from the unfavorable pressure gradient wherein the flow is in an unstable state in which small freestream fluctuations can be amplified; it is far enough downstream that the static pressure is stable and equal to the free-stream static pressure. At the same time, this location is far enough upstream so as not to be affected significantly by turbulence-induced noise that grows as the boundary-layer flow grows with increasing distance downstream.

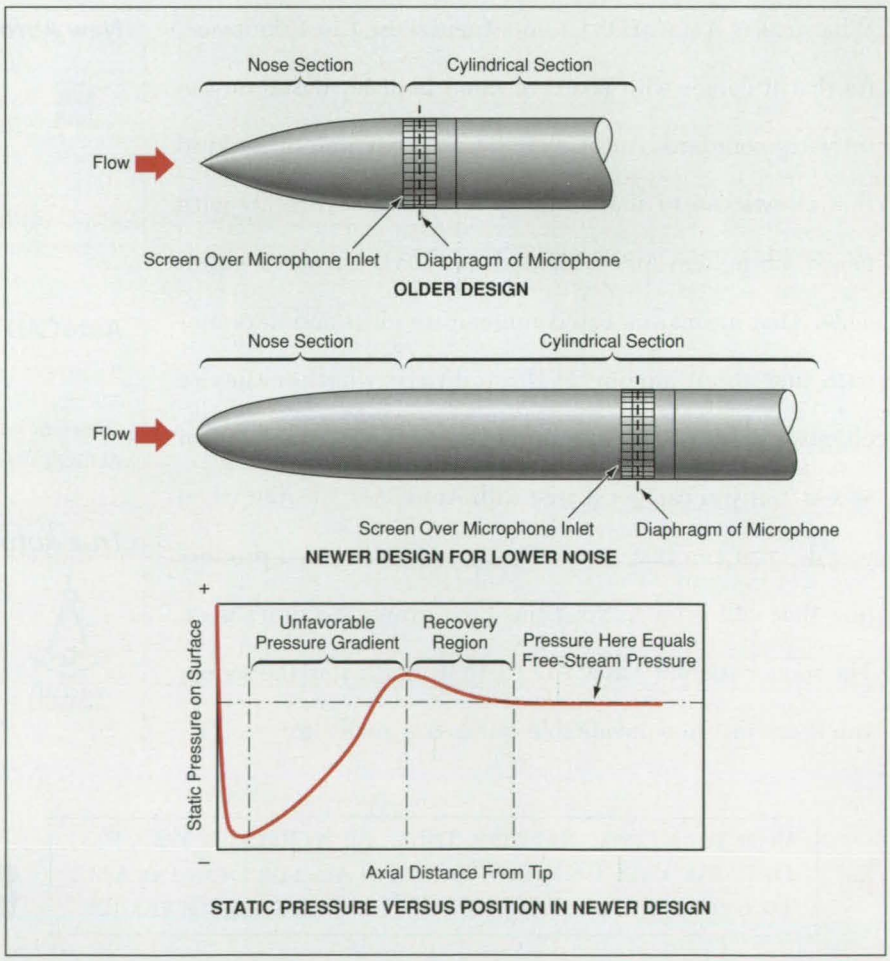


Figure 1. **Older and Newer Designs of Acoustic Sensors** for use in subsonic flows differ in the shapes of the nose sections and placements of microphone inlets. An alternative newer design (not shown) more suitable for use in supersonic and hypersonic flows calls for a sharp nose longer than that of the older design.

Figure 2 shows noise levels obtained from the outputs of sensors of the older and newer designs. The data from the sensor of older design indicate higher levels of noise at several frequencies ranging from about 20 to about 80 kHz, while the data from the sensor of newer design indicate generally lower noise levels with no high peaks in this frequency range.

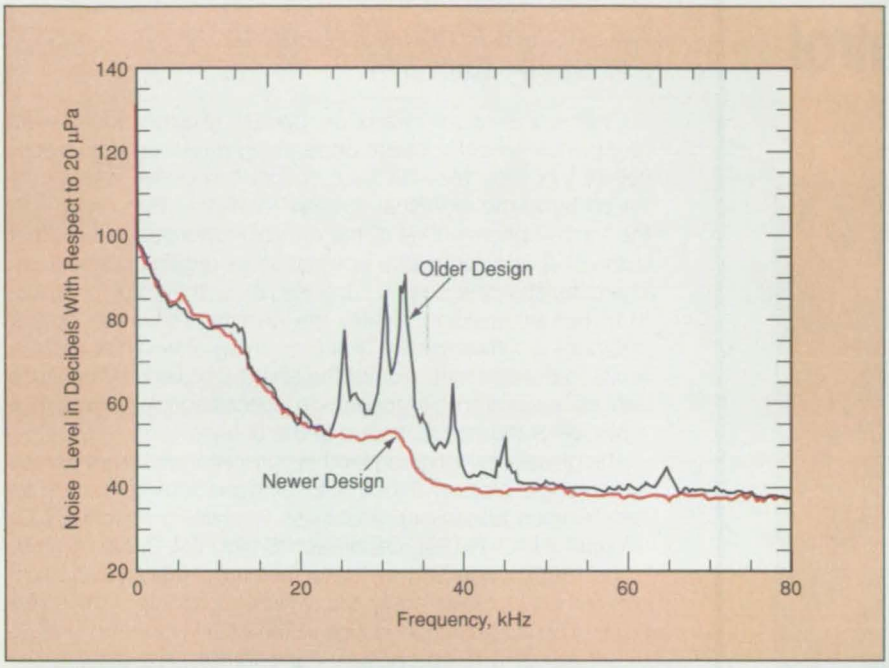


Figure 2. **Noise Levels vs. Frequency** were measured in the outputs of a sensor of the older design and a sensor of the newer design in a wind tunnel at a speed of 200 knots (103 m/s).

This work was done by Christopher S. Allen of Sterling Federal Systems for **Ames Research Center**. *For further information,* ***write in 47*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,477,506). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-12001.

Sensors Would Monitor Rocket Exhausts for Signs of Wear

Marshall Space Flight Center, Alabama

Optoelectronic sensor systems are being developed for installation on rocket engines to monitor exhaust gases for signs of wear in the engines. These systems would yield data on the concentrations of critical rocket-component metals in rocket-exhaust gases by measuring emission and absorption spectra characteristic of the metals. The sensor systems would not only provide measurement data to engine controllers in real time but would also store measurement data in nonvolatile onboard memories to provide histories of losses of metal from the engines. The historical data would be useful in making decisions concerning maintenance and withdrawal from service. The principal innovative feature of these systems lies in their highly miniaturized and rugged designs; with suitable modifications, these designs could be adapted to spectral monitoring systems for commercial turbojet and turbofan engines.

This work was done by David B. Duncan of Duncan Technologies, Inc., 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; (205) 544-0021. Refer to MFS-26381.

Dual-Mode Chemical Sensors

Chemical species and their concentrations would be determined optically.

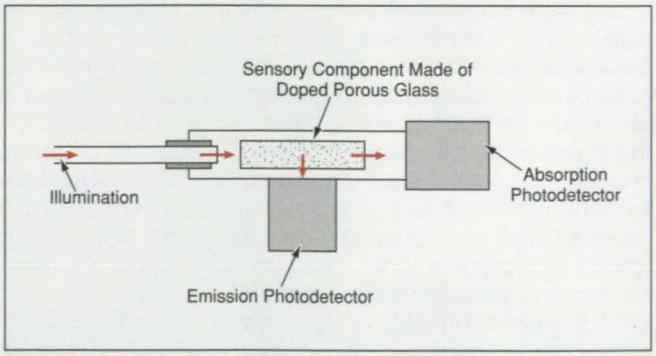
NASA's Jet Propulsion Laboratory, Pasadena, California

Chemical sensors based on porous glasses doped with reactive chromophores are undergoing development. A sensor of this type exhibits dual optical responses when infiltrated by some chemical species (analytes) that react with the chromophores. One of the optical responses is a distinct color — that is, a unique absorption or reflection spectrum characteristic of a specific analyte; thus, the color or spectrum can be used to identify the analyte. The other optical response is luminescence, the quenching of which is proportional to the concentration of the analyte; thus, luminescence can be measured by absorption spectroscopy to obtain a measure of the concentration of the analyte.

The glasses investigated for this purpose thus far are porous silica sol-gel glasses doped with oxovanadium centers. [See also "Porous Silica Sol-Gel Glasses Containing Reactive V_2O_5 Groups" (NPO-19135), *Laser Tech Briefs*, Vol. 3, No. 1 (February 1995), page 30.] In these materials, the oxovanadium centers act as Lewis-acid sites, which coordinate small molecules. This coordination results in the color unique to analyte molecules of a given species. For example, water turns the glass orange, hydrogen sulfide turns it deep amber, and formaldehyde turns it green. In addition to these chromic changes, the glass luminesces green (with a spectral peak at a wavelength of 520 nm).

The figure illustrates a likely configuration for a sensor of this type. The doped-glass sensory component would be packaged to intercept excitatory light delivered via an optical fiber. Also included in the package would be two photodetectors; one photodetector would be collinear with the illuminating beam of light for measuring absorption, while the other photodetector would be perpendicular to the beam for measuring luminescence. The sensory material could be applied as a film at the tip of the optical fiber, or it could be deposited to form a channel in an optical waveguide device at the tip of the fiber.

This work was done by Albert E. Stiegman and Gerald Voecks of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 75*** *on the TSP Request Card.*
NPO-19591



Light Delivered via the Optical Fiber would illuminate the sensory component. The outputs of the photodetectors could be used to determine the identity and concentration of an analyte.

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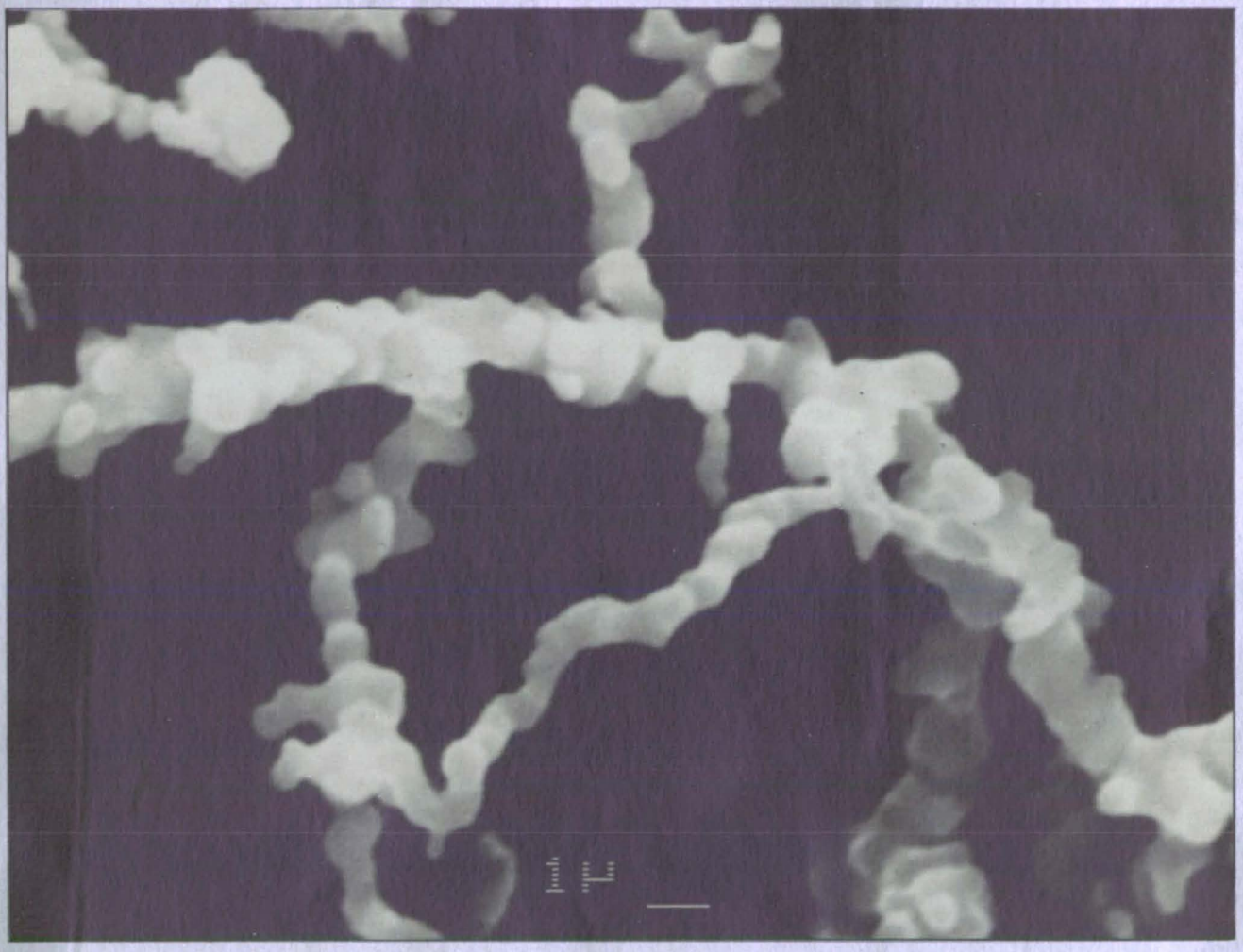

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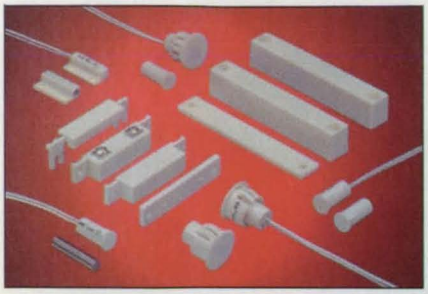

The MPS Series of **magnetic proximity sensors** from C&K Components, Watertown, MA, features hermetically sealed contacts, wide gap performance, Alnico V magnets, and O-ring shock protection. The sensors are suited for applications involving limit, path interruption, size, and level sensing and counting.

The sensor contacts are hermetically sealed within a glass capsule in a dry nitrogen atmosphere using a high-energy CO_2 laser, allowing the reed switch to operate in damp or dusty environments. The wide gap performance allows the magnet and switch to operate when misaligned, increasing sensitivity and providing easy installation. The ABS plastic housing meets or exceeds UL requirements for fire retardation. Prices begin at $2.00 to $3.00 each in quantities of 1000.

For More Information Write In No. 706

Litton Poly-Scientific, Blacksburg, VA, has introduced the Model DRBB-11-AA-01AA rugged absolute **position sensor** for measurement of mechanical rotation. Using brushless resolvers with integral electronics, the unit is a compact position transducer with DC input and digital output. It provides low sensitivity to variations in voltage, temperature, humidity, shock, and vibration.

No external circuitry is required; it is energized with ±5 VDC and obtains 12-bit serial data for interface to a computer. The unit requires five inputs and provides four outputs that are TTL compatible. It can be used with a differential line driver/receiver for high ambient noise and long distance data transmission applications.

For More Information Write In No. 707

The Temposonics L Series industrial **position sensors** from MTS Systems Corp., Research Triangle Park, NC, feature three integrated components: the wave guide, electronics, and application housing. The wave guide and electronics are fully encapsulated to minimize effects of shock and vibration. A selection of application housings are available, including an embeddable rod-style housing, profile-style housing, and standard rod housings.

The sensors offer 0.015% of full scale linearity, hysteresis of 0.00015", and feature adjustable zero, span, and set points; and dual analog outputs for velocity, position, or a second position. Standard output options include analog voltage and current, start/stop pulse, and pulse width modulation.

For More Information Write In No. 701

Clean Signal Sensors, Honolulu, HI, offers True Wav™ and DH™ ruggedized, weather resistant, signal-conditioned **sensors**. The True Wav is used for DC or AC watt, amp, and volt measurements, and measures true average power, rms current, and isolated rms volts. Two heads are integrated onto one cable with a DB15 connector termination. Each head has an internal temperature sensor with isolated voltage and temperature test leads. Accuracy is rated at ±2%.

The DH is a DC current, voltage, and temperature sensor that features, on one DB15 connector, two sensor heads. Each head includes one current, one voltage, and two temperature sensors, and each incorporates the CSS proprietary ground plane sandwich design to minimize external noise. The assembly is potted in a polyurethane mold for weather resistance. The sensor features an accuracy of ±1.5% and is available in single- and double-headed models.

For More Information Write In No. 709

Analog Devices, Wilmington, MA, offers the TMP03 and TMP04 digital output **temperature sensors**, which provide a sensor-on-a-chip system. The monolithic thermometers include sensor, A/D converter, voltage reference, and control logic functions for thermal monitoring systems. Applications include energy management systems, industrial process controllers, and laboratory instrumentation.

The sensors feature a measurement range from -40° C to 100° C. The TMP03 has an open-collector 5-mA output for data going to pulse-width modulated circuitry; the TMP04 provides TTL-CMOS compatible outputs for direct interface with DSPs and microcontrollers. Four versions of each sensor provide various operating temperature ranges and packaging options such as surface-mount SO-8 and TSSOP-8 devices. Prices start at $2.49 each in quantities of 1000.

For More Information Write In No. 710

The Model PCA40 and PC40 flat pack **capacitive sensors** from Gordon Products, Brookfield, CT, feature an external sensing element that can be used to enhance the sensitivity of the 1.5" square internal sensor or for attachment to application-specific sensing elements. Both models have shielded housings to allow mounting on grounded metal surfaces.

The self-contained sensors generate a low-power capacitive field, detecting intrusion into the field by any object with a dielectric constant higher than 1. The PC40 has switched NPN and PNP outputs; the PCA40 has an analog output. Applications include level monitoring of liquids and plastics, monitoring changes in material density or composition, and measuring distances to metal and non-metal targets. The PC40 is priced at $88; the PCA40 is $110.

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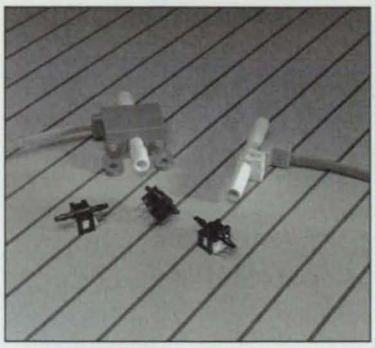
Electronic Design and Packaging, Livonia, MI, has introduced the SonaSwitch 1650 microprocessor-based **ultrasonic sensor**, available in two versions: two independent switch point outputs or 0-5 volt analog output. Both units are temperature-compensated for accuracy.

Features include a range from 6 inches to 10 feet, two 3-amp form C relay outputs or one 0-5 VDC 8-bit analog output, an ABS plastic EMI/RFI shielded enclosure, and a polymer protected electrostatic transducer for harsh environments. The sensors operate on 10-30 VDC and measure 2.25" x 3.5" x 0.90". Applications include absence/presence sorting and proximity sensing.

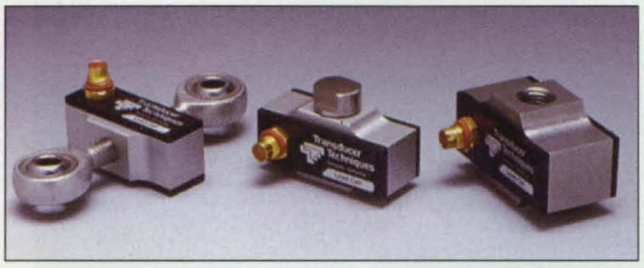
For More Information Write In No. 700



Honeywell's Micro Switch Division, Freeport, IL, has introduced the 20PC Series miniature flow-through **pressure sensors**. The 26PC Series is temperature-compensated, allowing part interchangeability; the 24PC Series is non-compensated for applications where calibration is done on-system.

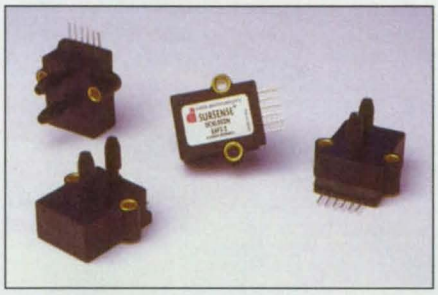
The sensors can measure dynamic or static pressure in a variety of applications, including medical, environmental, robotics, and manufacturing automation. A 24" wire harness provides mounting flexibility and is adaptable to user circuitry. Two sizes of medical-grade sensor ports accept standard tubing sizes and connectors. A variety of pressure ranges are available. Operating temperature range is from -40° to 85° C. Prices range from $16 to $40 for OEM quantities.

For More Information Write In No. 708



Transducer Techniques, Temecula, CA, offers the GS Series Gram Force **sensors** and the MLP Series universal low-profile **load cell**. The sensors are available in ranges from 0-30, 50, 100, 150, 250, and 1000 grams full scale. The sensing end is a 6-32 tapped-through hole that provides attachment for tension and/or compression from top to bottom. A bonded foil strain gauge full bridge provides output of 1 or 2 mv/v. Combined accuracy of non-linearity and hysteresis is 0.1% full scale or better. The load cell was designed for tension and compression applications in limited spaces. Non-repeatability is 0.05% FS; output is 2 mv/v nominal via a full Wheatstone strain gauge bridge.

For More Information Write In No. 702



The Sursense™ micromachined silicon **pressure sensors** from Data Instruments, Acton, MA, measures pressures from 1" of water to 1 psi for use as PC-board-mountable sensors in medical applications or field-installable sensors for HVAC applications. The sensors were designed to eliminate offset errors related to gravity, temperature sensitivity, vibration, and long-term drift.

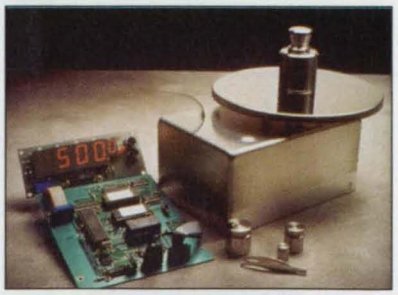
The sensors' piezoresistive technology can replace hot wire anemometers for airflow sensing. Available pressure ranges from 1" to 30" water are offered with either millivolt or amplified outputs. The 1" x 1" x 1" package can be PC-board-mounted. Variable air volume (VAV) pressure sensors are available with a range of 5" of water full scale and a 3/4-volt-per-inch of water output.

For More Information Write In No. 703

Lucas Control Systems Products, Fremont, CA, has announced the NovaSensor® NPP series plastic package **pressure sensors** designed for OEM applications that require small size and mild corrosive media isolation capabilities. The piezoresistive sensors provide signal output stability over -40° C to 125° C and are available in pressure ranges from 0-15, 0-30, and 0-100 psi. They provide unamplified full scale output of 60 ±20 mV with 3.0 Vdc excitation.

The sensors offer a combined linearity hysteresis and repeatability error of less than ±0.3%. They can be used in applications such as automotive, consumer altimeters, barometers, leak detection systems, medical patient monitoring, and portable gauges and manometers. A lead frame package design provides stress isolation and the silicon piezoresistive pressure die is gel-coated for protection in high-humidity and dusty environments. Unit prices are less than $3.00 in OEM quantities.

For More Information Write In No. 704



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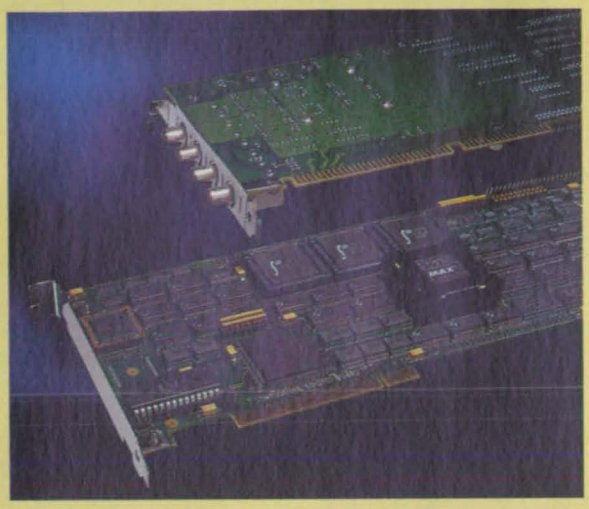

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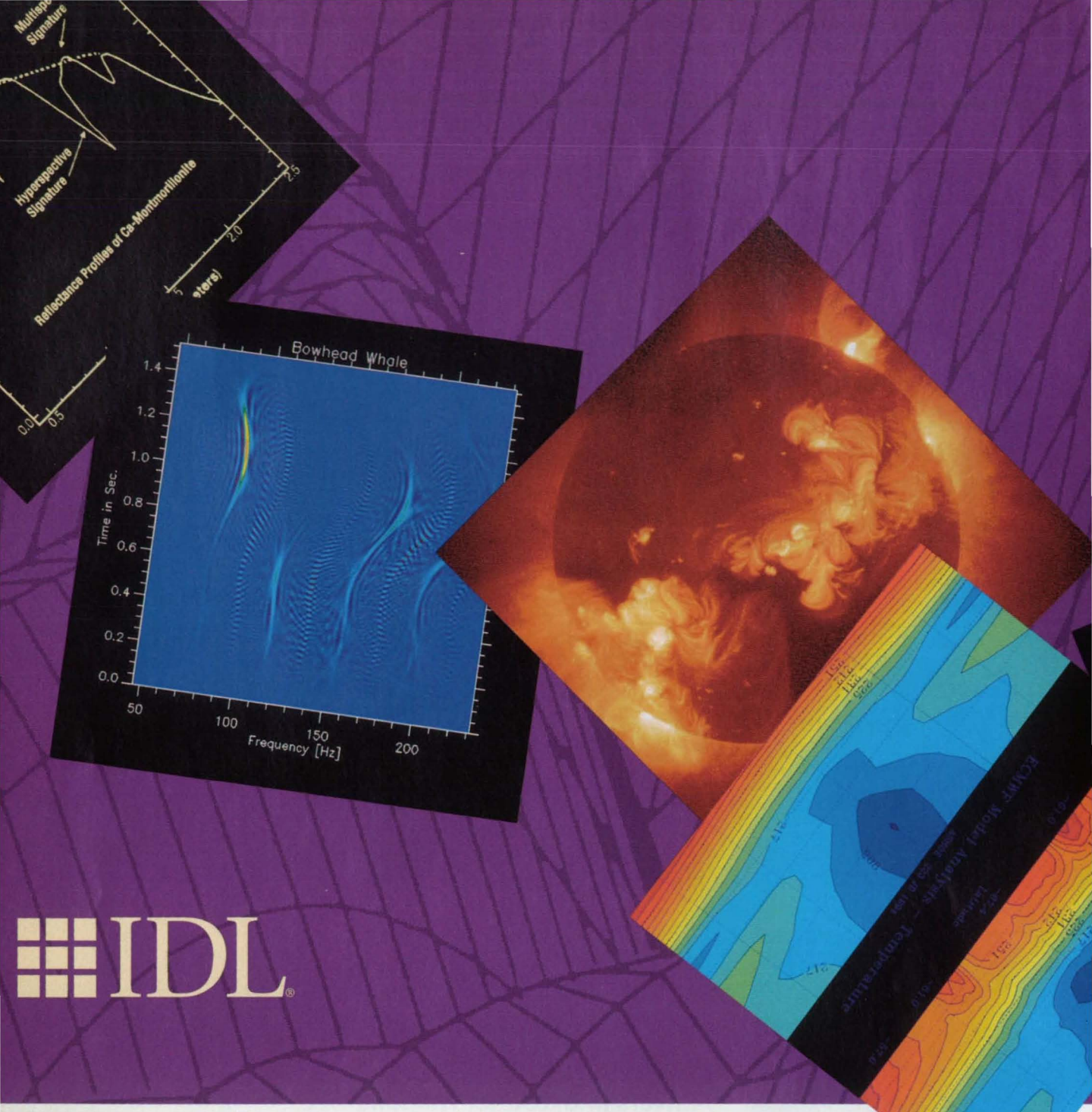

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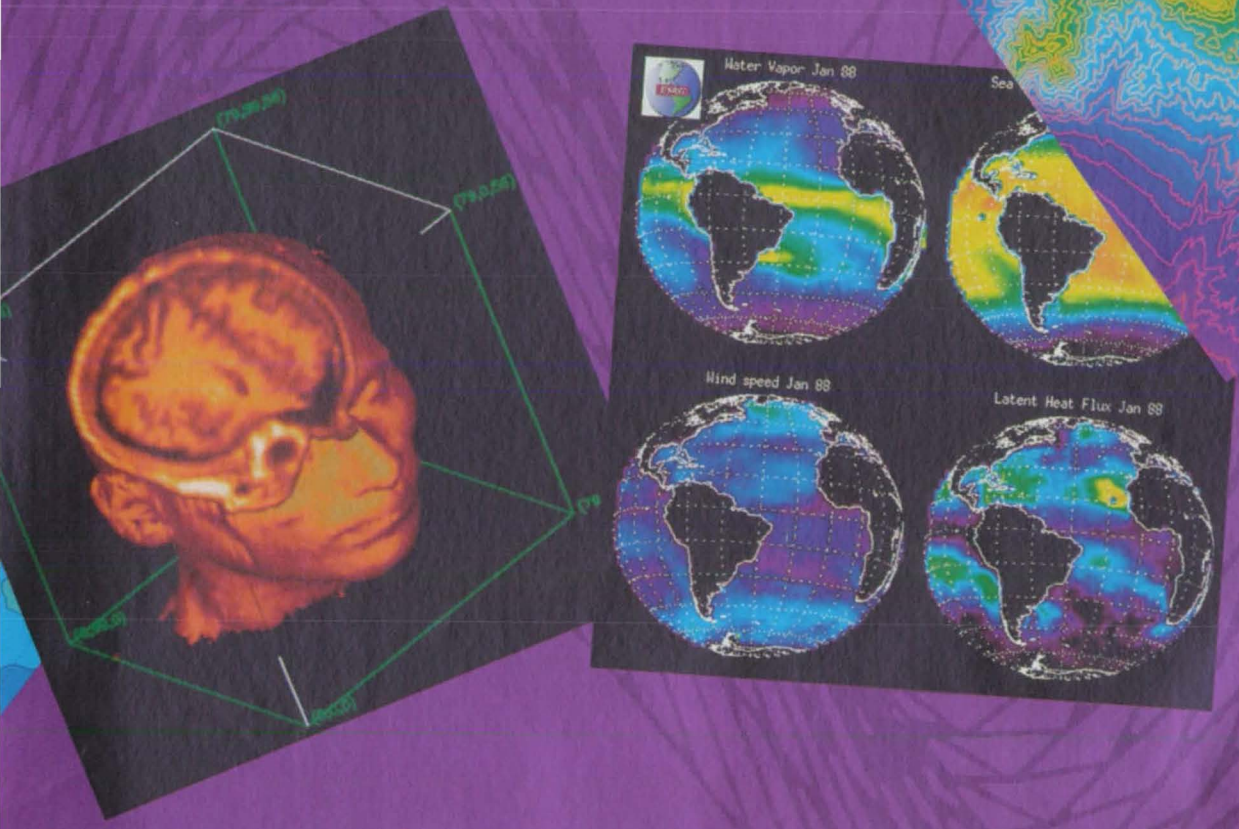

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For More Information Write In No. 684

Tracking a Microwave-Cavity Resonance by Use of Vibrations

The electromagnetic field is modulated by a vibrating rod.

NASA's Jet Propulsion Laboratory, Pasadena, California

A microwave heating apparatus that comprises a resonant cavity excited by a magnetron has been equipped with an automated tuning system (see figure) to maintain resonance. Resonance is a desirable condition because it maximizes the transfer of power to the material sample that one seeks to heat. Typically, the cavity becomes detuned from resonance during heating of the sample because the permittivity of the sample changes with temperature, altering the electromagnetic field in the cavity. Manual tuning to maintain resonance would be economically inefficient in a production situation. Thus, a system like this one that automatically compensates for the detuning effect can enhance efficiency and productivity in microwave processing of materials.

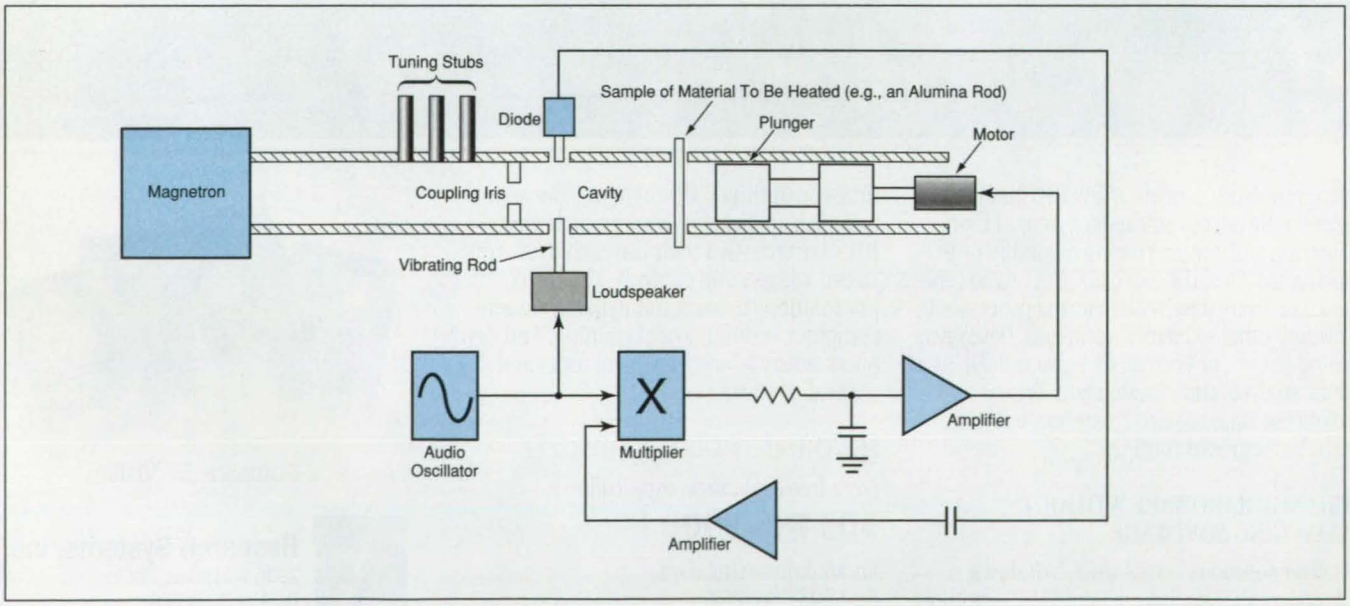
Like other automated resonance-tracking systems, this tuning system is based on a principle derived from that of old-fashioned radio tuning, in which one brackets a resonance by manual back-and-forth actuation of a tuning device while seeking an optimum quantitative or qualitative measure of the signal (e.g., maximum signal level or best sound). In both traditional manual tuning and in other automated resonance-tracking systems, the tuning adjustments usually vary the frequencies, but in this case, one does not have the option of frequency tuning because the frequency of oscillation of the magnetron is not adjustable and is nominally constant. Therefore, in this system, the main tuning adjustment is translation of a plunger along the cavity to bring the cavity to resonant length.

The back-and-forth tuning action needed to locate the resonance is provided by an auxiliary tuning device, which includes a hollow metal rod that is mounted on a loudspeaker outside the cavity and that protrudes into the cavity, preferably at a position of maximum electric field. An audio oscillator drives the loudspeaker at a convenient frequency between 30 and 100 Hz, causing the rod to vibrate and thereby impose a slight modulation on the microwave field in the cavity. A diode across the cavity from the vibrating rod detects the amplitude modulation of the electric field.

Both the signal from the audio oscillator and the amplified output of the diode are fed to the mixer at saturating amplitudes, so the low-pass-filtered output of the mixer depends only on the difference between the phases of these two signals. This phase difference is a measure of the deviation from resonance. Thus, the output of the mixer constitutes an error signal that indicates the adjustment needed to restore the cavity to resonance. Accordingly, this signal is fed to an amplifier, the output of which is fed to the motor that drives the plunger to obtain the required tuning adjustment.

The effectiveness of the automated tuning system was demonstrated in experiments in which the microwave apparatus was used to heat an alumina rod. The apparatus was operated with a forward microwave power of 200 W in two cases: one with, and one without automatic tuning. Without automatic tuning, the rod attained an asymptotic temperature of about 600 °C in 5 min. With automatic tuning, the temperature of the rod exceeded 900 °C (and was still increasing) in less than 2 min.

This work was done by Martin Barmatz and Ofer Iny of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 17*** *on the TSP Request Card. NPO-19390*



The **Vibrating Rod** modulates the electric field in the cavity. The phase difference between the vibrations and the modulation provides an indication of deviation from resonance and is used to control repositioning of the plunger to maintain resonance.

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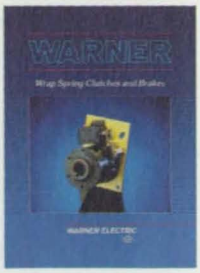

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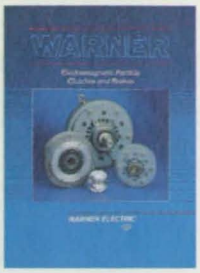

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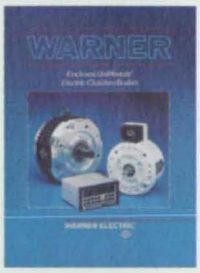

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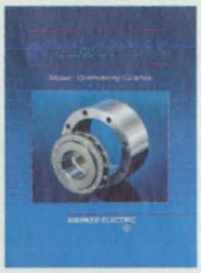

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For More Information Write In No. 676

Using Vibrations To Match Impedance of a Microwave Cavity

Phase modulation caused by vibration of a tuning stub indicates impedance mismatch.

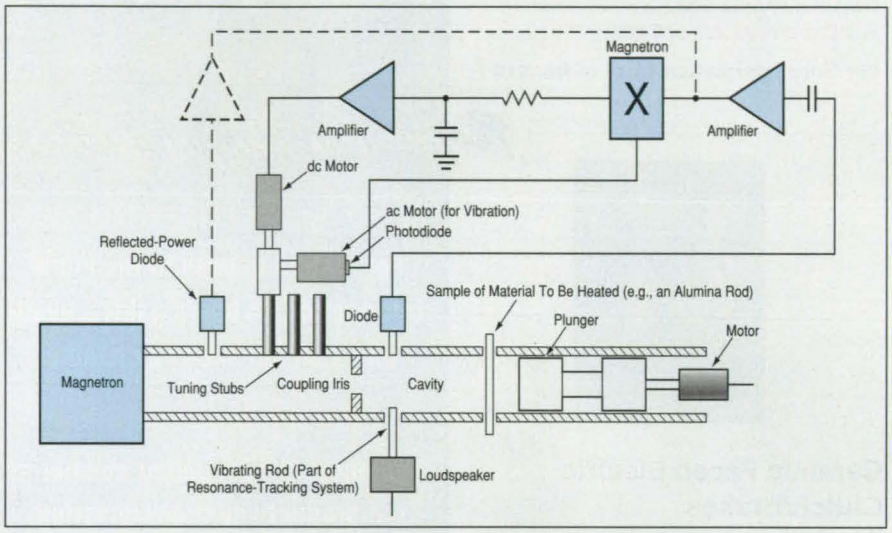
NASA's Jet Propulsion Laboratory, Pasadena, California

An automated feedback-control system performs matching of impedances between a microwave source (a magnetron) and a resonant microwave cavity that contains a sample of material to be heated by microwave power. Impedance matching is essential for transfer of maximum power. The basic function of the automated impedance-matching system is similar to that of the automated resonance-tracking system described in the preceding article, "Tracking a Microwave-Cavity Resonance by Use of Vibrations" (NPO-19390).

Both automated systems are needed for the same reason, namely that heating of the sample causes both the real and imaginary parts of the complex permittivity of the sample to change, thereby altering the electromagnetic field in the cavity. One of the resultant effects is a change in the input impedance of the cavity and therefore a decrease of power coupled into the cavity. Often, manual adjustments cannot be performed rapidly enough to compensate for such changes in impedance. Thus, a system like this one that automatically maintains an impedance match can enhance microwave processing of materials.

In this system (see figure), one of the tuning stubs is driven by two motors: an ac motor that causes the tuning stub to vibrate at a frequency of about 12 Hz or less and a dc motor that provides control over the steady or slowly varying (dc) position about which the stub vibrates. A photodiode on the ac motor serves as an indirect vibration frequency sensor by optoelectronically monitoring the oscillation of a shiny surface on the motor shaft. A diode crystal detector is positioned to monitor the microwave power transmitted into the cavity, while another such detector is positioned to monitor the power reflected from the cavity back toward the magnetron.

Either diode crystal detector can be used, along with the vibration sensor, to track the impedance match, because the vibration of the tuning stub modulates both the transmitted and reflected powers. The amplified output of the chosen diode crystal detector is fed to one input terminal of a mixer, while the output of the vibration sensor is fed to the other input terminal of the mixer. The low-pass-filtered output of the mixer is a measure of the difference between the phases of the vibration and the modulation, and this phase difference is a measure of the deviation of the dc position of the tuning stub from the optimum position for an impedance match. Thus, the low-pass-filtered, amplified output of the mixer is fed to the dc motor to move the stub up or down, as needed, toward the optimum position.



The **Vibrating Tuning Stub** modulates the power transmitted into and reflected from the cavity. The phase difference between the vibrations and the modulation provides an indication of deviation from impedance match and is used to control the dc position of the vibrating tuning stub to maintain impedance match.

This work was done by Martin Barmatz, Ofer Iny, Richard Zanteson, and Tzu-Yuan Yiin of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 18*** *on the TSP Request Card.*

NPO-19500

Portable PCM Format Synchronizer

John F. Kennedy Space Center, Florida

The pulse-code-modulation format synchronizer (PCMFS) is a portable, easy-to-use, microprocessor-based instrument that aids in testing of PCM data-transmission equipment and cables. Prior to the development of the PCMFS, testing involved the use of a large electronics rack that contained a PCM data decommutator, which had to be brought to each test site; it was necessary to spend considerable time moving the rack, connecting it to power and data cables, and configuring the decommutator for the specific data format for the site. The PCMFS eliminates the need for the rack and can be set up and operated much more easily and quickly. The PCMFS displays information on a vacuum fluorescent display module of six lines with 40 characters per line, and receives input from the user via a keypad of 20 keys. The PCMFS uses a menu system to accept input to set up all parameters needed for various data formats.

This work was done by James M. Schaffer and John M. Parks of **Kennedy Space Center.** *For further information,* ***write in 43*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11834.

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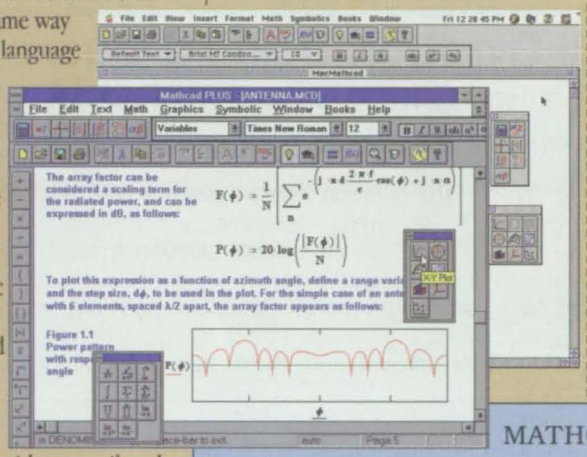

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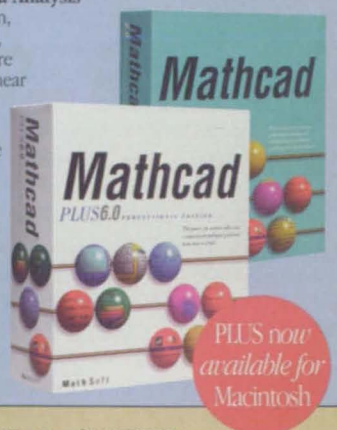

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Block-Error Detectors for Communication Lines

Patch panels are no longer needed.

Goddard Space Flight Center, Greenbelt, Maryland

Testing circuits have been custom-made for use in troubleshooting on specialized digital communication lines. A circuit of this type is called a "block-error detector — 4 port" ("BED4P" for short). A BED4P monitors the communications on either side of a full duplex line on which data are transmitted in 4,800-bit blocks with 22 redundant bits for detection of errors, and counts the number of blocks in which it detects errors. Each BED4P can accommodate as many as four of the specialized full duplex lines.

Previously, the monitoring was performed by use of testing circuits made from commercially available transistor/transistor-logic (TTL) integrated circuits. It was necessary to operate these older testing circuits in conjunction with a patch panel that, among other things, attenuated the monitored signals by a factor of 10. The patch panel added to the cost of troubleshooting and constituted another piece of equipment that could fail. Furthermore, because of the 10:1 attenuation, one could not be assured that the signals fed to the test circuits gave true indications of the signals on the communication lines.

The BED4Ps are made from programmable logic devices (PLDs). They include front-panel test points that make TTL-level signals available for troubleshooting. Front-panel controls enable the user to select either side of a communication line and to choose the direction of the timing signal (with or against the data signal).

Whereas each of the older testing circuits contained about 40 of the TTL integrated circuits, each BED4P contains only about 16 integrated circuits. In addition, the BED4Ps operate faster; they are capable of working at rates up to 6.4 Mb/s. Yet another advantage is that the PLD architecture is upwardly scalable; that is, more PLD integrated circuits can be incorporated to enhance performance.

This work was done by Clayton B. Sigman and Howard C. Dew of **Goddard Space Flight Center.** *No further documentation is available.*

GSC-13569

Phase-Locking a Gyrotron Using a Quasi-Optical Circulator

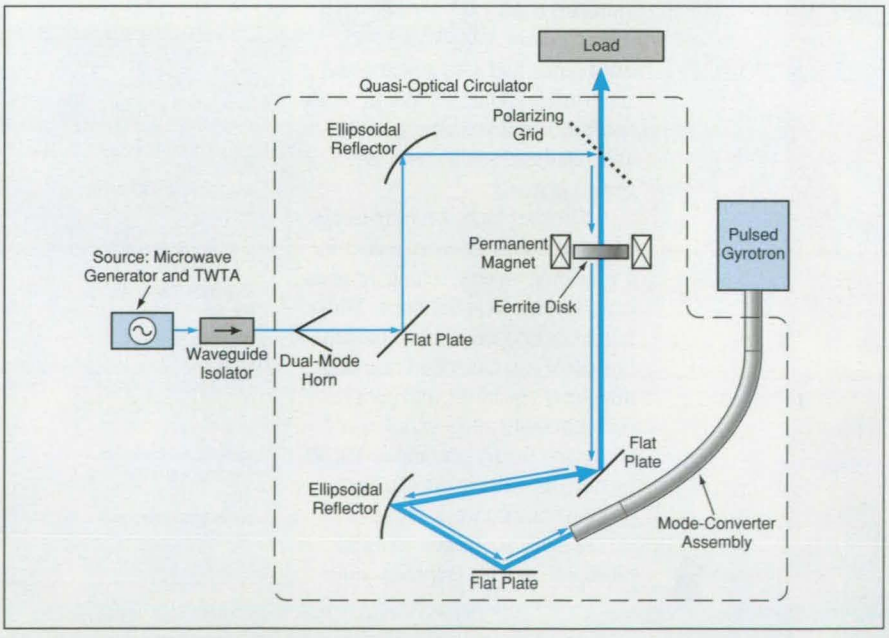
This system is a prototype of high-power, coherent, millimeter-wave oscillators.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates schematically an experiment in which a second-harmonic gyrotron with an output frequency of 34.52 GHz and pulsed output power as high as 100 kW was phase-locked by injection of a stable, lower-power signal via a quasi-optical circulator. Gyrotron oscillators have been developed primarily for use in electron-cyclotron-resonance heating of plasmas, and thus far have not been used much in other applications because, in the absence of phase-locking, their outputs are incoherent. By demonstrating coherent operation, the present system is a prototype of a high-power, coherent, millimeter-wave oscillator that could be used in radar and communication systems.

It is necessary not only to phase-lock the gyrotron to the stable, lower-power signal source, but also to prevent injection phase-locking of the lower-power signal source by the output of the gyrotron. The quasi-optical circulator is a beam-waveguide/circulator subsystem that provides the input/output coupling to satisfy this requirement; it allows the lower-power phase-locking signal to be coupled into the gyrotron, while isolating the gyrotron output from the lower-power signal source. (A conventional circulator cannot be used in this system because the gyrotron output is delivered via an unconventional oversized circular waveguide.)

The gyrotron in this system is of type GY-32, which features a complexly shaped electron-beam/electromagnetic-wave-interaction cavity that favors second-harmonic operation and provides high mode selectivity, as needed for efficient and stable operation with injection phase locking. The source of the phase-locking signal is a microwave-signal generator of the frequency-synthesizer type. The source signal is fed to a 100-W traveling-wave-tube amplifier (TWTA). The output of the TWTA is fed through a conventional



This **Gyrotron-Oscillator System** includes a quasi-optical circulator, which provides the input/output isolation, mode conversion, and mode selectivity necessary for effective injection phase locking. The waveguide isolator provides additional protection against phase locking of the source by the gyrotron.

waveguide isolator that provides more than 35 dB of isolation, then through a smooth-wall dual-mode horn that provides a Gaussian beam for launching into the quasi-optical isolator.

Upon entering the quasi-optical isolator, the beam is reflected by a flat plate. An ellipsoidal mirror focuses the reflected beam and redirects the focused beam toward a polarizing grid of copper strips on a disk of fused quartz. The polarization of the beam at this point is such that the beam is reflected by the grid through a circulator, which consists of a disk of ferrite material biased with a 1-kilogauss permanent magnet. The disk produces a 45° Faraday rotation of the microwave beam passing through it.

After emerging from the circulator disk, the beam is focused and reflected into a mode-converter assembly in the form of concatenated sections of waveguide specially shaped with a curve, a nonlinear taper, and ripples; this is necessary for coupling of the phase-locking signal with the selected second-harmonic mode in the gyrotron. The gyrotron output follows the reverse path back to the circulator disk, where it undergoes another 45° rotation, so that its polarization becomes perpendicular to that of the injected beam. Because of its polarization, the output beam passes out of the system through the polarizing grid and is absorbed by a free-space load.

In experiments, a small portion of the gyrotron output power was received by a horn antenna located near the free-space load and was sent to the input port of a balanced mixer, where it was combined with a sample of the injection signal from a waveguide coupler located at the TWTA output. The resulting mixer output voltage, related to the instantaneous phase difference between the output and injection signals, was fed into a digitizing oscilloscope. The digitized data were recorded by a computer and stored for later analysis. The results of the experiments showed that the gyrotron oscillator had been successfully phase-locked. The quasi-optical circulator, including the mode-converter assembly, was measured to have an insertion loss of 1 dB and an isolation of greater than 25 dB. The waveguide isolator in the path of the low-power signal from the source was found to provide an additional 35 dB of isolation, so that the total isolation was found to be 60 dB.

This work was done by Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 48*** *on the TSP Request Card.*
NPO-19584

Dynamic Braking and Differential Coupling of dc Servomotors

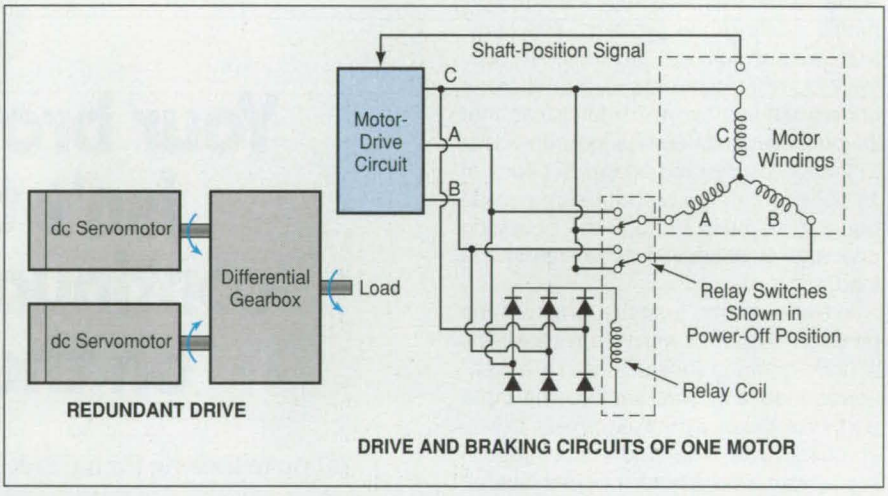
When one motor fails, the other can still drive the load.

Goddard Space Flight Center, Greenbelt, Maryland

The figure illustrates aspects of a redundant drive that includes two dc servomotors coupled to a load via a differential gearbox. As explained below, when one of the motors loses drive power, it functions as a dynamic brake. If the other motor continues to function, then the dynamic braking resists back driving of the failed motor by the functional motor, enabling the functional motor to continue driving the load via the differential, albeit at reduced speed and available torque.

Each motor is equipped with relay switches that can be set to connect two of three winding terminals to either (1) the corresponding terminals of the motor-drive circuit or (2) the third winding terminal in a short-circuit configuration. When the motor-drive circuitry is operating correctly, the diodes shown in the figure route current through the relay coil, causing the relay switches to connect the windings to the motor-drive terminals of the drive circuit. When the drive circuit fails for any reason and drive power is no longer supplied, the relay switches close, short-circuiting the windings; this action converts the motor to a dynamic brake.

This work was done by Craig Tooley and Joanne Baker of **Goddard Space Flight Center.** *For further information,* ***write in 35*** *on the TSP Request Card.*
GSC-13695



Both Motors Drive the Load via the differential gearbox in nominal operation. Either motor becomes a dynamic brake when it loses power, in which case the other motor continues to drive the load at reduced power.

Making Catalysts and Electrodes for Liquid-Feed Fuel Cells

Several recent developments are brought together.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved catalyst materials and electrode structures for liquid-feed, direct-oxidation fuel cells, and techniques for manufacturing them have been developed in recent years. Selected aspects of some of these materials, structures, and techniques at earlier stages of their evolution were reported in a number of prior articles in *NASA Tech Briefs.* Some of these developments have been brought together to synthesize a design concept and process for manufacturing improved fuel liquid-feed, direct-oxidation fuel cells that consume methanol and other water-soluble oxygenated organic compounds.

The direct electro-oxidation of water-soluble oxygenated organic compounds in such fuel cells is determined by the activity levels of electrocatalysts and the designs of electrodes and membrane/electrode structures. Three

main considerations arise in the development of such a cell:

1. Of the catalyst materials known, the one that exhibits the highest performance in this regard is an alloy of platinum and ruthenium. The activity of a Pt/Ru catalyst depends largely on its surface composition and surface area. Therefore, it is desirable to enhance the surface composition and surface area of the catalyst.
2. Experiments have shown that feeding methanol in liquid form (dissolved in water) offers performance superior to that obtained when feeding methanol in vapor form. A liquid-feed design requires special wettability characteristics, which can be achieved by fabricating electrode structures with suitable proportions of hydrophobic and hydrophilic constituents.
3. Electrodes must be integrated with a proton-conducting membrane to form a membrane/electrode structure. The conditions for the fabrication of this structure are critical to the performance of the cell.

The preparation of a Pt/Ru catalyst of the desired surface composition and surface area begins with mixing of chloroplatinic acid and potassium pentachloroaquoruthehium(III) salts in a large excess of hydrochloric acid. The resulting solution is neutralized with a large excess of sodium carbonate, yielding particles composed of hydroxides of Pt and Ru dispersed in large amounts of sodium chloride and sodium carbonate. The hydroxide particles are reduced to metal in a hydrogen atmosphere at a temperature of 225 °C; the dispersal of the particle prevents sintering of them during this reduction treatment. The mixture is then washed in deionized water to dissolve the sodium compounds, leaving behind insoluble Ru/Pt particles that are micron-sized and remain suspended in the water. The particles are removed from the water by centrifugation and dried to obtain the catalyst in powder form.

To make an ink to coat the surfaces of the electrodes, the Pt/Ru powder is dispersed into a solution that contains dissolved Nafion™, which is a perfluorosulfonic acid-based hydrophilic, proton-conducting ion-exchange polymer that exhibits relatively high thermal and electrochemical stability. A lower degree of wettability is needed on the cathode; to reduce the wettability, a dilute suspension of polytetrafluoroethylene particles in water is added to the ink to be used on the cathode. The appropriate ink is then spread on a piece of carbon-fiber paper impregnated with Nafion™ and polytetrafluoroethylene to form each electrode. To form a unitary electrode/membrane structure, the electrode papers are pressed together with a Nafion™ membrane at a pressure of 1,250 psi (8.6 MPa), with a temperature schedule that includes a maximum of 146 °C.

This work was done by Sekharipuram Narayanan, Subbarao Surampudi, Harvey A. Frank, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 52*** *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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Refer to NPO-19893, volume and number of this NASA Tech Briefs *issue, and the page number.*

Silent Systems Would Augment Emergency-Vehicle Sirens

Marshall Space Flight Center, Alabama

Tests of a prototype have demonstrated the feasibility of proposed radio-communication systems that would warn drivers of approaching trains, fire trucks, ambulances, police cars, and other fast-moving vehicles operating in emergency modes. These systems would supplement the warnings provided by sirens, horns, bells, and whistles, which deaf drivers cannot hear and, which drivers with partially impaired or normal hearing also sometimes do not hear. A transmitter in an emergency vehicle would automatically be activated when the vehicle went into the emergency mode; the transmitter would continuously transmit a signal indicative of the type of emergency vehicle. In the case of trains, the transmitter would be active at all times. A receiver in each of the other vehicles participating in the system would be turned on by the ignition switch; it would decode the signal transmitted by the emergency vehicle. The receiver would also estimate the distance between the two vehicles from the strength of the received signal. The information on the type of emergency vehicle and distance would be displayed by use of light-emitting diodes. Optionally, the signal transmitted by the emergency vehicle could be used to switch traffic lights to give that vehicle the right of way.

This work was done by James R. Currie, J. Dwight England, and Phylliss A. Smith of **Marshall Space Flight Center.** *For further information,* ***write in 31*** *on the TSP Request Card. MFS-31069.*

Parallel Cancellation of Interference in CDMA Communication

The complexity of equipment would hardly exceed that of a conventional CDMA receiver.

NASA's Jet Propulsion Laboratory, Pasadena, California

A practical interference-cancellation scheme has been proposed to improve the performance of a receiver in a code-division multiple-access (CDMA) communication system carrying digital data encoded in pseudonoise signals via binary-phase-shift-keying (BPSK) modulation. In the proposed scheme, parallel processing would be used to simultaneously remove, from each user, an estimate of the total interference produced by the other users — each user receiving equal treatment in this respect.

In reducing the extent to which interference among multiple users degrades performance, the proposed scheme would increase the capacity of the system in the sense that it would increase the number of users that the system could accommodate simultaneously at a given level of performance. The increase in capacity would approach that of an older interference-cancellation scheme based on a maximum-likelihood algorithm. However, whereas the complexity of equipment needed to implement the older scheme increases exponentially with the number of users, the complexity of equipment needed to implement the proposed scheme would increase linearly with the number of users; in other words, the complexity of the equipment would hardly exceed that of a conventional CDMA multiuser receiver that lacks interference-canceling capability.

Figure 1 schematically illustrates an *M*-user CDMA receiver with one stage of interference-cancellation parallel processing according to the proposed scheme (more such stages could be added to improve performance). In a separate channel dedicated to each user, an attempt would be made to demodulate the received signal, taking account of the user's known pseudonoise code. The demodulated signal (which should nominally be a binary waveform in the absence of noise and

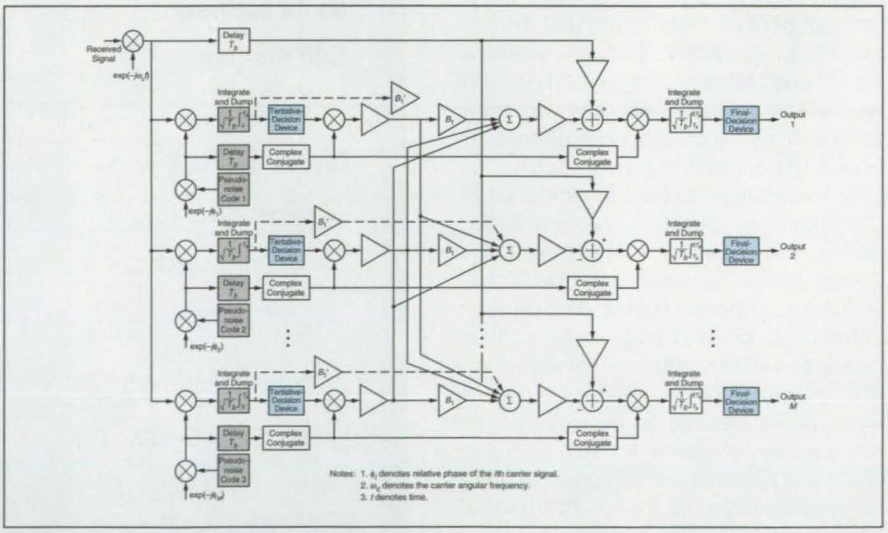

Figure 1. This ***M*-User CDMA Receiver**, shown here in complex baseband representation, would include one stage of interference-cancellation parallel processing. More such stages could be added to improve performance.

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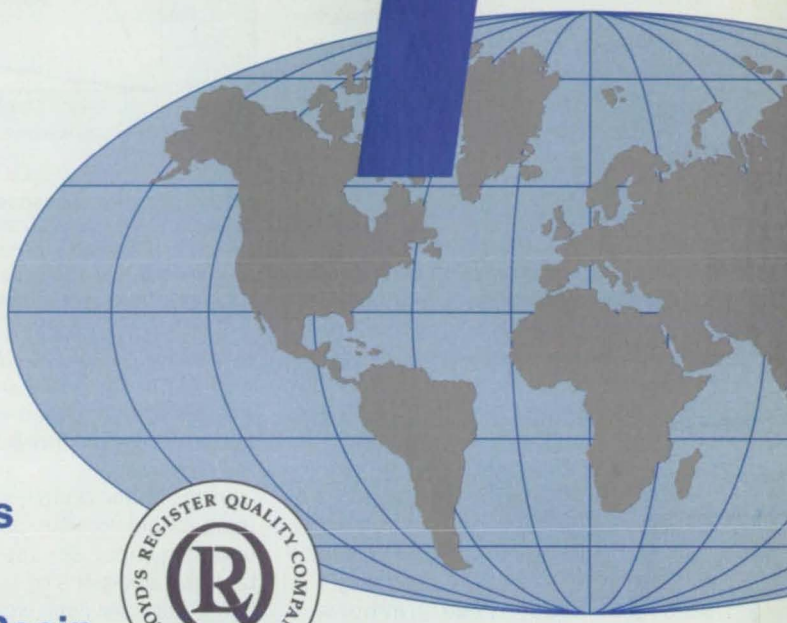

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interference) would be fed to a circuit that would render a tentative decision as to whether the demodulated signal momentarily represented a 0 or a 1.

This circuit, labeled "tentative-decision device" in Figure 1, could be a hard limiter (a one-bit quantizer), a linear-response circuit (equivalently, a digitizer or quantizer with an infinite number of bits), or a soft quantizer (e.g., a quantizer with hyperbolic-tangent nonlinearity, intermediate between linearity and hard limiting). In addition, each tentative-decision device could be preceded by a linear-response circuit with a null (zero-response) zone centered at the origin; the null zones could eliminate attempts to cancel interference when the fidelity of the tentative decisions is poor, i.e., it is better not to cancel the interference at all than to increase it as a result of erroneous tentative decisions.

In the case of convolutionally coded modulation, there would be essentially two options regarding the tentative decisions made for each user in the presence of the total interference. In one option, the decisions would be made while ignoring the fact that each user's data are encoded (that is, treating the symbol stream as though it were uncoded). These symbol-by-symbol decisions would then be respread and remodulated directly onto the carrier of each user. This would be the simplest of the two options in that only one symbol or bit period T_b would be needed to make the decisions.

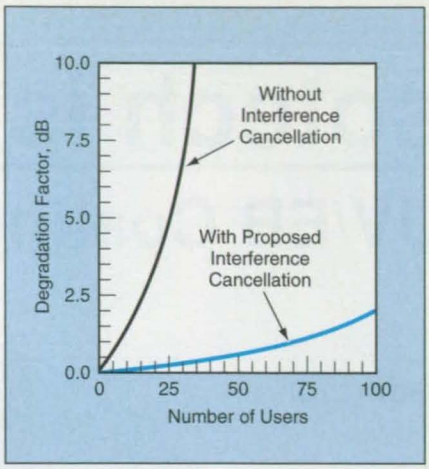

Figure 2. The **Performance of a CDMA Receiver** with interference cancellation according to the proposed scheme would substantially exceed that of the same receiver without interference cancellation.

In the other option, one would treat each incoming user data stream as a coded symbol stream and make the tentative decisions by use of a convolutional decoder (with soft or hard decision). The resulting bit stream would be reencoded before respreading and remodulation onto the carrier. This option would yield better performance, but would entail a delay proportional to the size of a buffer memory in the decoder. The nature of the final-decision device shown in Figure 1 would depend on whether the underlying data were uncoded or coded: If the data were not coded, the final-decision device would be a hard limiter; when the data were coded, the final-decision device would be a decoder.

One final note of explanation pertains to the choice between the alternative amplification paths with gain coefficients B_1 and B'_1 indicated in Figure 1. A nonzero value of either B_1 or B'_1 implies the existence of a "leakage" path in the sense that the interference-cancellation would include a portion of the output from the user of interest. The motivation for allowing such a leakage path stems from steepest-descent-gradient considerations. The choice between B_1 and B'_1 depends on whether the leakage signal was derived from the user's unquantized or quantized integrate-and-dump output.

It is common practice to quantify the performance of a CDMA system in terms of a degradation factor as a function of M; the degradation factor is defined as the increase in the decibel level of the bit signal-to-noise ratio needed to achieve the same level of performance (same bit-error rate) with M users as with only one user. Figure 2 shows a plot of the degradation factor from a computer simulation for a CDMA system using a bit-error rate of 0.01 and a processing gain of 100, with and without the proposed interference-cancellation scheme. Clearly, the number of users with interference cancellation could be increased substantially before performance would become degraded to the same extent as without interference cancellation.

This work was done by Dariush Divsalar and Marvin K. Simon of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 41*** *on the TSP Request Card.*

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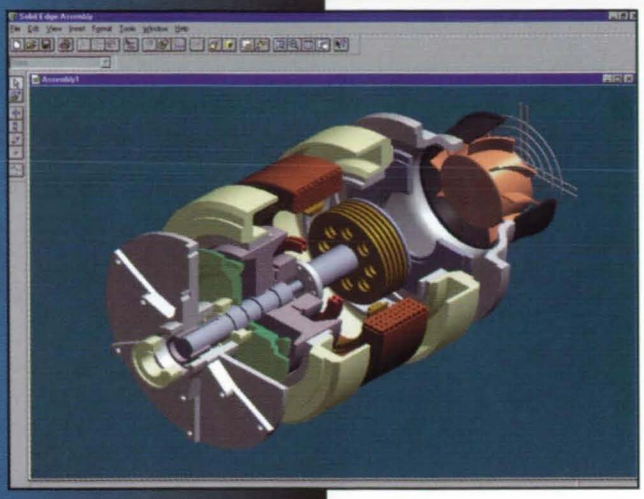

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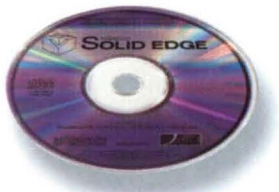

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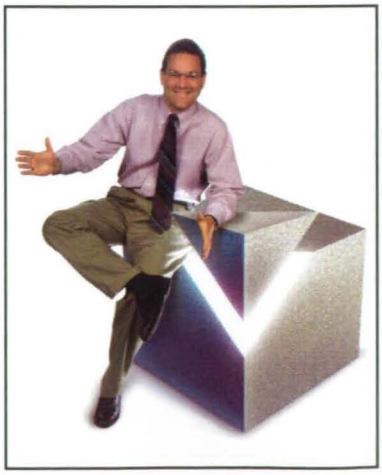

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A VME-Based Architecture for Parallel Computing

Marshall Space Flight Center, Alabama

VME-PARALLEL is an architecture for parallel computing that has been proposed as a cost-effective, scalable alternative to the shared-memory, shared-bus architecture and the multicomputer, distributed-memory architecture. As its name implies, the VME-PARALLEL concept is based on the VersaModule Eurocard bus (VMEbus). In a VME-PARALLEL system, off-the-shelf multiple VMEbus single-board processors would be mounted in one or more VME chassis called a "processing chassis"; the processors in each chassis would be interconnected by a VME backplane or backplanes. Each processor in each chassis would also be connected to other processors in the same and/or different chassis by direct communication links via custom-made link circuit boards — one such board for each processor, residing in the processing chassis alongside the processor board. In addition, an interconnection box containing a patch panel or similar device would be needed to complete the links between processors in the same and/or different processing chassis. Each separate processing chassis could remain an independent VMEbus, or one VMEbus could be logically extended to include all the processing chassis by use of a VME-to-VME link. Processors could be added, as needed, to solve large computing problems. The estimated speed with which a VME-PARALLEL system could transfer data between processors exceeds that of a comparable shared-memory, shared-bus system. A preliminary cost analysis suggests that VME-PARALLEL systems would be cost-effective.

This work was done by Kenneth G. Ricks and John M. Weir of **Marshall Space Flight Center.** *For further information,* ***write in 25*** *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; (205) 544-0021. Refer to MFS-31098.

Parallel Digital Demodulators Using Multirate Filter Banks

Signals would be divided into parts that would be processed at low rates.

NASA's Jet Propulsion Laboratory, Pasadena, California

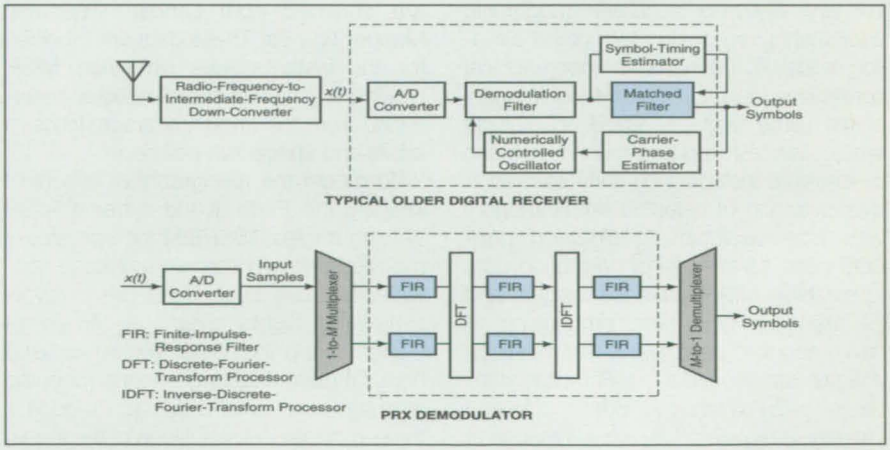
The parallel receiver (PRX) architecture has been proposed as the basis of a type of digital demodulator for the reception of multiple-gigahertz radio signals carrying digital information (symbols) at rates as high as hundreds of megabits per second. The PRX architecture involves the use of multirate digital filter banks to demodulate, track, and detect received symbol streams. This architecture is well-suited to implementation in relatively inexpensive, high-density, low-power complementary metal oxide/semiconductor (CMOS) very-large-scale integrated circuits.

The frequency responses of digital integrated circuits of the types currently available for processing the signals in question impose an upper limit of about 50 megabits per second on the data rates achievable in digital receivers of older design. The PRX architecture would provide the desired high data rates despite the limited frequency responses of digital signal-processing circuits: It would do this by effectively dividing the spectrum of the incoming sampled, digitized signal into components in each of M frequency subbands. [The concept of processing signals in subbands by use of multiple digital filters was also described in "Parallel Digital Phase-Locked Loops" (NPO-19044) *NASA Tech Briefs*, Vol. 19, No. 6 (June, 1995), page 52.] The processing rate in each subband would be less than either the symbol rate or the Nyquist sampling rate; by suitable choice of M, the processing rate could be made low enough so as not to exceed the speed limit of the available processing circuitry.

An all-digital receiver performs demodulation, matched filtering, synchronization with the carrier signal, and recovery of symbol timing. The upper part of the figure shows the major functional blocks of a typical digital receiver of older design. The input signal $x(t)$ (where t denotes time) is bandpass sampled and converted to a discrete time sequence by an analog-to-digital (A/D) converter with a uniform sampling period of T_S. The output of the matched filter in this receiver is the estimated symbol sequence (complex or real). The rate of processing in the digital signal-processing functional blocks following the A/D converter is the minimum useful processing rate of $1/2T_S$.

The PRX architecture, illustrated in the lower part of the figure, can be regarded as a parallelized version of the older architecture shown in the upper part of the figure. The input signal would be parallelized into $2M$ paths (two paths for each frequency subband). The signal component in each subband would be decimated by M and processed by the digital filtering circuitry at a rate of $1/MT_S$. The signal would be filtered by an analysis-and-synthesis filter bank based on discrete Fourier transforms (DFTs) augmented with the parallel equivalent of the matched-filtering operation of the older receiver architecture. The outputs from the M subband channels would be the detected symbols and would be recombined into a single stream of symbols by a demultiplexer.

This work was done by Ramin Sadr, Sami Hinedi, and Dan Raphaeli of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 99*** *on the TSP Request Card. NPO-19620*



A **PRX Demodulator** would process part of the signal spectrum in each of M subbands in a parallelized version of a typical older digital receiver. The processing in each band would be performed at $1/M$ of the full sampling rate.

Simulating EOS MISR Data

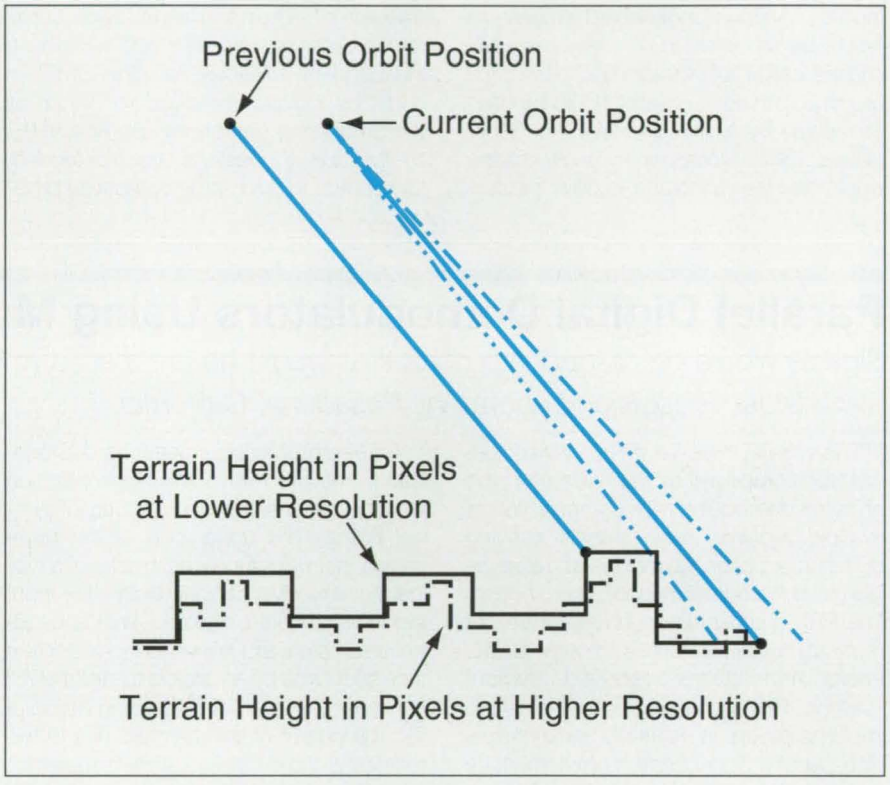
Synthetic radiometric data aid the development of the ground data-processing system.

NASA's Jet Propulsion Laboratory, Pasadena, California

The MISRSIM computer program synthesizes an approximate version of the measurement data to be acquired by the Multi-angle Imaging Spectro-Radiometer (MISR), which is scheduled to be launched into polar orbit aboard The Earth Observing System AM1 satellite in June 1998. MISRSIM is used to test the performances of computer-simulated prototypes of the MISR ground data-processing system. MISRSIM is needed because no existing instrument provides measurement data that resemble the MISR data closely enough.

The MISR contains nine cameras at fixed viewing angles; one pointed at the nadir, the others pointed at angles of 26.1°, 45.6°, 60.0°, and 70.5° fore and aft along the ground track of the satellite. The focal plane of each camera is occupied by four linear arrays of charge-coupled-device photodetectors (CCDs). These arrays are oriented perpendicular to the satellite ground track. Each array contains 1,504 photoactive and 16 light-shielded pixels. Each array is preceded by a band-pass filter with a different nominal wavelength; the wavelengths are 443, 555, 670, and 865 nm. Utilizing the motion along the ground track to scan in push-broom fashion, the cameras thus produce image data from multiple look angles and in multiple spectral bands.

The ground data-processing task is to combine the MISR outputs into comprehensive multispectral, multiple-look-angle imagery, ensuring accurate geographic coordinates, registration with digital elevation models (DEMs) used for topographical corrections, and coregistration of imagery of the same target acquired on multiple orbits. This task requires much geometric processing, including (1) early calibration by correlation of selected MISR imagery with high-resolution, geolocated non-EOS data, (2) the use of calibration data to establish MISR reference images, and (3) standard geometric processing of newly acquired data, using the reference images as secondary calibration standards with which the newly acquired imagery is registered by a combination of back-projection, image-point-intersection techniques, and limited image matching via brightness-correlation techniques. MISRSIM provides the data needed to test all of the elements of this geometric processing.



Ray Casting (in this case meaning projection of lines of sight to their intersections with the terrain) is used in generating views from the perspectives of the MISR cameras.

The input radiance data for MISRSIM are obtained from Landsat Thematic Mapper scenes. These data are modified for the instantaneous simulated MISR viewing angles and coordinates as determined from the known characteristics of orbits and spacecraft pointing.

To model the topographical effects of imaging the Earth at the extreme MISR viewing angles, MISRSIM incorporates a modified version of terrain-rendering software that has been used previously in simulating flights over the terrain of California and the planet Venus. As used here, "terrain rendering" means mapping of image data onto DEMs to produce a three-dimensional simulation of the terrain surface. The terrain-rendering software uses a ray-casting algorithm, in which a given view is calculated from a given point in space (an eye point) relative to the terrain (see figure). The field of view and aspect ratio define a view plane, perpendicular to the line of sight, that represents the image to be computed. In the original version of the terrain-rendering software, the view plane was a finite rectangular plane like the one that would be imaged in an ordinary (frame) camera. For MISRSIM, the terrain-rendering software has been modified so that the view plane represents what is seen by a linear array of CCDs. The radiances of the view planes as observed by the corresponding CCDs are converted into simulated raw output data by use of the known optical and electrical characteristics of the MISR.

This work was done by Scott A. Lewicki of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 79*** *on the TSP Request Card. NPO-19443*

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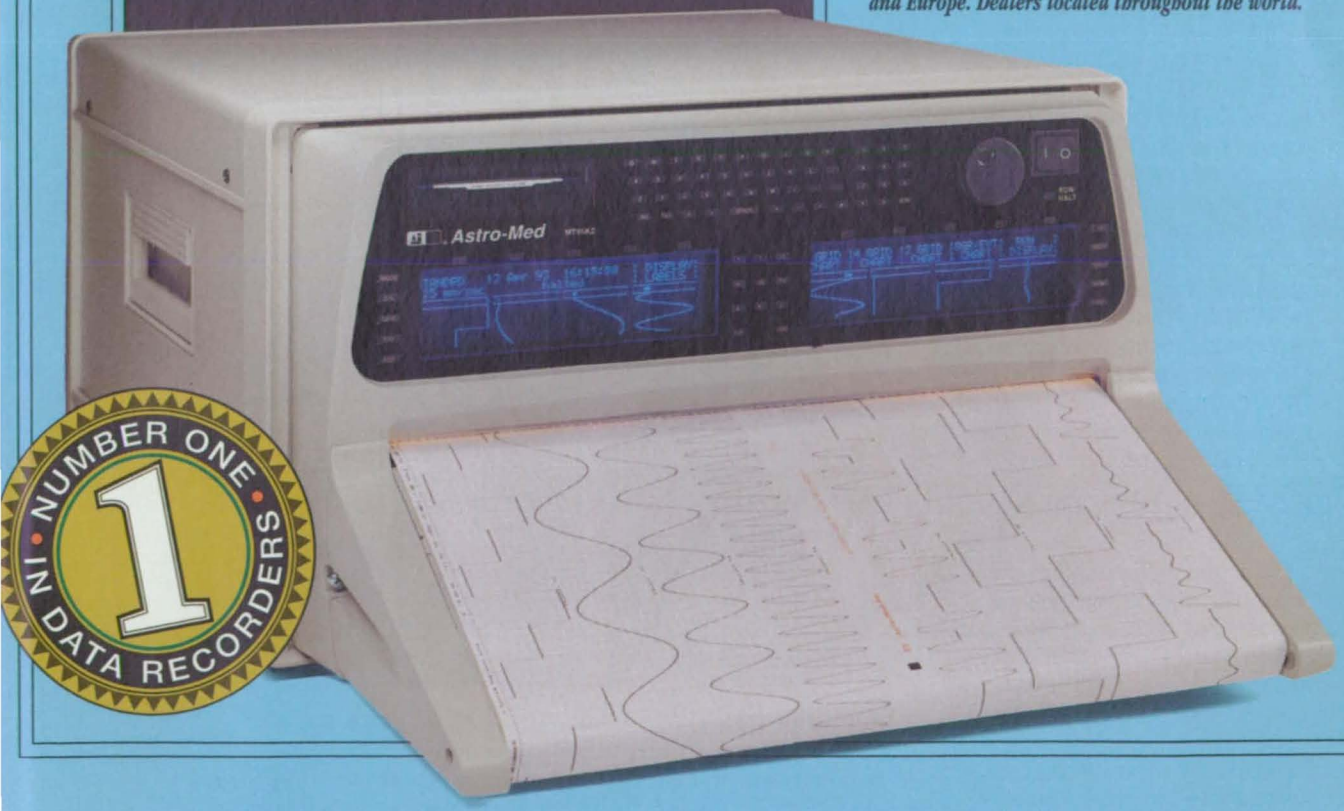


X-Ray Fluorescence Alloy- and Sulfur-Analysis Programs

John F. Kennedy Space Center, Florida

The Alloyscan and Sulfurscan computer programs enable quantitative analysis of alloy compositions and sulfur contents from x-ray-fluorescence measurements. Both programs implement a standard-matching routine, which derives concentrations through comparisons with known standards. A previous program does not provide the standard-matching option for quantitation, and it requires more time to perform the same analyses. The Alloyscan program enables the user to find a standard alloy that most closely matches the composition of the alloy represented by the x-ray-fluorescence data, and it provides three closest-matching standards for three groups of elements. The specificity of Sulfurscan reduces the time needed for analysis and manipulation of data.

This work was done by John A. W. Harkless of Morehouse College for **Kennedy Space Center.** *For further information,* ***write in 55*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11766.

Extracting Hydrocarbon Contaminants With Supercritical CO_2

The amount of solvent needed to sample contaminants is reduced sharply.

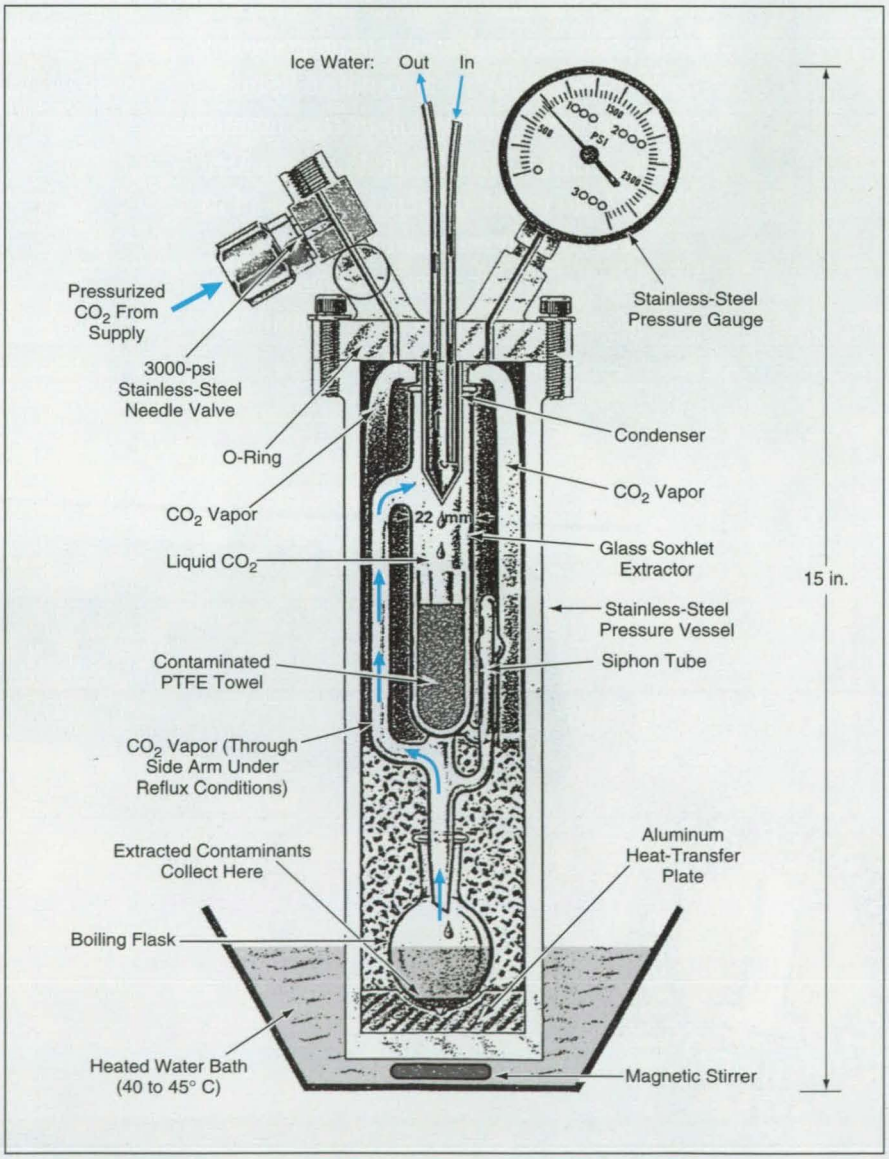
Marshall Space Flight Center, Alabama

An improved process for sampling hydrocarbon grease and oil contaminants on a surface includes the following steps:

1. The surface is wiped with a clean towel made of a non-hydrocarbon-based polytetrafluoroethylene (PTFE) cloth.
2. The contaminants are extracted from the towel and concentrated by the Soxhlet technique, using CO_2 at supercritical temperature and pressure as the solvent.
3. The concentrated contaminants are dissolved in about typically 5 mL of an organic solvent for analysis by Fourier-transform infrared (FTIR) spectroscopy.

The improved process replaces an older contaminant-sampling process that also included wiping, Soxhlet extraction, and FTIR spectroscopy. The towels used in the older process were made, variously, of nylon or polyester fabrics. These fabrics contain some plasticizers and sizing agents, which can be extracted along with the contaminants and can thus give rise to spurious FTIR spectroscopic readings that interfere with readings of contaminants. Moreover, the older process included an additional preparatory step of Soxhlet extraction to remove any hydrocarbon residue from manufacture of the towels.

In the older process, a volatile chlorinated organic liquid (typically CCl_4) was used as the solvent, and the amount used was much larger (typically 205 mL) than that of the organic solvent used in the improved process. Concerns over toxicity and damage to the environment have led to legal restrictions on the use of organic solvents. In contrast, the CO_2 used as the major solvent in the improved process is environmentally benign and nontoxic.



A **High-Pressure Soxhlet Extractor** containing supercritical carbon dioxide is used to extract contaminants from a PTFE towel for analysis by FTIR spectroscopy.

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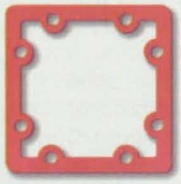

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Engraving Wood

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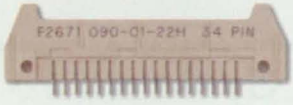

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For More Information Write In No. 520

The PTFE towels used in the improved process, as manufactured, do not contain extractable residues that could interfere with infrared analysis. A commercial high-pressure Soxhlet extraction apparatus is used in this process. The apparatus includes a glass Soxhlet extractor, wherein a towel is placed after wiping a contaminated surface. The glass Soxhlet extractor is then sealed into a metal pressure vessel; this is necessary to make it possible to hold CO_2 at supercritical pressure, thus making it possible to maintain the CO_2 in the liquid state in a chamber within the extractor that contains the towel (see figure). Liquid carbon dioxide is added to the interior of the extractor through a purifier and pressure valves, and the interior pressure is built up to about 850 psi (5.9 MPa).

The bottom of the pressure vessel is immersed in a water bath that is heated to a temperature between 40 and 45 °C; this causes boiling of the CO_2 at the bottom. At the same time, a condenser at the top of the extractor is cooled to 0 °C by ice water; CO_2 vapor that has risen from the bottom condenses and drips into the chamber that contains the contaminated towel. There, the liquid CO_2 dissolves the contaminants. When the amount of condensate CO_2 rises to a level above that of a siphon tube, it flows to a collection flask at the bottom, carrying dissolved contaminants with it. When the liquid CO_2 in the collection flask boils along with the surrounding liquid CO_2, the contaminants remain in the flask while the CO_2 refluxes to the condenser at the top. The cycle is then repeated until all of the contaminants have been removed from the towel. The apparatus is then disassembled and the contaminants are dissolved and analyzed as described above.

This work was done by Larry E. Hill of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 45*** *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; (205) 544-0021. Refer to MFS-30118.

Using Ozone To Sterilize a Rinse Tank

Marshall Space Flight Center, Alabama

Ozone is used to sterilize a tank that holds deionized rinse water. The tank is open to the atmosphere and thus provides ample opportunity for the growth of microbes in the water. In the absence of sterilization, such growth produces a black deposit of bacteria, slime, fungus, and cellulose fiber around the inner wall of the tank within a few days. Eventually, the chips of the deposit can come loose from the tank wall and become trapped in inaccessible places in the equipment rinsed in the tank. Thus, it becomes necessary to take the tank out of service every few days to scrub it clean. Utilizing the established technique of sterilization by ozone to reduce the frequency of scrubbing and the time out of service, the rinse plumbing was modified so that a pump now circulates the water between the tank and a chamber that houses a commercial ozone generator. The ozone destroys bacteria in the water, thus inhibiting the growth of the deposit. The optimal frequency and duration of exposure of the water to ozone has not yet been determined.

This work was done by Benjamina G. Montoya of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-30116*

Infrared Water-Film Monitor for Hydroponic System

John F. Kennedy Space Center, Florida

A prototype instrument measures the thickness of a film of water on a nutrient-supply tube in a hydroponic system. The instrument includes an incandescent lamp as a source of infrared light, plus a lead sulfide infrared photodetector, which measures the portion of light reflected from the water film. The amount of infrared light absorbed increases (and thus the amount reflected decreases) with the thickness of the water film. In initial experiments, it was found that to enable resolution of the thickness of the film in the thickness range of interest, it was necessary to add electronic offsets and extra gain in the circuits that process the photodetector output signals. The heat produced by the instrument was found to cause drift in its readings. Shielding and addition of a compensating reference detector reduced the drift. The addition of a 2.5-μm long-wavelength-pass filter helped to reduce interference from shorter-wavelength radiation.

This work was done by J. David Collins and Ronald C. Fox of **Kennedy Space Center**; *Robert C. Youngquist, John S. Moerk, William D. Haskell, and Robert B. Cox of I-Net; and Kenneth F. Anderson, Carol W. Carlson, and Howard W. Wells of The Bionetics Corp. For further information,* ***write in 3*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11716.

Using Sodium Chloride Windows To Sample Surface Contaminants

Marshall Space Flight Center, Alabama

Preliminary experiments have demonstrated the feasibility of using sodium chloride windows to sample organic contaminants on solid surfaces. This method of sampling was conceived as an alternative to sampling with cotton swabs followed by extraction of the sampled contaminants from the swabs by use of carbon tetrachloride. In the present method, a disk of sodium chloride made for use as an infrared-transmission window is removed from its protective package and placed in contact with the surface to be inspected. The disk absorbs some of the contaminants directly from the surface.

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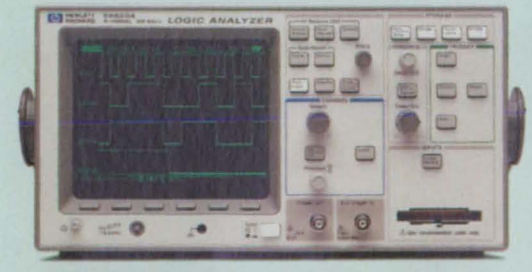

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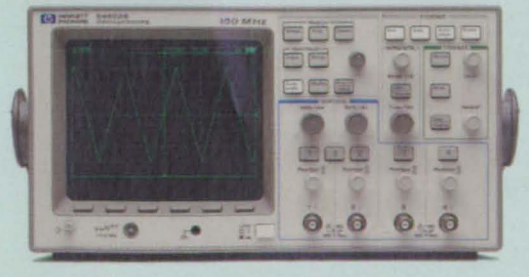

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The sample of contaminants is then analyzed directly by Fourier-transform infrared spectroscopy; there is no need for such intermediate steps as extraction of the sample by a solvent.

This work was done by Susan M. Stern and Larry E. Hill of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 54*** *on the TSP Request Card. MFS-30087*

Light Source for Testing Hydrogen-Fire Detectors

A portable unit emits radiation like that of hydrogen burning in air.

Stennis Space Center, Mississippi

A portable, battery-powered hydrogen-fire-simulating device produces both ultraviolet and infrared light. It is designed to serve as a stimulus in tests of multispectral hydrogen-fire detectors. Its output radiation imitates, both temporally and spectrally, the emissions characteristic of a hydrogen fire in air — at least to the extent needed to trigger a properly functioning detector.

A multispectral hydrogen-fire detector senses ultraviolet emission concurrently with temporally varying infrared emission. Accordingly, the hydrogen-fire simulator contains a portable ultraviolet lamp similar to that in an ultraviolet-only flashlight, plus a quartz/halogen lamp, which is chosen because its hot tungsten filament produces a strong near-infrared spectral component and its quartz envelope transmits that component efficiently. (A fused-silica protective window on the detector is also transparent in this spectral range.) The current applied to the quartz/halogen lamp is modulated to vary the intensity of the infrared emission and thereby imitate the flicker of a hydrogen flame.

This work was done by Daniel Olive of Sverdrup Technology, Inc., for **Stennis Space Center**. *For further information,* ***write in 93*** *on the TSP Request Card. SSC-00025*

Capacitive Differential-Pressure Gauge for High Temperature

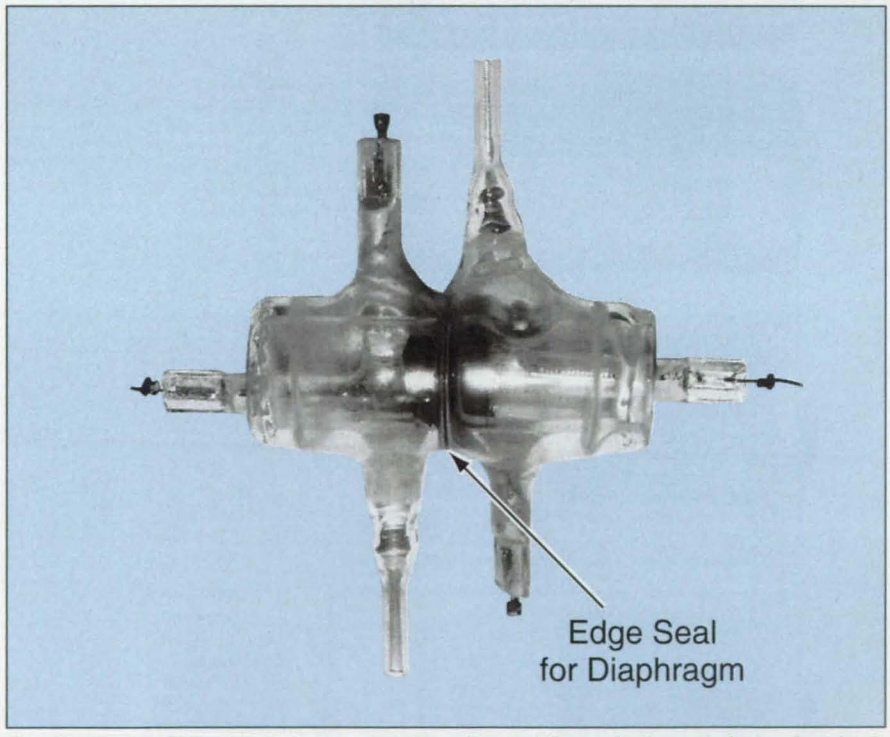
The gauge is made largely of quartz.

Lewis Research Center, Cleveland, Ohio

The figure shows a prototype of a capacitive diaphragm-type gauge for measuring differential pressures as small as a few millitorr (1 millitorr ≈ 0.13 Pa) at temperatures up to 750 °C. Both the gauge housing and the sensory diaphragm are made of quartz. The choice of quartz for the diaphragm is dictated by the fact that quartz is the only material known to retain adequate elasticity at the maximum temperature.

To form conductive patches to serve as electrodes on the diaphragm and on the housing surfaces facing the diaphragm, gold paint was deposited on these areas and baked. Hermetic seals for the wires to the electrodes were formed by fusing the quartz housing material around the wires at the feedthrough points in the manner of standard halogen-lamp terminations. The design thickness of the diaphragm was 0.003 in. (0.08 mm). A highly skilled glass blower made the diaphragm as thin as possible; the estimated thickness varied with radial position, ranging from 0.003 to 0.010 in. (0.08 to 0.25 mm).

The development of the gauge was terminated before its low-pressure response could be optimized and before a test could be conducted at high temperature. However, a test at room temperature showed that the response of the gauge was linear and repeatable at differential pressures up to 25 in. of H_2O [47 torr (6.2 kPa)].



This **Prototype Gauge** includes a quartz housing and hermetically sealed electrical feedthroughs similar to those of halogen lamps.

This work was done by V. Hruby of Busek Co., Inc., and G. Finkenbeiner of G. Finkenbeiner, Inc., for **Lewis Research Center**. *For further information,* ***write in 46*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15928.

Ohmic Heating of Copper-Coated Graphite Fibers

Wetting and dewetting behavior of this and other metal-matrix/fiber combinations can be determined.

Lewis Research Center, Cleveland, Ohio

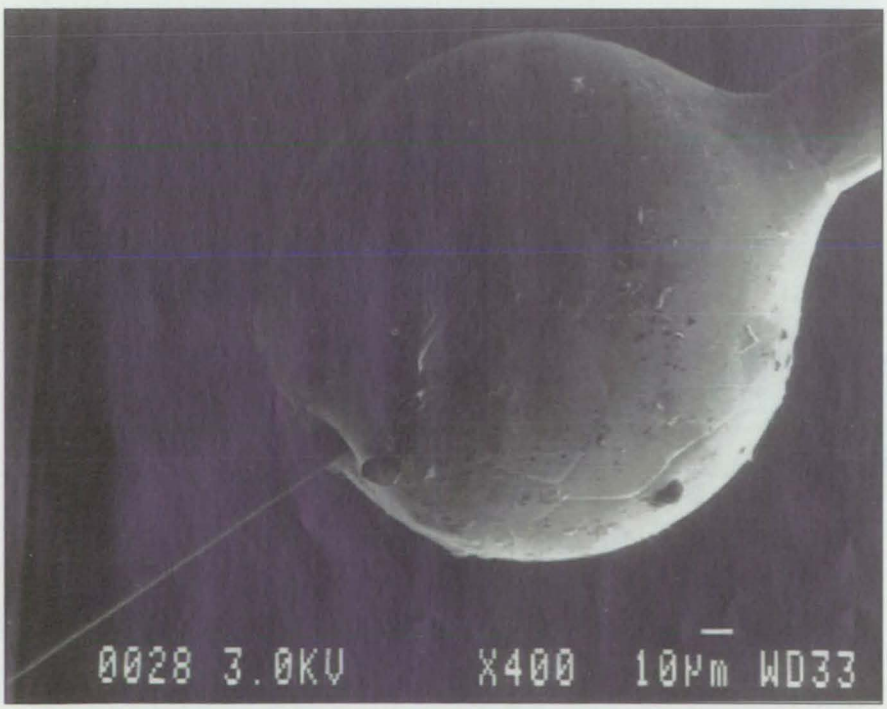
A simple ohmic-heating test provides information on the wetting and dewetting behaviors of copper coatings on graphite fibers at and near the melting temperature of copper (1,356 K). The test was devised as a means for rapid screening and comparison of various bonding layers that are used to increase adhesion between the fibers and matrices in graphite-fiber/copper-matrix composite materials. The test can be applied to other coated fibers that are candidates for development into metal-matrix/fiber composites.

In some respects, the test resembles early experiments on incandescent filaments for light bulbs. A fiber or a thin bundle of fibers is examined, then its ends are connected to electrical contacts and mounted in a vacuum chamber equipped with an observation window. Once the chamber has been evacuated, a controlled dc current (typically < 5 A per fiber at < 20 V) is passed through the fiber or bundle to heat it to near the melting temperature of copper. Because the electrical contacts act as heat sinks, the hottest part of the fiber or bundle lies at its midlength. Therefore, the temperature is measured at the midlength position; in initial experiments, this was done by use of a long-focal-length optical pyrometer of the "disappearing filament" type.

As the fiber or bundle approaches the melting temperature, the experimenter can watch for any visible changes in the metal coating. Afterward, the fiber or bundle is allowed to cool, removed from the chamber, and examined. In the initial experiments, the examination was conducted with a scanning electron microscope equipped with an energy-dispersive x-ray spectrometer. The results of this postheating examination are compared with those of the pre-heating examination to identify changes indicative of wetting or dewetting (see figure) and of degradation of bonding coats.

This work was done by Phillip B. Abel of **Lewis Research Center.** *For further information,* ***write in 76*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16224.



Dewetting of a Graphite Fiber by molten copper is clearly indicated by the pulling back of the copper surface film into a bead. There was no bonding coat between the graphite and the copper. This behavior is typical of the lack of adhesion between molten copper and bare graphite.

Regenerative Single-Unit Fuel Cells

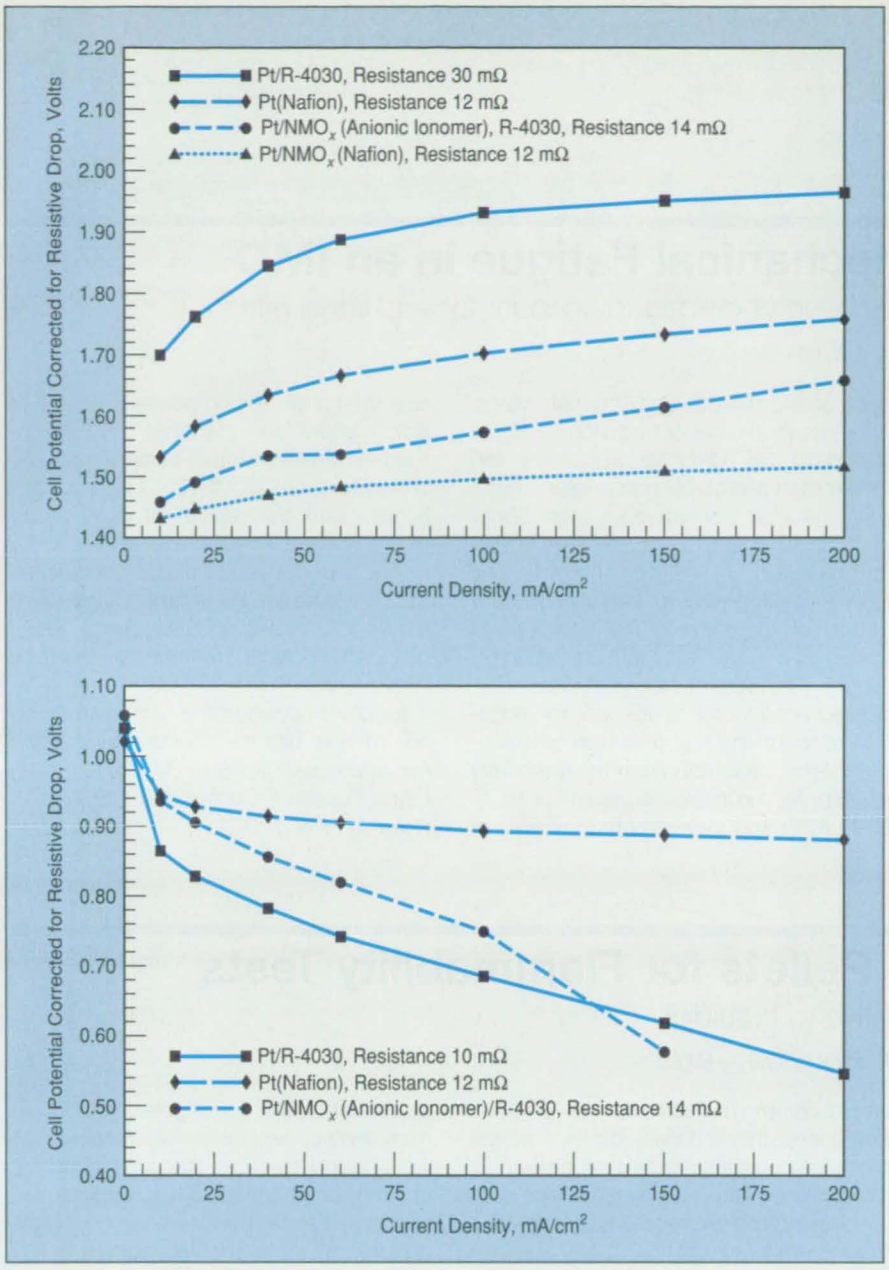
A single unit can be used as a fuel cell or electrolysis cell, as needed.

Lewis Research Center, Cleveland, Ohio

Prototypes of a class of efficient single-unit regenerative fuel cells have been built and tested. These prototypes feature solid ionomer alkaline membranes. The development of these prototypes is important because single-unit regenerative fuel cells can serve as either fuel cells or electrolysis cells, and therefore may become key components of future electric-power-generating/energy-storage systems. Potentially, the use of single-unit regenerative fuel cells (as compared with the use of electrolysis cells separate from fuel cells) could increase the energy densities of such systems.

Although the alkaline-electrolyte and proton-exchange-membrane fuel-cell and electrolyzer technologies are well-developed, single-unit regenerative fuel cells based on either technology have not been practical heretofore. This has been due primarily to a lack of stable, efficient, high-performance bifunctional oxygen electrodes. Furthermore, single-unit regenerative fuel cells based on either technology would perform poorly in at least one mode: an alkaline-electrolyte unit would perform better as a fuel cell than as an electrolyzer; a proton-exchange-membrane unit would perform better as an electrolyzer than as a fuel cell.

Accordingly, the present single-unit regenerative fuel cells combine the best features of alkaline-electrolyte technology with those of proton-exchange-membrane technology. One of the prototype cells contains a platinum black hydrogen electrode and a dual-layer oxygen electrode on an RAI R-4030™ anion-exchange membrane. The inner layer of the dual-layer oxygen electrode is in intimate contact with the membrane; this layer comprises an advanced oxygen catalyst made of platinum plus oxides of an alloy of noble metals (Pt/NMOx) and is imbued with a liquid anionic ionomer to achieve the most efficient performance. The outer layer is in intimate contact with the inner layer; this outer layer consists of platinum black doped



The **Performances of the Cells** were measured in operation in the fuel-cell and electrolyzer modes at a temperature of 40°C.

with sufficient polytetrafluoroethylene to render the electrode hydrophobic.

To obtain baseline data, a similar cell was constructed with a single-layer platinum black oxygen electrode instead of the complex dual-layer oxygen electrode. For further comparison, two additional prototype cells were made with Nafion 117™ cation-exchange membranes instead of RAI R-4030™ anion-exchange membranes. One of these additional cells contains a Pt/NMO$_x$ oxygen catalyst imbued with a liquid cationic ionomer instead of the liquid anionic monomer; the other contains a standard platinum black oxygen catalyst.

The figures show the measured performances of the cells. The round-trip efficiency of the first-mentioned cell at a current density of 40 mA/cm^2 was found to be 54 percent, which is quite high for the operating temperature of 40 °C. Higher efficiencies are expected at higher operating temperatures.

This work was done by John A. Kosek, Cecelia C. Cropley, and Anthony B. LaConti of Giner, Inc., for **Lewis Research Center.** *For further information,* ***write in 90*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15647.

Simulating Thermomechanical Fatigue in an IMC

An evolving computer program has been upgraded to account for additional effects.

Lewis Research Center, Cleveland, Ohio

Recent work has been directed toward improving the METCAN computer code, which has been developed for computational simulation of stresses, strains, and fatigue in metal-matrix composite materials. METCAN is a modular code that continues to evolve. One of its unique features is a multifactor interaction relationship (MFIR), which represents the high-temperature nonlinear behaviors of the constituent materials in a composite. The MFIR represents each quantifiable property of each constituent material as a product of factors that depend on temperature, time, strength of the material, metallurgical reactions, and the numbers of mechanical and thermal cycles. The research described focused on improving METCAN as applied to an intermetallic-matrix composite (IMC) material that comprises silicon fibers in a matrix alloy of 65Ti+24Al+11Nb (composition in weight percentages). One of the improvements was a modification of the term in the numbers of cycles to account for thermomechanical fatigue. Another improvement was incorporation of a factor to account for oxidation of fibers and matrix at high temperature. After calibration for the particular composite, the improved version of METCAN was used to predict fatigue lives of specimens of the composite in air and in argon under two standard cyclic thermomechanical-fatigue testing regimes. The predictions of METCAN agreed fairly well with the results of tests under those regimes.

This work was done by Christos C. Chamis of **Lewis Research Center** *and Michael T. Tong of Sverdrup Technology, Inc. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16004.

Improved Solid-Fuel Pellets for Flammability Tests

Reformulated material is less sensitive to humidity.

Lyndon B. Johnson Space Center, Houston, Texas

Improved formulations have been devised for solid-fuel pellets used in igniters in flammability testing of materials. Modified versions of the improved formulations might also prove useful in solid-fuel pellets for household, workshop, and industrial applications.

In the original application that gave rise to the need for the improved formulations, the solid-fuel pellets were made of hexamethylenetetramine (HMTA) as a fuel mixed with gum arabic as a binder and sodium metasilicate as a filler. Frequently, these pellets did not satisfy the NASA specifications that pertain to the particular flammability tests, and they were found to be unacceptably sensitive to ambient humidity.

A review of the literature and some experimentation led to the conclusion that solid-fuel pellets could be made of HMTA, gum arabic, and alternative filler materials. Glass and silica were found to be suitable replacements for the sodium metasilicate filler. Pellets made of HMTA, gum arabic, and glass or silica beads were found to meet the specifications and to be insensitive to humidity as related to their performances in tests according to the specifications.

This work was done by Amit Jain of Rockwell International Corp. for **Johnson Space Center.** *For further information,* ***write in 40*** *on the TSP Request Card.*

MSC-22604

Composite Flexible Blanket Insulation Sewn With SiC Threads

Ames Research Center, Moffett Field, California

Lightweight composite flexible blanket insulation materials for protecting personnel and equipment against temperatures up to more than 1,000 °C are undergoing development. Intended originally for use on spacecraft reentering the atmosphere of the Earth, these insulating blankets could also be adapted to such terrestrial applications as protective clothing for firefighters. The designs of these insulating blankets combine established concepts of multilayer insulation and of high-temperature ceramic insulation, which have been described in numerous articles in *NASA Tech Briefs*. A typical insulating blanket of this type is a quilt that includes multiple reflective layers of aluminum foil (or aluminum film on a polyimide substrate) separated by aluminoborosilicate cloth, plus an overlying layer of silica felt, all sandwiched between ceramic (silica or silicon carbide) fabric face sheets. The choice of materials and of the numbers and thick-

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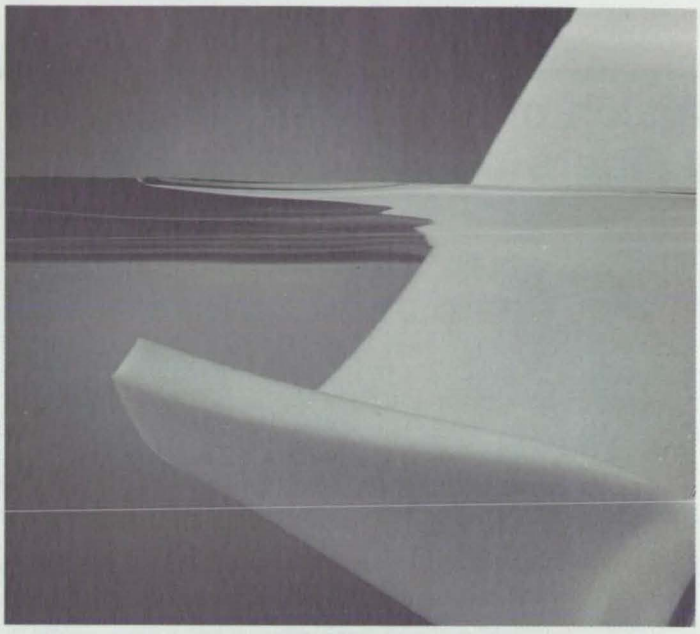

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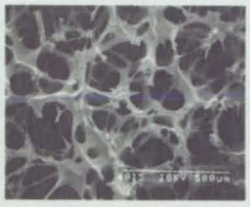

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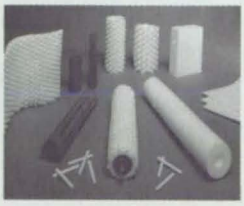

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nesses of the various layers can be optimized for each specific application. A principle innovative aspect of this development is the use of threads of silicon carbide (as distinguished from threads of quartz or other silica-based materials) to stitch the blanket layers together. [The use of silicon carbide threads in thermally insulating blankets was reported previously in "Silicon Carbide Threads for High-Temperature Service" (ARC-12406), *NASA Tech Briefs*, Vol. 15, No. 4 (April 1991), page 64.] In comparison with silica-based threads, those made from silicon carbide offer advantages of greater thermal emissivity and greater retention of strength at high temperatures.

This work was done by Paul M. Sawko of **Ames Research Center**. *For further information,* ***write in 82*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,436,075). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13373.

Thermal Expansion of Iron-Base Alloys Reinforced by Fibers

Results of experiments give clues as to interactions between fibers and matrices.

Lewis Research Center, Cleveland, Ohio

An experimental study was run on the thermal expansions of specimens of four kinds of composite materials. Each specimen comprised a matrix of either 68Fe/24Cr/8Al/0.06Y or 59.5Fe/40Al/0.5B alloy (numbers indicate approximate atomic percentages) and three plies of long, unidirectional fibers of either tungsten or single-crystal alumina. These composite materials were chosen for study partly because of their potential utility at high temperatures. They were also chosen partly because the constituent alloys and fibers exhibit a wide range of properties, including different coefficients of thermal expansion. The specimens were heated to temperatures up to about 1,100 °C, and their lengths as functions of temperature and time were measured by dilatometry, with corrections for the thermal expansions of the components of the experimental apparatus. Thermal strains and the corresponding coefficients of thermal expansion were computed from the measurements. Analysis of the numerical results revealed that the instantaneous coefficient of thermal expansion of each specimen depended on its thermal history and was sensitive to effects of relative inelasticity of the matrix and to bonding/debonding between the matrix and fibers.

This work was done by Donald W. Petrasek and Susan L. Draper of **Lewis Research Center** *and Beverly J. M. Aikin of Case Western Reserve University. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16005.

Metal-Matrix/Ceramic-Fiber Parts for Handling Oxygen

Lyndon B. Johnson Space Center, Houston, Texas

Metal-matrix/ceramic-fiber composite materials formulated to resist burning have been proposed as candidate materials for use in high-pressure-oxygen-handling equipment. These composites would be used in place of either (a) lightweight metals that pose a risk of flammability in pressurized oxygen and (b) metals that are less flammable but too heavy, too weak, and/or too expensive. Preliminary tests have shown that whereas aluminum becomes flammable in pure oxygen at a pressure as low as 25 psia (0.17 MPa), a composite of aluminum with 55 percent alumina/boria/silica fibers resists burning in pure oxygen at pressures up to 175 psia (1.2 MPa). While these results appear promising, there is still a long way to go; to be useful, a material would have to be strong, lightweight, and resistant to burning in oxygen at typical pressures of oxygen-handling systems; namely, pressures in the range of 3 to 6 kpsi (20 to 40 MPa). Other metal-matrix/ceramic-fiber composites are being evaluated at the NASA White Sands Test Facility at Las Cruces, New Mexico.

This work was done by Michelle A. Rucker of **Johnson Space Center**. *For further information,* ***write in 15*** *on the TSP Request Card. MSC-22650*

Modified Intermetallic Has High Temperature Potential

This alloy forms two different protective oxide coats in two different temperature ranges.

Lewis Research Center, Cleveland, Ohio

The substitution of a large proportion of molybdenum for the chromium in chromium silicide (Cr_3Si) yields an alloy with increased resistance to oxidation, erosion, and creep. This improved high-temperature alloy can potentially be used, for example, on blades and vanes exposed to hot, flowing, oxidizing gases in turbine engines. Other possible applications include chemically inert extrusion dies in the food, glass, and polymer-processing industries, where

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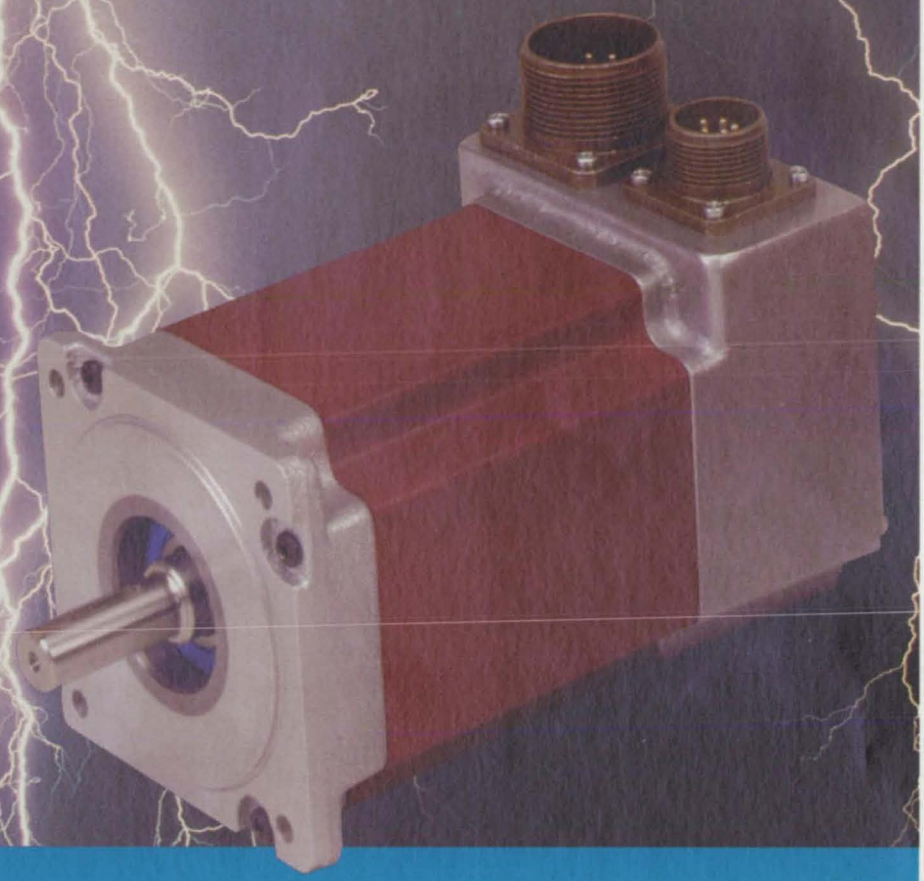

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resistance to erosion and corrosion are important.

By itself, the intermetallic compound Cr_3Si exhibits poor resistance due to oxidation at temperatures above 1,150 °C. This is partly because chromium oxidizes faster than silicon does. The silicon component oxidizes too slowly to form a protective SiO_2 coat.

The present improved alloy is $Cr_{40}Mo_{30}Si_{30}$. It was chosen after preliminary experiments as the best of a number of candidate alloys that were synthesized by arc-melting mixtures of various proportions of Cr, Mo, and Si. The microstructure of this alloy features two phases — Cr_3Si and Mo_5Si_3 — that form two protective oxides in different temperature ranges: Below 1,200 °C, a stable layer of Cr_2O_3 forms on the surface of the alloy. Above 1,200 °C, a stable layer of SiO_2 forms.

The addition of molybdenum decreases the melting point of the alloy only slightly, to about 1,700 °C. At the same time, it increases the creep resistance to about that of $MoSi_2$ reinforced with silicon carbide particles, but without making the alloy highly susceptible to low-temperature oxidative disintegration, unlike $MoSi_2$. The mass density of the alloy is less than that of superalloys. The alloy is brittle, but the addition of partially stabilized zirconia or another suitable agent may provide a measure of toughening.

This work was done by Sai V. Raj of **Lewis Research Center.** *For further information,* ***write in 66*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15697.

Fully-Coupled Deformation and Damage Analysis for MMCs

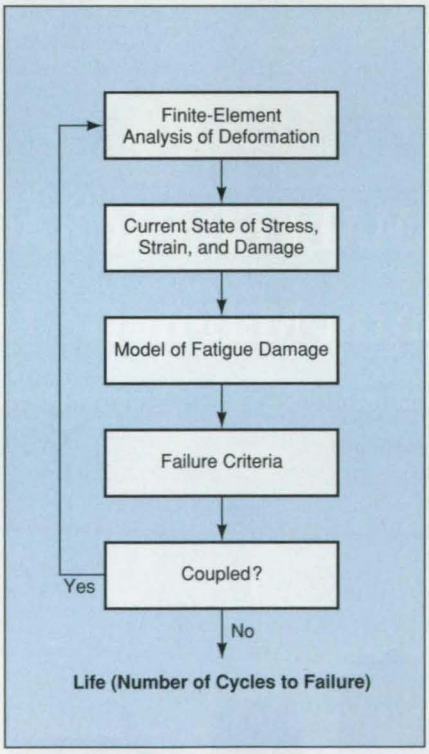
Effects of fatigue damage are taken into account in finite element computations.

Lewis Research Center, Cleveland, Ohio

A proposed method for predicting the fatigue lives of metal-matrix composite (MMC) structural components involves finite-element analysis fully coupled with a fatigue-damage model (see figure). In this method, the effects of fatigue damage are taken into account in the finite-element solution by use of the concept of effective stress, according to which damage is accounted for through the degradation of material properties which results in degradation of the individual finite-element stiffness matrices. As damage progresses through a structural component, these changes in the stiffness matrices give rise to redistribution of the computed stresses in the finite elements.

A fatigue-damage algorithm derived from a multiaxial, transversely isotropic, isothermal, stress-based, continuum-damage-mechanics mathematical model is implemented into the nonlinear finite-element code MARC.

The fatigue-damage algorithm consists of three subroutines, two of which are used to degrade the elastic and plastic properties, respectively of the composite material. The third subroutine is used to store the current state of stress in each finite element during a load cycle; this subroutine also invokes the damage calculations when the last increment in load, during a load cycle, has been computed for the last finite element. The load cycles are defined by the user through the MARC input data deck, and are used to achieve redistribution of computed stresses in the structure due to the occurrence of material degradation. The number of increments of load per load cycle is also specified by the user; this is necessary so that the program can determine when a given load cycle has been completed and the damage calculations can begin.



Effects of Fatigue Damage are taken into account in finite-element computational simulation of stresses and strain.

In the present version of the method, the damage calculations are controlled by the increment in damage. The user specifies the allowable increment in damage as a fraction of the total possible damage. Based on the new value of damage, the number of cycles to failure for a given element in its present state of stress is calculated and stored. Next, a sorting subroutine is called to determine which element is characterized by the minimum number of cycles to failure. This element is denoted the controlling element, and its number of cycles to failure is denoted the controlling number of cycles.

Once the controlling number of cycles has been determined, the corresponding actual amount of damage in all of the remaining elements must be recalculated. Once an element attains 98 percent damage, the element is assumed to fail. At this point the stiffness of the element is fixed at 2 percent of its original value, and the element is no longer considered in subsequent damage calculations. In preparation for the subsequent load cycle, the properties of the material in each element are degraded according to the element's newly calculated damage.

This work was done by Steven M. Arnold of **Lewis Research Center** *and Thomas E. Wilt of the University of Toledo. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16002.

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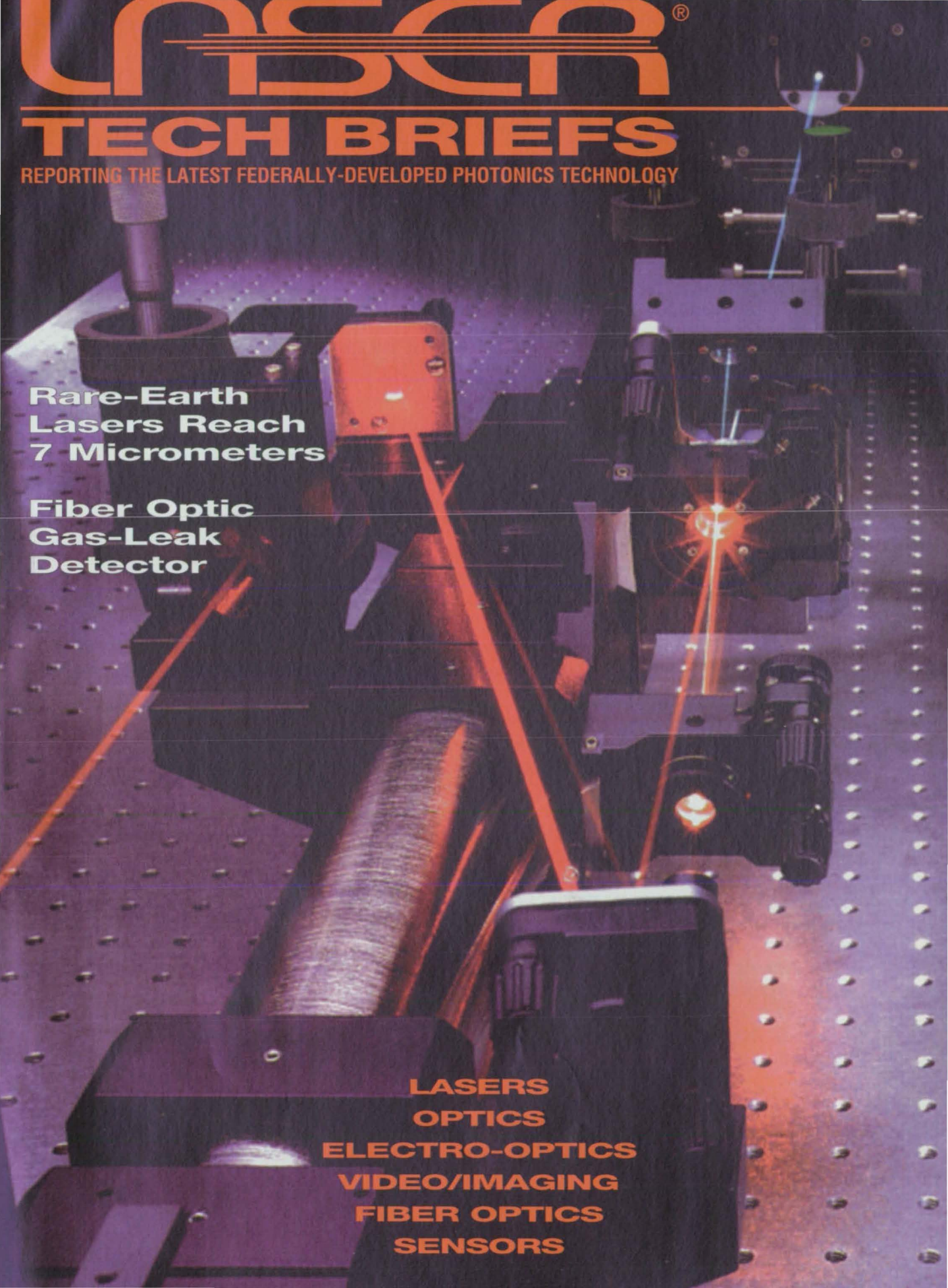

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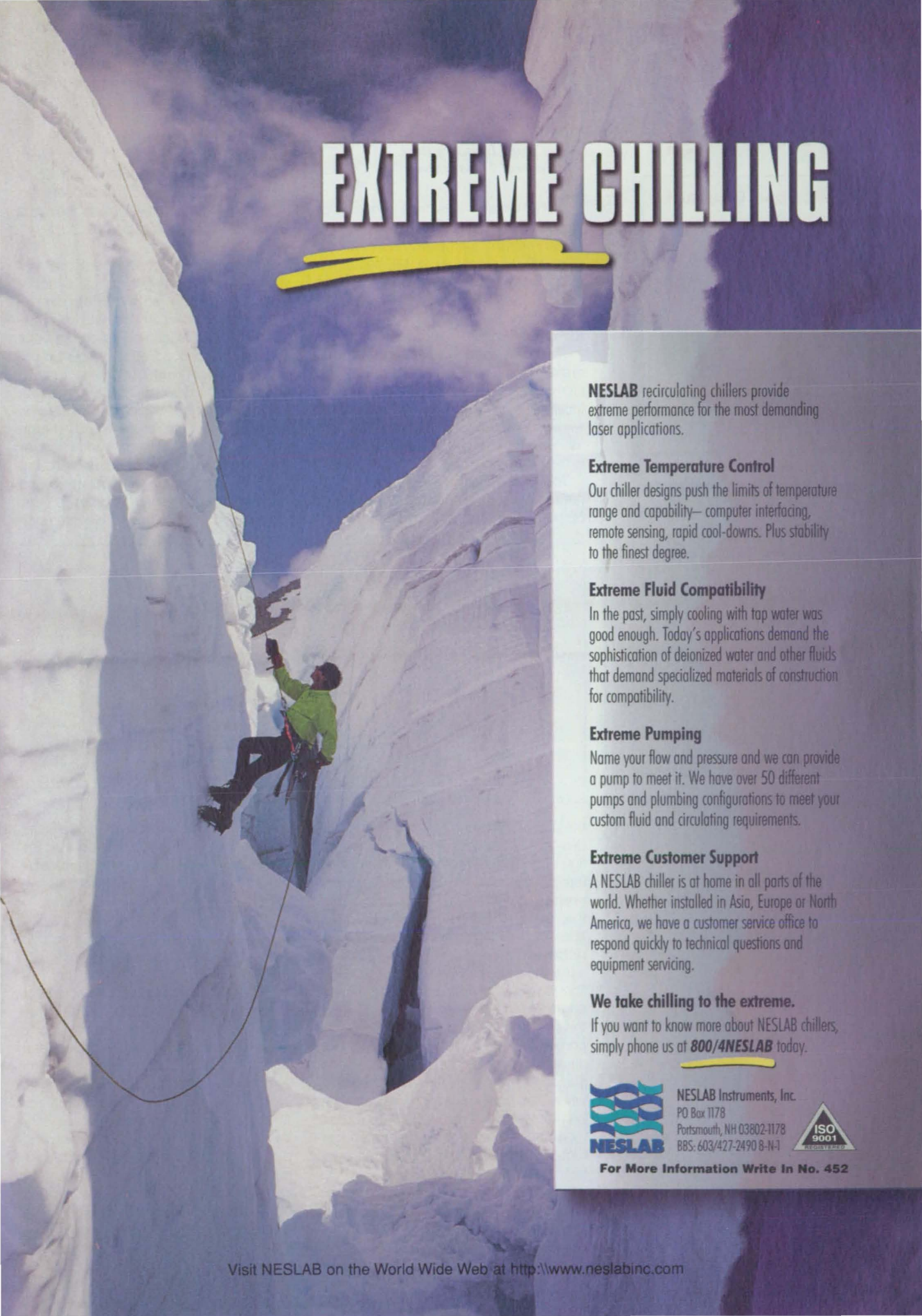
A complete beam delivery system such as the one seen here, as well as engineering and manufacturing expertise, can be provided at Spectra-Physics Lasers' new state-of-the-art optics, machining, and optical assembly facility in Oroville, CA. *Photo courtesy Spectra-Physics Lasers Inc.*



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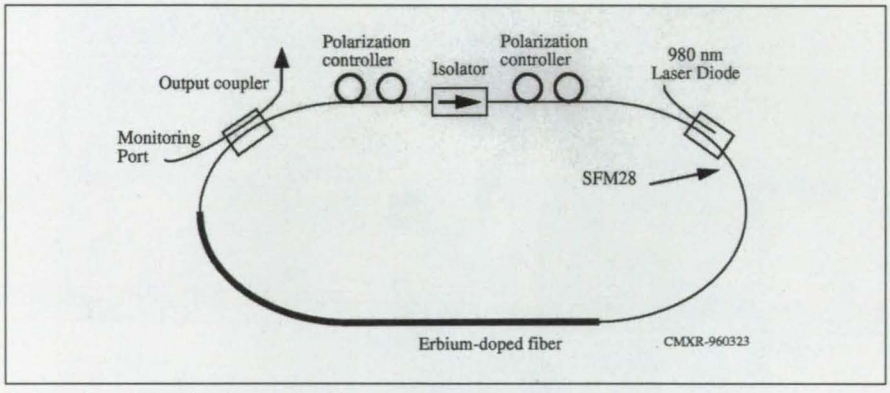
NEWS BRIEFS

Notes from Industry and the Federal Laboratories

With Small Business Innovation Research (SBIR) funding from the Departments of Commerce and Defense, Clark-MXR Inc. of Dexter, MI, has developed what its president Philippe Bado calls a radically new ultrafast laser source, for the first time bringing femtosecond pulses into the industrial world.

The beam source, developed in collaboration with Dr. Erich Ippen and Dr. Hermann Haus of the Massachusetts Institute of Technology, is erbium-doped single-mode optical fiber. A commercially available high-power 980-nm diode laser is the pump source.

The new design substantially eliminates nonlinear effects that have limited output energy in ultrafast lasers, through the use of the patented "stretched-pulse design." The laser's ring cavity (see the figure) is divided into two sections of differing fiber, the erbium fiber part with positive group velocity dispersion, and the standard SFM28 communication fiber part with negative group velocity dispersion.



Schematic of the stretched-pulse fiber ring laser.

As the optical pulse races around the fiber loop, it is first stretched (chirped) and then compressed (unchirped). Thus the overall loop has zero dispersion, supporting the bandwidth associated with ultrashort pulses. The output coupler is placed at the end of the erbium section, where the pulse duration is expected to be greatest. As a result the output energy is approximately two orders of magnitude higher than that of "conventional" fiber lasers.

Clark-MXR offers two models based on this design, the ErF™ and the SErF™. The former is a modelocked laser operating at 1550 nm. At a repetition rate of 37 MHz and an average power of more than 50 mW, pulse energy works out in excess of 1 nJ. The SErF, the frequency-doubled 775-nm version, is well suited as a seed source for Ti:sapphire regenerative amplifier systems. Winding the fiber in a compact loop makes the laser head, including the pump source, just 12 in. wide and 24 in. long. Bado expects further work will lead to systems of the same size able to produce microjoule pulses.

Gryphon Optics, a new company that manufactures diffractive optics, announced its founding at the SPIE Annual Meeting in Denver in August. Its president is Paul Fileger and its applications engineer Dr. Bruce Peters, who held the same position at Teledyne Brown Engineering Electro-Optics Products Group. Gryphon, which is located in Huntsville, AL, provides optical design and analysis, and diffractive and microrefractive optical components and assemblies for applications in industrial and medical laser material processing, laser diagnostic, scanning, and telecommunications systems, gas and diode laser beam shaping, and conventional optics aberration correction. Gryphon may be reached at PO Box 14490, Huntsville, AL 35815; (205) 837-2565.

Companies continue to establish World Wide Web sites at a fast clip. Among them is Resonetics Inc. of Nashua, NH, a supplier of laser micromachining services and systems. Its Home Page is at http://www.resonetics.com. The site includes a list of products and services, a company profile, upcoming events, and technical papers and articles.

MII of Sanatoga, PA, has set up a site at http://www.miipgt.com. The site contains information on medical imaging and display components and precision optical glass components. Information on camera tubes, cathode ray tubes, optical parts, and technical service and support is accessible, along with a company profile. The Precision Glass Technologies division of MII is also represented.

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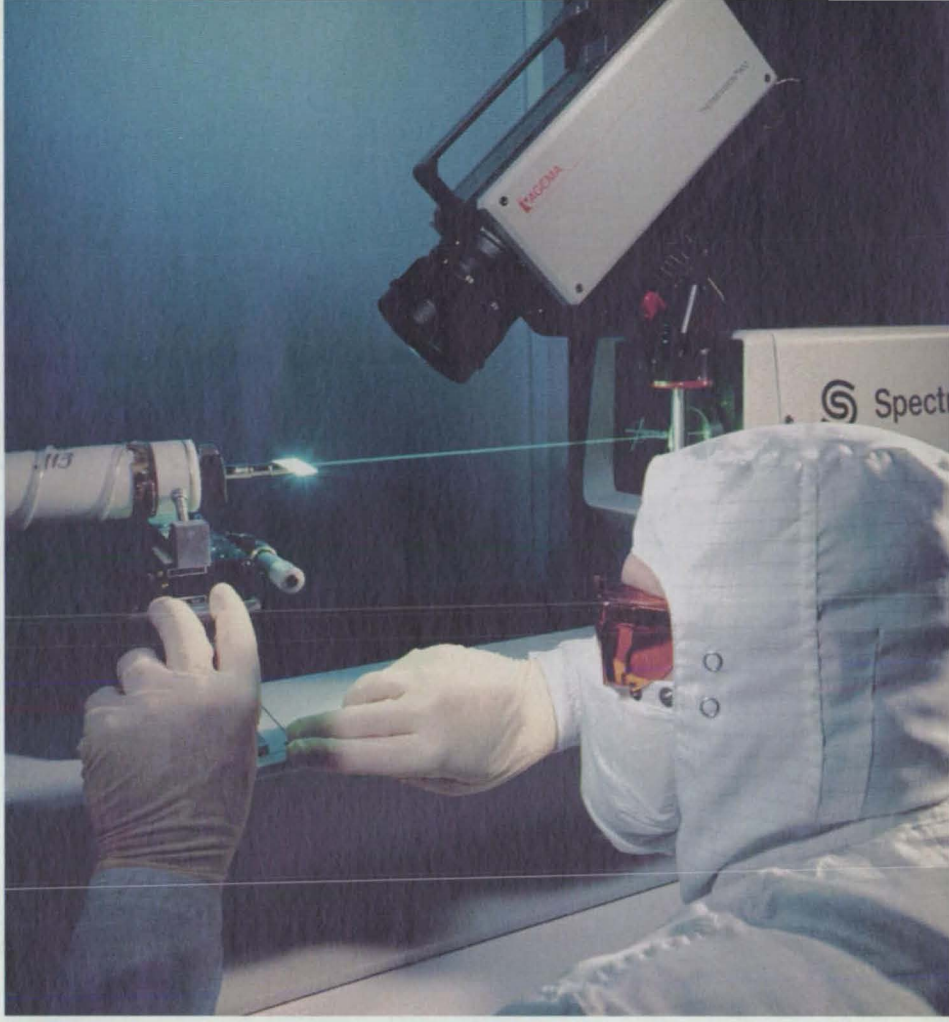

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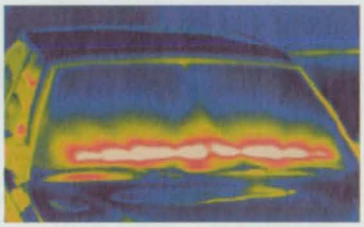

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NASA TECH BRIEFS

Mapping Planar Geologic Features in Deep Underground Mines

A Geolaser and mapping method have been developed and patented to map features where metal interferes with compass readings.

Spokane Research Center, Department of Energy, Spokane, Washington

A fundamental problem of mapping planar geologic features in deep underground mines is the presence of metal (water and air pipes, track, equipment, etc.) that affects the accuracy and consistency of compasses. To date, deep underground geologic mapping methods include use of transits or theodolites, both of which are cumbersome and time-consuming to use. To complicate the mapping process, each planar feature must be surveyed, and if that feature is not apparent on the opposite wall, it cannot be measured. Another method is to stretch a tape measure between two survey spads and place a string along a planar feature on one wall and out into the opening until it intersects the tape measure. This method, in addition to being time-consuming, is also inaccurate.

Geolaser was developed to make quick, accurate, and reliable measurements in deep underground mines where the presence of metal interferes with conventionally used compasses. Operation of Geolaser is based on the fact that any beam of light laid horizontally along a planar feature will define the strike of that feature. Thus a beam can actually project where a planar geologic feature should occur along the back or opposite rib in an underground opening.

Figure 1. **Metal strips** along one side or the bottom of the Geolaser can be extended to allow the instrument to be placed in a tight opening.

First, a plan view map of the mine showing survey spads is required. Underground, a tape measure is stretched from spad to spad. Geolaser is then placed on any planar geologic feature to be mapped, and a level contained in the unit is used to orient the beam horizontally. If the instrument cannot be placed in a tight opening, metal strips along one side or the bottom of the instrument can be extended to fit into the opening (see Figure 1). The laser beam is activated and the beam traced to its intersection of the beam with the tape measure (Figure 2). A 4-to-6-foot rod is placed perpendicular to the tape measure to mark its intersection with the beam. The location of Geolaser and the point where the beam crosses the tape measure are marked on the mine map. The resulting line between these points defines the line of strike relative to the survey line between the two spads. The time needed to take a measurement is about 20 seconds, and two people are required.

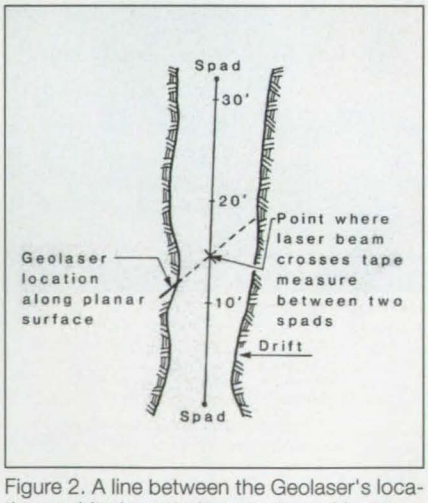


Figure 2. A line between the Geolaser's location and its beam's intersection with a tape measure defines the **line of strike** relative to a survey line between two spads.

Bureau of Mines personnel have tested the instrument and methodology extensively and have successfully mapped planar geologic features at several deep underground mines. Time saved mapping with Geolaser is estimat-

ed at about 50 percent, with an increase in accuracy.

This work was done by Douglas F. Scott of the **U.S. Department of Energy Spokane Research Center**. *A patent has been issued. Inquiries concerning rights for the commercial use of this invention should be addressed to Douglas F. Scott, Spokane Research Center, E. 315 Montgomery Ave., Spokane, WA 99207; (509) 484-1610; FAX (509) 353-2652; E-mail: scottd@src.usbm.gov.*

Laser Spot Welding of Brazing-Alloy Foil

Marshall Space Flight Center, Alabama

Brazing-alloy foils 0.0015 to 0.004 in. (0.04 to 0.1 mm) thick would be spot-welded in place by use of a laser, according to a proposal. The laser spot-welding system to be used for this purpose would include a commercially available neodymium:yttrium aluminum garnet (Nd:YAG) laser. It would also include a fiber-optic transmission cable that, in comparison with the electric power cable used in electrical-resistance spot welding, would be lighter in weight and more maneuverable. The quality and consistency of the laser spot welds would exceed those of electrical-resistance spot welds.

This work was done by Jeffrey L. Gilbert and Lyle B. Spiegel of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 96*** *on the TSP Request Card. MFS-30059*

Modified Triple-Cantilever Bimorph Actuator

NASA's Jet Propulsion Laboratory, Pasadena, California

A triple-cantilever bimorph actuator has been proposed for use in adjusting the axial position and/or tilt of a mirror or other object in three degrees of freedom. This actuator would be a modified version of the device described in "Controlling Mirror Tilt With a Bimorph Actuator" (NPO-19303), *NASA Tech Briefs*, Vol. 19, No. 11 (November 1995), page 70. In both the previous and present versions, three piezoelectric or piezoceramic bimorphs would be mounted as cantilever beams at equal angular intervals about the axis of a cylindrical housing to provide approximately axial translation to three similarly angularly spaced points near the periphery of a round mirror in the housing, and capacitive proximity sensors would provide cantilever-deflection feedback. In both versions, a voltage could be applied to each bimorph independently to tilt the mirror in the required direction. In the modified version, the three bimorphs could also be simultaneously commanded to produce equal axial translations to translate the mirror axially without tilting it. The two versions would differ somewhat in the geometry of mounting of the bimorphs and in the connections

between the bimorphs and the mirror. The design of the modified version could be optimized for operation in cryogenic apparatuses. In most other respects, the basic principles and the basic design parameters of the two versions would be essentially the same.

This work was done by Yoseph Bar-Cohen of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 26*** *on the TSP Request Card.*
NPO-19312

New Mid-Infrared Solid-State Lasers

Efficient operation is demonstrated at the longest wavelength ever reported for rare-earth lasers.

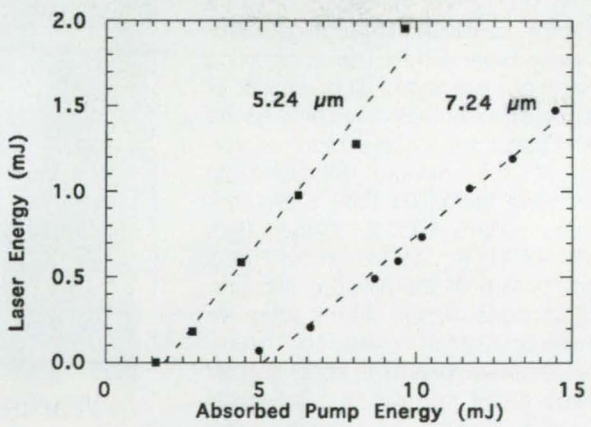
Naval Research Laboratory (NRL), Washington, DC

Solid-state lasers based on rare-earth ions provide rugged high-brightness sources for many real-world applications. But until now these lasers have been restricted to operation in the visible and near-infrared: $\lambda = \leq 3$ μm. A goal of research at NRL is to extend the useful range of rare-earth solid-state lasers into the mid-infrared range: 3 μm (<) λ (<) 10 μm. Toward this goal is work to explore the optical properties of rare-earth ions doped into unconventional host crystals. Demonstration of this technique involves two new mid-IR lasers using the rare earth praseodymium. These can now provide compact and efficient sources with emission lines centered at 5.2 and 7.2 μm.

As the emission wavelength of a potential laser material increases, nonradiative decay processes become more energetically allowed. These processes compete with and eventually quench fluorescence from the metastable quantum states needed for laser operation. For rare-earth solid-state lasers the most important of these nonradiative decay mechanisms is called multiphonon quenching. This process allows the excited states of 4f electrons to decay through the production of quantized vibrations of the solid matrix, called phonons. As a result, previous solid-state lasers have been restricted to efficient operation at wavelengths shorter than 3 μm. The key to achieving rare-earth lasers in the mid-IR is the selection of a host material that has very low-energy phonons. Lanthanum trichloride is one such host crystal, with a maximum phonon energy of only 210 cm^{-1}.

A good laser host material must also be transparent throughout the spectral range of interest and accommodate doping of the active ion. Lanthanum trichloride is optically uniaxial and is transparent from the UV to 15 μm. Also, praseodymium ions substitute easily at the C3h symmetry lanthanum crystal site. The new lasers use crystals doped with approximately 1% praseodymium. Optical-quality crystals were grown using a vertical Bridgman technique.

One disadvantage of lanthanum trichloride as a laser host is that it is hygroscopic. Laser chambers must be sealed with a dry atmosphere. A polished crystal was mounted on a temperature-controlled heat sink inside a nearly hemispheric 20-cm resonator. The crystal was oriented near Brewster angle with the optical axis in the plane of incidence. Dichroic mirrors allowed operation at 5 or 7 μm and single-end pumping at 2.02 μm with a pulsed thulium:YAG laser. This pump laser produced polarized pulses with Gaussian spatial profiles and durations as long as 400 μs.



Output energy of the **praseodymium laser** with the crystal temperature fixed at 140 K.

At room temperature a 7.2-μm laser threshold was obtained with only 4 mJ of absorbed pump energy, and slope efficiencies of 4% were observed. With the crystal temperature reduced to 140 K, 7-μm slope efficiencies of 15% were observed, as shown in the figure. For the 5.2-μm transition, slope efficiencies of 28% were observed. Both of the new laser transitions originate in the Pr^{+3} $^3F_3$ level, and the lifetime of this upper state is measured to be 300 μs.

Compact and efficient 5- or 7-μm praseodymium lasers should now be possible using commercial 1.5-μm InGaAs/InP laser diode arrays as the pump source. More generally, the low-energy phonon host that made this demonstration possible can now be applied to many other solid-state lasers in the 3-to-10μm range. Potential applications for such sources include illuminators for infrared imaging and countermeasures systems as well as chemical and biological sensing systems.

This work was done by S.R. Bowman, Joseph Ganem, and B.J. Feldman in the Laser Physics Branch at the **Naval Research Laboratory**. *For further information contact Steve Bowman at Code 5640, NRL, Washington, DC 20375-5320; (202) 767-9418; FAX (202) 404-7530; E-mail: bowman2@nrlps1.navy.mil.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Transfer Office, Code 1003.1, Naval Research Lab, 4555 Overlook Ave. SW, Washington, DC 20375-5000.

Using Ultrasound To Measure Thicknesses of Lenses

Marshall Space Flight Center, Alabama

An ultrasonic thickness-measuring apparatus has been designed especially for measuring the thicknesses of lenses during and after fabrication. The advantage of ultrasonic measurement over customary micrometer measurement is that an ultrasonic transducer is less likely to introduce scratches into the lens surfaces. In a typical application, an ultrasonic transducer and an ultrasonic delay line are connected to a transducer, and the lens or other specimen to be measured is positioned below the delay line. A fluid medium such as water is placed between the delay line and the specimen being measured to ensure good ultrasonic coupling. An ultrasonic receiver collects the reflected ultrasonic waves and determines the thickness of the specimen from the speed of sound and the round-trip travel time of reflected sound.

This work was done by Hoa T. Bui of Hughes for **Marshall Space Flight Center.** *For further information,* ***write in 69*** *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 Hughes Aircraft Company. Inquiries concerning licenses for its commercial development should be addressed to

Hughes Aircraft Company
7200 Hughes Terrace
Los Angeles, CA 90080-7200

Refer to MFS-28964, volume and number of this NASA Tech Briefs *issue, and the page number.*

Lightweight Mirrors Withstand Large Temperature Excursions

Quartz optical faceplates are supported by ceramic foam substrates.

Lewis Research Center, Cleveland, Ohio

Lightweight mirrors made from composite materials have been developed for use as solar concentrators in outer space. These mirrors could also be suitable for terrestrial applications that involve large temperature excursions.

A mirror of this type is 0.5 in. (13 mm) thick and 6 in. (15 cm) in diameter, and its reflective surface is concave with a radius of 72 in. (183 cm). The main structural body of the mirror is a substrate made from reticulated vitreous carbon foam infiltrated with a ceramic. A faceplate with a mirror surface is made from a rough precurved quartz blank; the blank is ground and polished to obtain the required mirror surface, then a thin layer of aluminum is bonded to this surface to make it reflective.

The mirror surface has a slope error less than 1.0 milliradian and a root-mean-square surface roughness less than 50 Å. The areal density of the mirror is less than 0.35 g/cm^2. A state-of-the-art lightweight mirror of prior design has a slope error of 2.0 milliradians and an areal density between 0.5 and 0.6 g/cm^2. A mirror of the present type was found to retain its optical properties after three temperature cycles between ambient and –193 °C, 200 cycles between ambient and 200 °C, and 200 cycles between 0 and 200 °C.

This work was done by Richard B. Kaplan and Brian E. Williams of Ultramet for **Lewis Research Center.** *For further information,* ***write in 97*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15543.

Line-Focusing Optics for Multiple-Pass Laser Welding

Marshall Space Flight Center, Alabama

A lens-and-mirror optical assembly has been developed for use in multiple-pass laser welding in the conduction mode (a shallow-weld-pool mode, as distinguished from the full-penetration keyhole mode). The laser beam is focused to a point in the keyhole mode. However, to produce the more diffuse heating pattern needed in the conduction mode, the present optical assembly focuses a CO_2-laser beam nominally to a short line (more realistically, to a soft oval) aligned either along or across the weld seam. Testing of multiple-pass laser welds made with the line-focusing optical assembly showed none of the porosity found in multiple-pass keyhole welds.

This work was done by D. Mark Shelley, Ralph J. Moores, and Lyle L. Spiegel of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 80*** *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; (205) 544-0021. Refer to MFS-29976.

Boresighting Tool for Cameras With One-Dimensional Detectors

Small collimators project target patterns that can be used to measure pointing angles.

NASA's Jet Propulsion Laboratory, Pasadena, California

A specially designed tool provides for the boresighting of nine cameras that contain one-dimensional photodetectors and that are mounted in an optical bench. The tool includes an array of nine small collimators precisely positioned and oriented in another optical bench, such that when the two optical benches are brought together on precisely machined faying surfaces, each collimator faces one of the cameras.

Each collimator contains a small, precisely aligned target with a dual-chevron pattern that is imaged onto the one-dimensional imaging detector (a linear

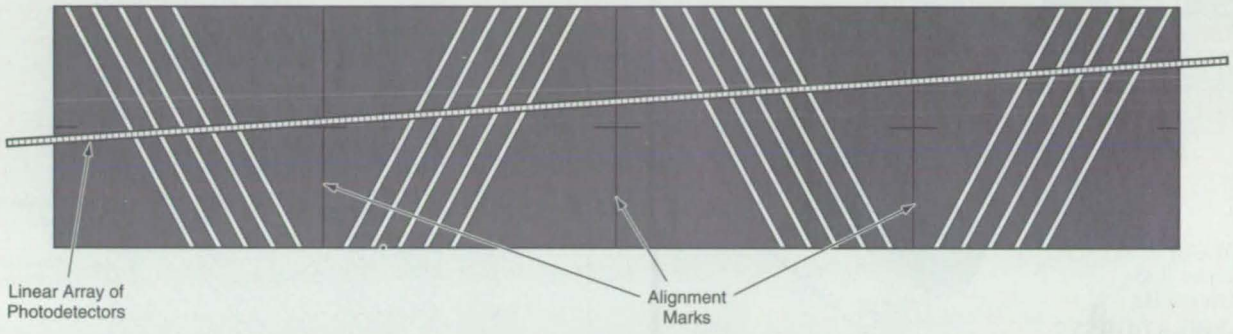


Figure 1. The **Dual-Chevron Target Pattern** projected onto the linear array of photodetectors yields data on the azimuthal, elevational, and rotational misalignment of the camera. The multiple bars are used to increase sampling and thus the accuracy.

array of photodetectors) in the facing camera (see Figure 1).

Figure 2 shows three collimator/camera pairs that produce a magnified view, like the one shown in Figure 1, of the target pattern as projected onto the focal plane of the camera. The basic idea is that data from the target image projected onto the one-dimensional imaging detector can be processed to extract three parameters (x, y, and rotation) of the orientation of the camera with respect to the collimator and target.

This work was done by Lawrence J. Steimle of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 58*** *on the TSP Request Card. NPO-19388*

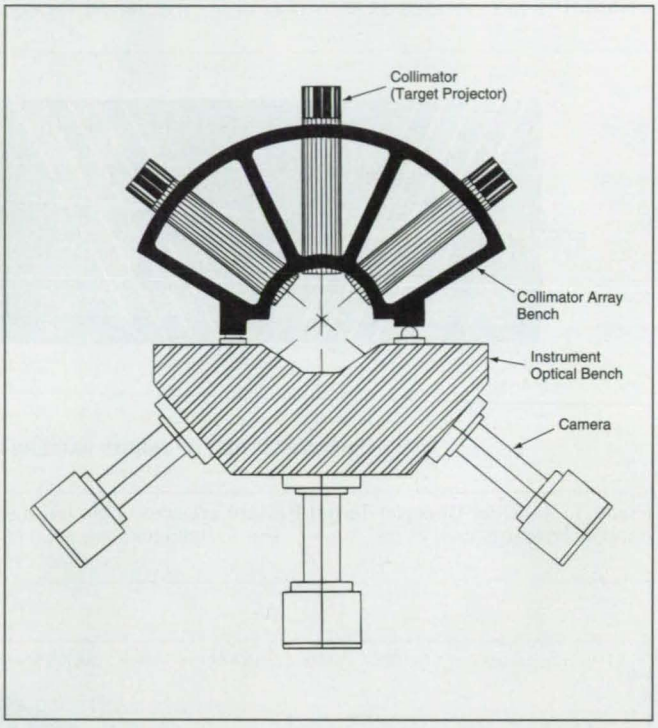


Figure 2. A **Multicamera Boresight Configuration** is shown here with three cameras.

Progress in X-Ray-Based Displacement and Strain Measurement

Lewis Research Center, Cleveland, Ohio

A recent work discusses the basic principle and the development of noncontact extensometry of objects in hot or otherwise hostile environments by use of focusing and scanning of x-rays. The method was described previously in *Laser Tech Briefs* in "X-Ray Measurements of Displacements in Hostile Environments" (LEW-15905), supplement to *NASA Tech Briefs*, Vol. 19, No. 6, (June, 1995), page 18a. Recent refinements include the development of a high-resolution scanner with a position measurement accuracy on the order of 0.1 micron. Medical applications are also being considered.

This work was done by Howard A. Canistraro, Eric H. Jordan, and Douglas M. Pease of the University of Connecticut for **Lewis Research Center.** *No further documentation is available. LEW-16001.*

Fiber-Optic-Based Compact Gas-Leak Detector and Localizer

This instrument can also be used to monitor process gases *in situ*.

Lewis Research Center, Cleveland, Ohio

A Raman-scattering instrument that includes a main housing and a fiber-optic coupling to a probe head is designed for use in real-time determination of the concentrations of gas molecules of various species in a small probe volume near the probe head. Such a determination is possible because the Raman-scattered light contains spectral information specific to each species.

The development of this instrument is significant because the ability to monitor the composition of a gas in real time is advantageous in a broad range of applications. In gas-processing plants, there is a need to monitor processes in real time. In steel-processing plants, there is a need to monitor the compositions of endothermic gases, which are critical to the qualities of the end products. The use of instant monitoring techniques to detect hazardous gas leaks will increase safety and facilitate ground operations at spacecraft-launching sites. Current monitoring techniques involve the use of chemical sensors, which are often limited to single species, respond relatively slowly, and have limited useful lifetimes under some hostile conditions. Moreover, such sensors contain point-contact transducers that must be exposed to the gases to be monitored.

The instrument is illustrated schematically in Figure 1. The main housing of the instrument contains a laser that supplies the light to be Raman-scattered; the housing also contains the sensitive equipment that detects and spectrally analyzes the Raman-scattered light. The instrumentation in the housing is connected via three optical fibers to the probe head, which can thus be located remotely — possibly in an environment too hostile to allow the presence of personnel.

The laser is of the argon-ion type and emits a green beam with a power of 0.2 W. The beam is mechanically chopped, then transmitted to the probe head via one of the optical fibers, which is chosen to be of the single-mode type to ensure good definition of the probe volume. The probe head contains a graded-index-of-refraction lens, a short-wavelength-pass filter, two dichroic mirrors, a focusing/collection lens, a fully reflecting mirror, and a refocusing lens.

The probe head collects the light scattered back by the molecules in the probe volume and couples this light into another of the optical fibers for transmission to the spectrometric instrumentation in the main housing. A lock-in amplifier in this instrumentation extracts a signal proportional to the intensity of the scattered light. Some of the laser light scattered within the probe head is coupled into the remaining optical fiber, which guides this light back to a photodiode for use as a reference to correct

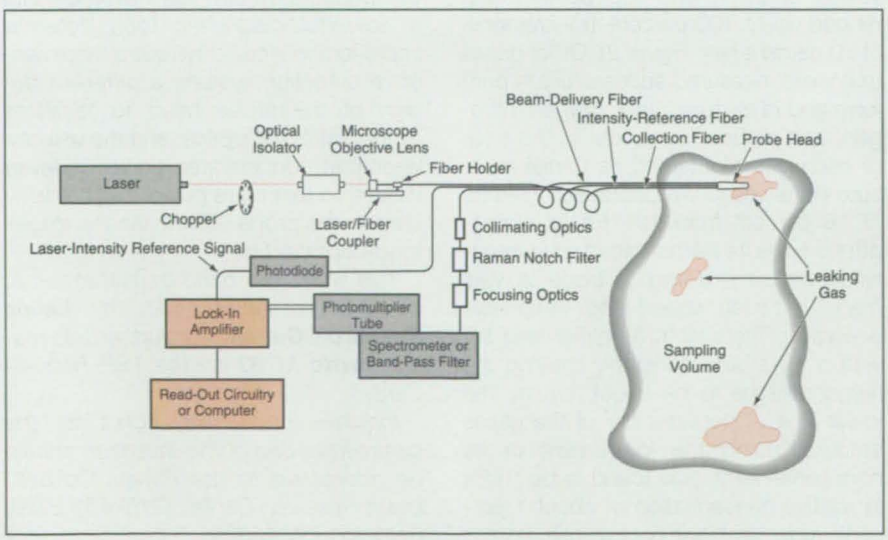


Figure 1. The **Fiber-Optic-Based Compact Gas-Leak Detector and Localizer** is a Raman-scattering instrument with a remote optical probe head connected via optical fibers to sensitive instrumentation in a main housing.

OPTICAL LIQUIDS

R. P. Cargille's Specialty Optical Liquids catalog features high-transmission, safe-handling laser liquids plus fused silica matching liquids and specific refractive-index liquids (1.300 to 2.11 n_D). The catalog now includes comparative diagrams of glasses and optical liquids. R. P. Cargille Laboratories, Inc., 55 Commerce Road, Cedar Grove, NJ 07009-1289; (201) 239-6633; (201) 239-6096.

R. P. Cargille Laboratories

For More Information Write In No. 392

CONSTANT-TEMPERATURE SOLUTIONS FOR SEMICONDUCTOR INDUSTRY

NESLAB introduces its new product catalog, featuring constant-temperature equipment designed specifically for the semiconductor industry. This catalog includes features, specifications, application tips, and customizing options available including refrigeration, controller, pump, fluid, heater, and electrical specs. For more information contact Terri Pruett, Marketing Coordinator, NESLAB Instruments, Inc., PO Box 1178, Portsmouth, NH 03802-1178; (603) 430-2251; FAX (603) 436-8411.

NESLAB Instruments Inc.

For More Information Write In No. 390

DUAL-CHANNEL LASER POWER/ ENERGY METER

Ophir Optronics Inc. introduces the new Model Laserstar Display dual-channel laser power/energy meter. The Model Laserstar Display works with all three types of detector heads (thermal, pyroelectric, and photodiode). This provides a measurement range from nanowatts to kilowatts and microjoules to joules. Upgrades to dual-channel and GPIB(ieee) are available. Measure two channels independently or ratio A/B,B/A combining different head types. For more information call 1-800-383-0814. Ophir Optronics Inc., 200 Corporate Place, #7, Peabody, MA; FAX (508) 535-5999.

Ophir Optronics Inc.

For More Information Write In No. 391

FREE CATALOG "OPTICS FOR INDUSTRY"

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For More Information Write In No. 393

for fluctuations in the intensity of the laser beam. Calibration charts enable direct readout of the concentrations of the various species.

In experiments to evaluate the instrument, measurements were performed on single and mixed gases in an enclosed vessel at ambient temperature and atmospheric total pressure. Hydrogen was mixed with other gases in various relative concentrations that started at values of 0, 1, and 2.8 percent and ranged up to 100 percent in increments of 10 percent (see Figure 2). Other gases that were measured successfully in pure form and in mixtures were oxygen, nitrogen, and carbon monoxide. In the case of each gas of interest, its partial pressure in the vessel was increased in steps of 10 percent from 10^{-7} Pa to atmospheric while its Raman-scattering intensities were monitored. A trade-off was made between speed and obtainable accuracy: The lock-in amplifier was set with a 10-s time constant, causing the response time to be about 1 min. The lower limit of detectability of the gases studied, using the instrument in its nonoptimal form, was found to be 1 kPa (a relative concentration of about 1 percent under ambient conditions).

This instrument is capable of *in situ* monitoring of many gases and opens up exciting new possibilities in many areas of leak detection. Optical fibers that endure temperatures up to 700 °C provide access to hot environments; thus, the useful temperature range of this instrument is from cryogenic to 700 °C. With the addition of a fiber-optic multiplexer, the instrument can be used to monitor gases at several locations simultaneously. Continued development in the effort to optimize the performances of components will turn this instrument into a powerful diagnostic tool. Potential improvements could include a more sensitive detection system, a different design of the probe head to facilitate alignment of the optics, and the use of a laser that concentrates power in fewer modes so that more power can be delivered to the probe volume via the single-mode optical fiber.

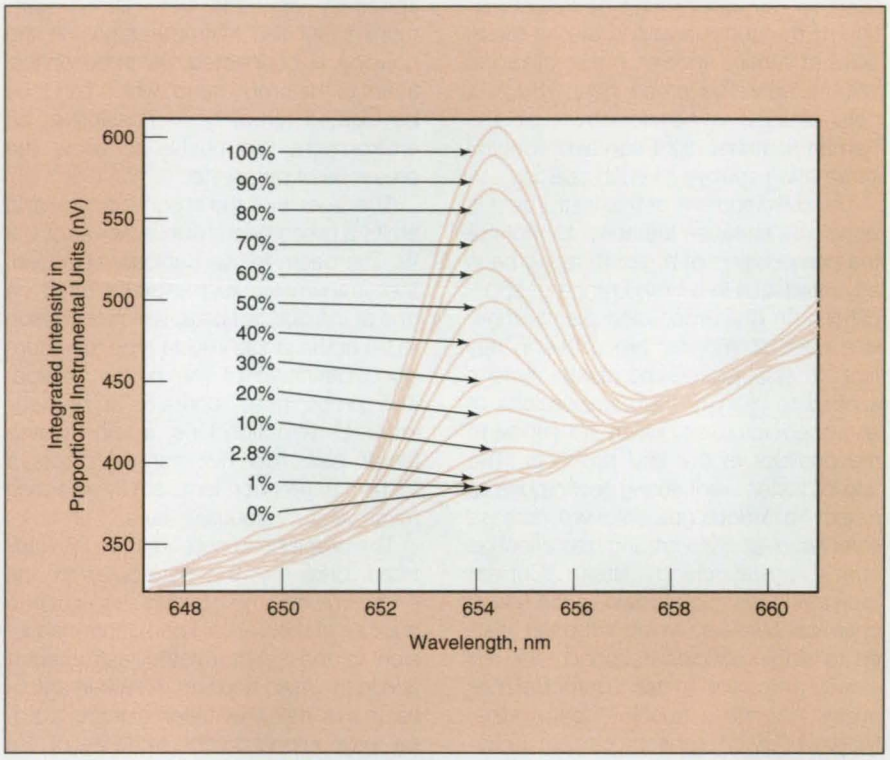


Figure 2. These **Raman Spectra** were obtained from measurements of light scattered from a gas mixture containing various percentages of hydrogen. Note that, as expected, the intensity of the hydrogen Raman spectral line increases with the proportion of hydrogen.

This work was done by Wilhelmus A. de Groot of NYMA, Inc., for **Lewis Research Center.** *For further information,* ***write in 63*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15889.

NEW PRODUCTS

Axial Gradient Index Material

LightPath Technologies Inc., Albuquerque, NM, offers Gradium™ glass, a new gradient index material whose index of refraction varies along the optical axis. When spherical radii are applied to Gradium blanks, the resulting lenses behave as aspherics, eliminating spherical aberration; with proper lens shape factor, coma is reduced. The company can supply blanks with diameters in excess of 2.5 in. with index changes of 0.15. Plano-convex lenses and cemented achromatic doublets can also be supplied. LightPath is also licensing uses of Gradium glass.

For More Information Write In No. 800

Fiber Optic Light Source

The 150-W DCR II fiber optic light source from Fostec Inc., Auburn, NY, is a compact, rugged unit switch-selectable for both 120 and 230 V. It has a rheostat for variable light intensity and a 9-pin connector for remote intensity control via an analog input. Light output is stable within 1 percent. An iris diaphragm version is available. The unit is CSA/UL approved and CE compliant, and comes with a 2-year warranty.

For More Information Write In No. 801

Compact Excimer Laser

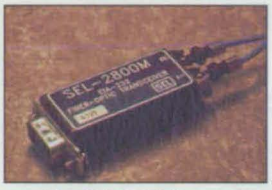
The Model MSX-250 is the newest addition to the line of ArF/KrF excimer lasers from MPB Technologies Inc., Pointe Claire, PC, Canada. The laser offers pulse energies up to 55 mJ and average powers to 2 W (248 nm) from a compact unit with a footprint of 18 X 10 in. It features all-metal-ceramic construction and what the company calls maintenance-free preionization and gas circulation schemes. A modular design concept is intended to facilitate scheduled maintenance in heavy-usage industrial applications. The thyratron carries a warranty of 2 years or 3×10^8 pulses, whichever comes first.

For More Information Write In No. 802

Protective Eyewear for Laser Alignment

Uvex Safety Inc., Smithfield, RI, introduces two new spectacle-style laser alignment models to its DVO® (Diffuse Viewing Only) family of protective eyewear. The DVO LOTG-Argon, designed for diffuse viewing of CW argon lasers (450-514 nm) up to 1 W, and LOTG-HeNe, for HeNe lasers (633 nm) up to 10 mW, allow wearers to see beam termination points and thus keep their eyewear on during laser adjustment procedures and R&D operations. The lenses have the patented *uvex 4C+*® antifog, antistatic, antiscratch, and anti-UV coating.

For More Information Write In No. 803



Rugged Fiber Optic Transceiver

Schweitzer Engineering Laboratories (SEL), Pullman, WA, developed the SEL-2800 fiber optic transceiver specifically to provide electrically isolated noise-free EIA-232 communications over distances up to 500 m in harsh physical and RFI/EMI environments. The SEL-2800 connects directly to a 9-pin serial port, draws its power from it, and transmits at the port's baud rate up to 40kbaud. The transceiver is designed to work with the V-System fiber optic cable assembly from Spectran Specialty Optics.

For More Information Write In No. 804

Ultrasensitive Thermal Detector

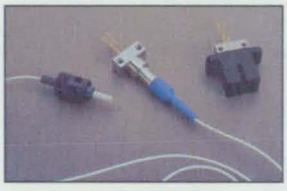
Available from Ophir Optronics Inc., Peabody, MA, is the Model 2A thermal detector. With a flat spectral response of 0.19-12 µm, it can measure from 50 µW to 2 W of average power as well as single pulses of energy from 10s of µJ up to 2 J. The Model 2A comes with a removable light tube that can be combined with interchangeable filters and/or quartz windows to minimize thermal background. It is compatible with Ophir Models Nova, AN-2, and the new LaserStar displays.

For More Information Write In No. 805

Circular Geometry Gauge

Precitech Inc., Keene, NH, says that low cost is a leading feature of its FMS 8150 large-capacity circular geometry gauge for the lab or shop floor. The unit accommodates workpieces up to 16 in. in diameter and 17 in. high, and weights to 200 lb. The 6-in. air-bearing spindle has an accuracy of ±0.02 µm, and the digital servo drive has standard 6- and 10-rpm speeds. The spindle accepts an optional 6-in.- or 8-in.-diameter tilt/centering worktable. The instrument can measure out-of-roundness, eccentricity, flatness, perpendicularity, and more.

For More Information Write In No. 806



Visible and Infrared Laser Diodes

A new line of visible and infrared laser diodes available from Fiberoptic Alignment Solutions, Batavia, IL, requires very low operating current and has a capacity of up to 2 mW of coupled power. Available wavelengths are 635, 650, 670, 780, 850, 1310, and 1550 nm. Operating temperature is between -10 °C and +40 °C. Custom and standard designs are available in pigtailed and connectorized versions. Applications include test and measurement, medical equipment, data communications and video, and as visual fault finders, the company says.

For More Information Write In No. 807

Laser Micromachining with Three Wavelengths

New Wave Research Inc., Sunnyvale, CA, says that its QuikLaze™ Nd:YAG-based laser micromachining system is the only one that offers three different wavelengths in a single unit. In semiconductor applications, the green wavelength (532 nm) removes silicon dioxide from metal lines and cuts them; the ultraviolet (355 nm) removes nitride or polyimide; and the infrared (1064 nm) cuts metal lines with less risk of damage to silicon or GaAs than the green. Energy range is 0.4-0.6 mJ depending on wavelength.

For More Information Write In No. 808

Automated Computerized Spherometer

The Opti-Pro CURV (Computerized Universal Radius Verifier) from CNC Systems Inc., Ontario, NY, is an automatic spherometer based on a three-ball contacting technique and PC-compatible software. The company says it is easily calibrated using a plano test plate and any known sphere or test plate. Printout of the information screen provides a QC report that can be dated, part- and lot-numbered to meet ISO 9000 standards. Applications include radius-of-curvature inspection for concave and convex optical components, spheres, and balls. Basic price is $8995.

For More Information Write In No. 809

Laser Optic Strain Sensor

The Cooke Corp., Tonawanda, NY, offers a laser optic strain sensor based on laser speckle interferometry. It can do full-field deformation and strain measurement in the longitudinal direction on areas of approximately 30 X 40 mm. Using IR laser light and a video camera, measurements are noncontact and reference marks are not required. The device can measure all nonreflecting surfaces such as metals, elastomers, plastics, ceramics, concrete, wood, rubber-to-metal connections, etc.

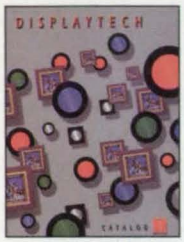
For More Information Write In No. 810

ZnSe Lenses for High-Power CO2 Lasers

Laser Research Optics, Providence, RI, introduces a line of low-absorption zinc selenide lenses in eight standard diameters (0.5-3.0 in.) and a range of focal lengths for high-power carbon dioxide lasers. With typical total absorption of <0.3 percent, the lenses have antireflective coatings on both sides. Offered in plano-convex and meniscus shapes, the lenses are suited for medical laser and industrial cutting applications where depth of field is important, the company says.

For More Information Write In No. 811

NEW LITERATURE



Ferroelectric Liquid Crystal Display Products

Displaytech Inc., Boulder, CO, has compiled a 38-page full-color catalog that includes descriptions and specifications on all of its ferroelectric liquid crystal-related products. They include integrated-circuit spatial light modulators (SLMs), shutters, polarization rotators, red-green-blue FASTfilter switchable color filters, and video shutters for CCD cameras. Among new products featured are the ChronoColor™ miniature displays that measure less than 1/2 in. diagonally, and a spatial light modulator system for optical correlation.

For More Information Write In No. 815

Compact Modular Laser Rangefinders

The 6-page full-color brochure published by ALST, Orlando, FL, details its line of compact, modular eyesafe and non-eyesafe laser rangefinders. It describes ALST's Nd:YAG and erbium glass-based technologies, and gives range estimates and intended applications for the systems. Detection graphs indicate the rangefinders' performance under various visibility conditions. The brochure also contains specifications for the entire line.

For More Information Write In No. 816

Precision Off-the-Shelf Optics

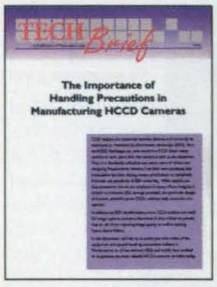
The 1996-1997 Optics and Optical Instruments Catalog from Edmund Scientific, Barrington, NJ, features the expanded lines of precision off-the-shelf optics and TechSpec™ Optic matrices for design, prototype, and production. The catalog includes more than 8000 optical and scientific products, among them lasers, optics, positioning equipment, fiber optics, video microscopy systems, microscopes, telescopes, magnifiers, machine vision, lab equipment, and accessories. Edmund can manufacture precision parabolic, spherical, and plano mirrors in many shapes and substrates.

For More Information Write In No. 817

Lasers for Science and Industry

A 30-page full-color "1996 Scientific and Industrial Product Catalog" from Spectra-Physics Lasers, Mountain View, CA, supplies descriptions, applications information, and features for the company's lasers, components, and accessories. These include water- and air-cooled ion and gas lasers, tunable CW and ultrashort-pulsed lasers, ultrashort amplifier systems, the tunable pulsed optical parametric oscillator, Nd:YAG lasers, and diode-pumped lasers. Custom optical components and thin-film coatings can be produced; accessories include interferometers, polarization rotators, and mounts.

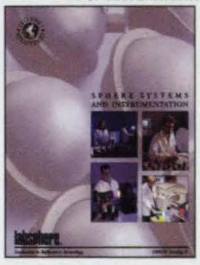
For More Information Write In No. 818



Technical Note on CCD Manufacture

Photometrics Ltd., Tucson, AZ, has produced a technical brief outlining the importance of precautionary procedures in the manufacture of charge-coupled device (CCD) cameras. The 4-page document describes the company's 624-sq.-ft. clean room, equipped with four laminar-flow hoods to provide Class 100 clean areas for CCD handling. Temperature and humidity levels are also controlled, reducing the likelihood of electrostatic discharges that can result in CCD failure.

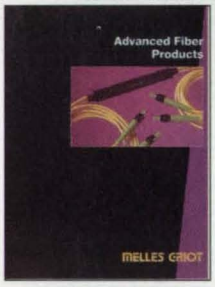
For More Information Write In No. 819



Integrating Spheres and Instrumentation

A new 120-page publication, "1996/97 Sphere Systems and Instrumentation Catalog," from Labsphere Inc., North Sutton, NH, focuses on the company's complete line of integrating sphere systems and sphere controls, light sources, and detectors. The catalog contains product specifications, applications, and technical information for sphere systems for lamp measurement, light-source calibration, laser power measurement, and reflectance/transmittance measurement. A 16-page technical section concludes the catalog.

For More Information Write In No. 820



Fiber Optics for Advanced Transmission Systems

Melles Griot, Irvine, CA, has put together a 10-page full-color brochure about its line of "Advanced Fiber Optics." Among them are wavelength-division multiplexers, optical amplification systems, optical isolators and circulators, reflective fiber gratings, single-mode optical couplers, high-numerical-aperture silica fibers, and 980-nm pump fiber pigtails. The brochure has a pocket for data sheets with more detail on the individual products.

For More Information Write In No. 821

Video Solutions for Science and Industry

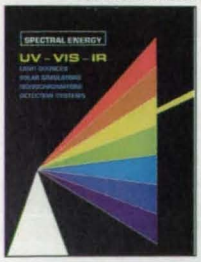
Cohu Inc. Electronics Division, San Diego, CA, offers an 8-page full-color 1996-97 product catalog, "Advanced Video Solutions for Science and Industry." It contains descriptions and specifications for the company's lines of monochrome interline-transfer and high-performance color CCD cameras, digital output CCD cameras, monochrome frame-transfer CCD cameras, digital signal processing color cameras, and high-performance monochrome and color interline-transfer CCD cameras. Featured is the new 6600 series monochrome progressive-scan CCD camera.

For More Information Write In No. 822

On-Site Vacuum Technology Training

MKS Instruments, Andover, MA, has released a new guide to its on-site training capabilities. The full-color brochure outlines standard course offerings such as "Introduction to the Creation and Control of the Vacuum Process Environment," "Introduction to Vacuum Gauging Techniques," and "Introduction to Thermal Mass Flow Controllers." MKS training programs are tailored to each company's needs, using modules of technical information, demonstration equipment, and hands-on activities for problem-solving and troubleshooting.

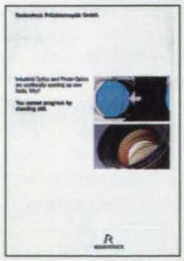
For More Information Write In No. 823



Light Generation, Dispersion, Detection

A 67-page catalog from Spectral Energy, Westwood, NJ, sets out particulars of its modular UV-VIS-near-IR light systems, comprising arc lamps, housings, power supplies, solar simulators, monochromators, photometers, and monochromatic photodetection devices. The booklet has sections on technical considerations relating to illumination systems and grating monochromators, arc lamp specification and selection tables, a monochromator selection guide, and product descriptions, including the new FM-1 filter monochromator.

For More Information Write In No. 824



Precision Optics and Components

Rodenstock Precision Optics, Rockford, IL, has issued a 16-page full-color brochure encompassing its laser, photographic, and x-ray lenses and components. Lenses include CCD, collimating/focusing, copying, enlarging/reducing, f-theta, graphic arts, image scanning/transfer, machine vision, and more. Components include beamsplitters, domes, mirrors, prisms, reticles, and windows. The brochure also describes the company's design, assembly, inspection, and testing methods.

For More Information Write In No. 825

Electronically Tunable Optical Filters

From Queensgate Instruments, East Meadow, NY, comes literature describing the QF and MF series of MicroFilters™. These electronically tunable fiber-pigtailed Fabry Perot filters are for the 1300- and 1550-nm communications bands. The QF series is designed for wavelength division multiplexing and fiber test instrumentation, where precise wavelength tuning is required. It uses capacitance micrometry for servo-stabilization of the transmitted wavelength. The MF series, designed for wavelength selection and filtering, operates from a ±15-V power supply.

For More Information Write In No. 826

Computer Programs

COSMIC: Transferring NASA Software

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

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, send in the Information Request Form or contact COSMIC directly.

If you don't find a program in this issue that meets your needs, visit the COSMIC World Wide Web pages to browse the catalog for programs in your area of interest. The COSMIC Software Catalog is available in print and free of charge on diskette, on-line, by E-mail, or FTP.

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Mathematics and Information Sciences

RULER 2.0: Optimizing Rules From Decision Trees

RULER 2.0 is an updated version of the RULER computer program, which generates classification rules in a process that includes iterative generation of multiple decision trees by multiple random sampling of subsets of a set of training data. The basic idea is that a decision tree contains a few good rules plus many weak rules attributable to random correlations that occur due to rapid partitioning of the data, and therefore the "best" rules out of a large family of trees are selected. RULER uses TreeMaker (see the next article) as a rule generator; it can also accept rules from other sources, including human authors. RULER 2.0 implements various decision-tree algorithms available in TreeMaker, then combines the rules from each decision tree to form a set of rules and conditions. Statistical tests of relevance are used to prune out the less relevant rules and conditions. A greedy minimal-covering algorithm is used to select a subset of the rules that cover the training data. The result is an accurate set of classification rules, typically more compact and robust than the set of rules generated by any single-tree algorithm. RULER can be used in either of two modes; a UNIX-command-line mode (convenient for scripts) and an interactive mode, which provides a text-based (ASCII) menu interface for compatibility with a variety of platforms and terminals. A graphical X-Window interface is available for Sun workstations under a separate release called X-CLASS (see the following article). RULER is applicable to many problems in diagnosis, automated control, and recognition of events and objects. It has already been applied successfully in astronomy, in science data analysis, and in industrial manufacturing settings.

This work was done by Usama M. Fayyad of Caltech for NASA's **Jet Propulsion Laboratory**. *For further information,* ***write in 21*** *on the TSP Request Card. NPO-19552*

TreeMaker 4.0

TreeMaker 4.0 is an updated version of the TreeMaker computer program, which helps the user to produce decision-tree classifiers from training data. Data are assumed to be in feature-vector format. Each feature (attribute) can be either continuous or discrete (categorical). The class variable must be categorical. TreeMaker includes modified versions of the commercially available ID3 and C4.5 algorithms and offers capabilities beyond those of the commercial versions. The GID3* algorithm in TreeMaker dynamically decides the values of a chosen attribute from which to branch, rather than branching on all values, and thereby avoiding overbranching. The O-Btree algorithm in TreeMaker uses a new family of selection measures instead of the impurity (e.g., entropy) measures in ID3. Another algorithm in TreeMaker implements multiinterval discretization of continuous-valued attributes rather than the binary discretization in ID3 and C4.5. TreeMaker is also capable of handling undefined values in attributes. TreeMaker can be used in either of two modes; a UNIX-command-line mode (convenient for scripts) and an interactive mode, which provides a text-based (ASCII) menu interface for compatibility with a variety of terminals. A version of TreeMaker with a graphical X-Windows interface, including tree-drawing and analysis software tools is available for Sun workstations under a separate release (see the next article). TreeMaker is applicable to many problems in diagnosis, automated control, and recognition of events and objects. It has already been applied successfully in astronomy, in science data analysis, and in industrial manufacturing settings.

This work was done by Usama M. Fayyad of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 22*** *on the TSP Request Card. NPO-19551*

XClass

The XClass computer program enables the user to produce decision trees and classification rules from training data, using an X Window system graphical user interface to the TreeMaker and RULER programs (see the two preceding articles). XClass conforms to the OPEN LOOK standard for graphical user interfaces. XClass offers several conveniences, including simultaneous use of both TreeMaker and RULER, popup and pinnable windows, and a logging facility for tracing and recording classifier building, modification, and classification operations. XClass also includes graphics for drawing trees and interactively influencing tree induction. XClass input data are assumed to be in feature-vector format. Each feature (attribute) can be either continuous or discrete (categorical). The class variable must be categorical. XClass is also capable of handling undefined values in attributes. XClass provides access to the various decision-tree algorithms available in TreeMaker, and to the rule set-induction algorithms in RULER. These algorithms produce accurate sets of classification rules, typically more compact and robust than the sets of rules generated by any single-tree algorithm.

This work was done by Usama M. Fayyad of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 23*** *on the TSP Request Card. NPO-19550*

Vibration-Damping Control via Extended-Horizon Liftings

Control gains are adjusted in a periodic manner.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of active suppression of vibrations in a flexible structure is particularly well-suited to a structure in which vibration sensors and vibration actuators are not necessarily collocated. The method involves periodic adjustment of gains in a control subsystem as a way of modulating control energy to higher frequencies and making the harmonics add in such a way that the system (comprising the structure, sensors, actuators, and control subsystem) appears to be of minimum phase. The advantage of this approach is that the system can be controlled more effectively when minimum-phase. The underlying mathematical concepts can also be applied to enable stable real-time equalization of communication channels.

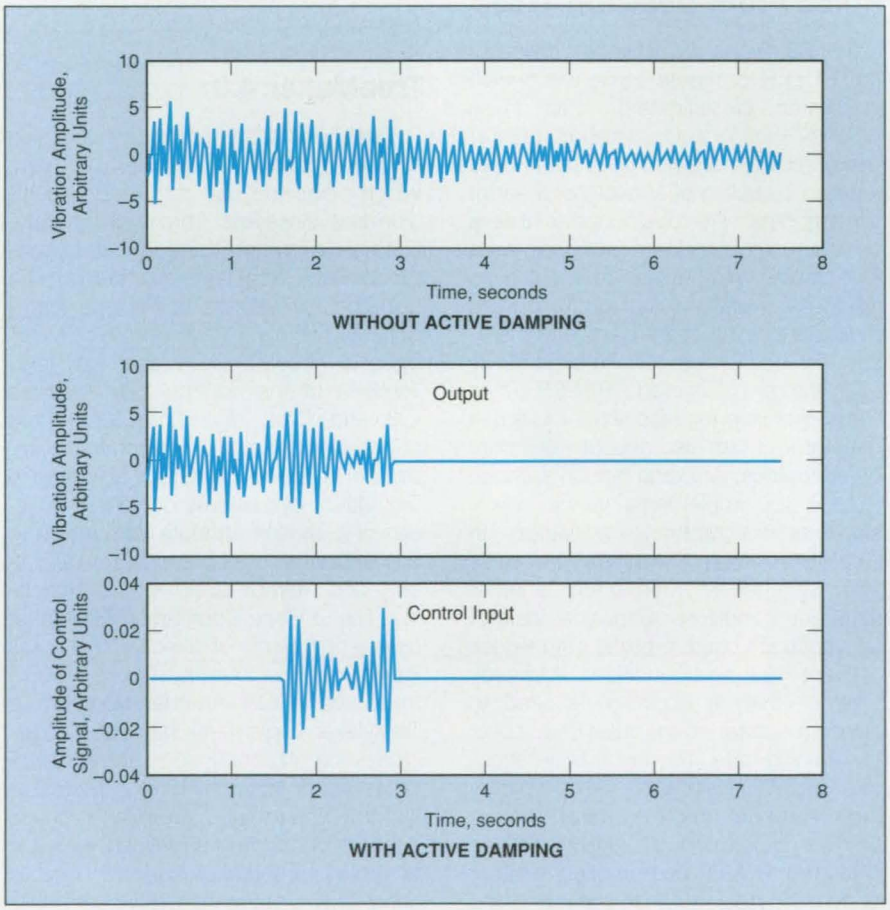
A non-minimum-phase system arises when one attempts to dampen vibrations on a flexible structure by sensing vibrations at one or more locations remote from the actuator(s) (i.e., a non-collocated source). Non-minimum-phase systems also arise in connection with efforts to control such diverse processes and equipment as aircraft, spacecraft, aiming instruments to track moving objects, flexible robots, chemical processes, acoustical systems, communication systems, compact-disk drives, and floppy-disk drives.

Non-minimum-phase systems are difficult to control, and generally require the use of low-bandwidth sluggish controllers. The present method of control makes a system act as though it were of minimum phase; that is, it makes the system move in the direction in which it is pushed. In so doing, this method enables the use of standard high-performance minimum-phase control designs.

The theoretical basis of the present method is a mathematical specialty called "extended-horizon liftings." As used here, "liftings" and "horizon" have special meanings, as explained below. A paper by R. Lozano published in 1989 presented a multirate-sampling method that enables stable inversion of the dynamical equations of any linear, time-invariant, finite-order plant, regardless of whether the plant (in this case, a structure equipped with actuators and sensors) is of minimum phase or nonminimum phase. The general approach in that method is based on a mathematical "lifting" in which a serial-to-parallel conversion is performed on the plant input and output signals, the converted signals are vectorized, and mappings between the vectorized quantities are considered.

The key property of Lozano's lifting that makes it so useful is that the transmission zeros of the transfer function of the lifted plant are annihilated (i.e., placed at the origin of the complex-frequency plane). This zero-annihilation property makes possible the stable (from the perspective of control) inversion, using standard control methods, of the dynamical equations of the lifted plant. This lifting has also been applied to developing stable adaptive control algorithms for non-minimum-phase systems.

"Horizon" as used here denotes the limits of the sampling period and thus the number of time samples and the corresponding dimensionality of the lifting. The horizon in Lozano's lifting is of size $2n$, where n is the plant order (the order of the dynamical equations of the plant). The mathematical derivation of the present method involves generalization of Lozano's $2n$ lifting and showing this lifting to be one in a large class of liftings that exhibit the zero-annihilation property. The



With **Active Damping** by a control system designed according to the method of extended-horizon liftings, the vibrations are damped instantaneously after the first horizon.

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Controlled-Shape Multicell Inflatable Structures

Pressures in individual cells would be controlled to control overall shapes.

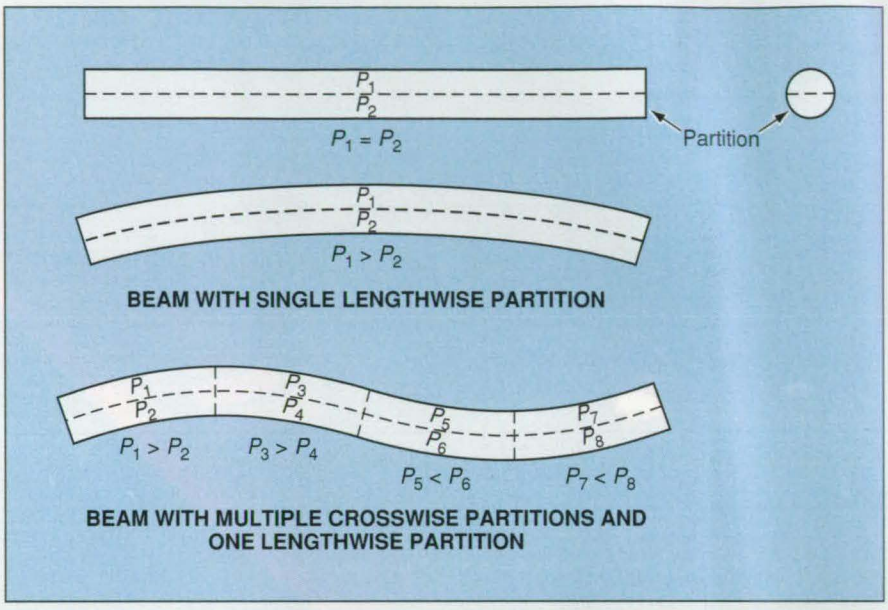
NASA's Jet Propulsion Laboratory, Pasadena, California

Inflatable structures of a proposed type would contain multiple cells, each of which could be inflated individually to a controlled pressure. For example, a lightweight, compactly storable reflector for a microwave antenna or a solar-energy receiver could be constructed as an inflatable structure and the pressures in the cells could be adjusted to maintain the required curvatures of the reflector surface.

Inflatable structures containing multiple, individually inflatable cells have been in commercial use for many years. For example, multiple cells in blimps and inflatable boats provide redundancy to preserve flotation and some structural rigidity in the event of leakage from one or a few cells. The multiplicity of cells would also afford such protective redundancy in the proposed structures. However, the primary reason for using multiple cells in the proposed structures would be to provide for systematic control of pressures in individual cells to control overall shapes.

The figure presents examples of simple inflatable tubular beams partitioned and differentially inflated to control shape. In the beam containing a single lengthwise partition, inflation of the top cell to a pressure greater than that of the bottom cell would make the beam concave as viewed from below. In the multiple-segment beam, more complicated shapes with multiple bends could be obtained by similar differential inflation of top and bottom cells in the various segments.

This work was done by Henry P. Diaz and Gun-Shing Chen of Caltech for **NASA's Jet Propulsion Laboratory**.



The **Shapes of Partitioned Inflatable Beams** could be controlled by differential inflation of the cells.

For further information, ***write in 39*** *on the TSP Request Card.*

NPO-19432

Ultrasonic High-Resolution Profilometry

This technique can be used as a rapid, nondestructive alternative to diamond-tip profilometry.

Lewis Research Center, Cleveland, Ohio

Ultrasonic high-resolution profilometry is a technique for scanning a plate specimen to map variations in its thickness or surface height. In its scanning aspect, ultrasonic high-resolution profilometry resembles diamond-tip profilometry, in which a diamond-tipped probe is scanned across a specimen surface while pressed against the surface with a prescribed small force. However, ultrasonic high-resolution profilometry offers two important advantages: (1) In diamond-tip profilometry, the dragging of the probe can alter the surface, but in ultrasonic high-resolution profilometry, the surface remains unchanged because there is no contact between it and the ultrasonic probe, and (2) it takes much less time to perform an ultrasonic scan than to map a surface by diamond-tip profilometry.

Ultrasonic high-resolution profilometry can be implemented with a conventional laboratory scanning ultrasonic apparatus that includes a tank containing a liquid (usually water) that serves as a coupling medium, a probe containing a focusing ultrasonic transducer mounted on a translation stage above the liquid, and electronic equipment for generating and processing ultrasonic signals. The specimen surface opposite the surface to be mapped should be flat. A supporting plate that has flat, parallel surfaces and that is somewhat larger than the specimen is placed on the floor of the tank. The specimen is laid with its flat surface down on the supporting plate. The coupling end of the ultrasonic probe is immersed in the liquid and, by use of the translation stage, is scanned in a horizontal plane above the specimen and the supporting plate (see figure).

For each horizontal position (x,y) of the ultrasonic probe, the signal-processing equipment is used to measure the time between transducer input and output electronic pulses. The output pulses selected are those resulting from the first reflections of pulses of ultrasound back toward the transducer. The vertical distance $d(x,y)$ between the probe and the specimen or supporting-plate surface below the probe is then calculated straightforwardly from

$$d(x,y) = \tfrac{1}{2}vt(x,y),$$

where v is the speed of sound in the liquid and $t(x,y)$ is the time taken by an ultrasonic pulse to make one round trip between the ultrasonic probe and the surface at

that position. Then the local thickness of the specimen can be calculated from

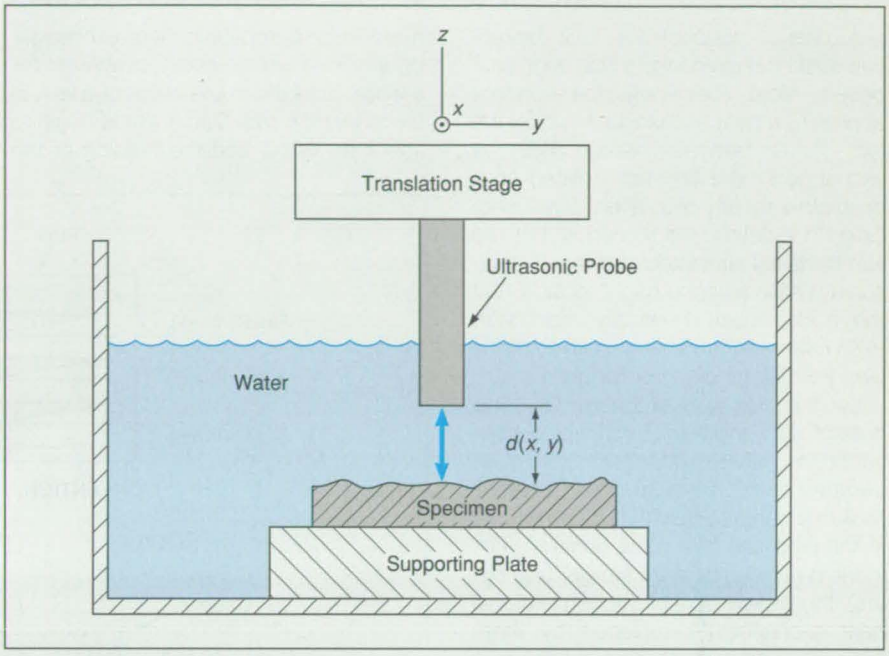
$$d(x,y) = \tfrac{1}{2}v[t0 - t(x,y)],$$

where t_0 is the round-trip travel time between the transducer and the supporting plate.

If the liquid in the tank is water, then the temperature of the liquid should be measured because the speed of sound in water depends upon temperature. The achievable horizontal resolution and vertical (thickness) resolution depend on the focal length, focal-spot size, and transducer frequency, which are related to each other in known ways. A typical transducer center frequency of 100 MHz and focal length of 0.5 in. (12.7 mm) produces a focal spot 25 to 50 μm wide, and measurements made with this transducer should yield thickness data with a resolution as fine as 7 μm if time-of-flight data are obtained with a 1-GHz analog-to-digital sampling rate and data are resolved using 8 bits. Such time-of-flight data are obtainable with a commercial ultrasonic scanning system. If a 16-bit resolution is employed, thickness and surface-depression resolutions can be significantly increased.

This work was done by Don J. Roth of **Lewis Research Center**. *For further information,* ***write in 27*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16228.



The **Ultrasonic Probe Is Scanned** across the specimen surface from above, without touching. The surface height and/or thickness of the specimen is calculated from ultrasonic-pulse round-trip travel times.

Fault-Tolerant Heat Exchanger

This heat exchanger could continue to function with two leaks.

Marshall Space Flight Center, Alabama

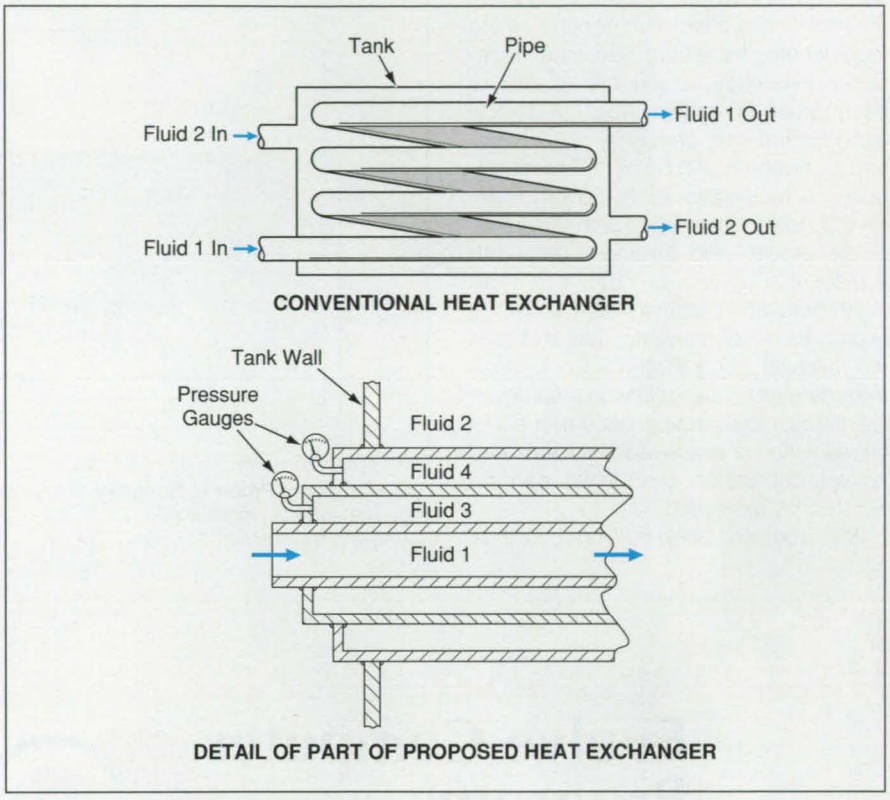
A design concept for fault-tolerant two-fluid heat exchangers has been proposed. More specifically, the concept applies to a heat exchanger in which the two fluids between which heat is exchanged must be kept isolated from each other for any of a variety of reasons. Often in practice, the reason is that the two fluids are circulated at different pressures. Other reasons might include that the fluids could chemically react with each other and/or either or both fluid(s) is (are) toxic alone or in combination.

Let the two heat-exchange fluids be called fluid 1 and fluid 2. In a typical conventional heat exchanger, fluid 1 is pumped through a pipe coiled inside a tank that contains fluid 2. If a leak occurs in the pipe, the two fluids begin to mix. In the proposed heat exchanger (see figure), the simple pipe of the conventional heat exchanger is replaced by three concentric pipes, with fluid 1 flowing in the inner pipe and two other fluids (fluids 3 and 4, which could be identical) in the two surrounding pipes.

The fluids 3 and 4 would be required to exhibit high effective thermal conductivity and to be chemically compatible with fluids 1 and 2. They could be liquids or gases at high pressure and could be circulated or not circulated, depending on specific design requirements. To enhance the transfer of heat, the gaps between the pipe walls could also be partly filled with metal vanes, metal rods, high-conductivity fibers, or high-conductivity porous material.

The pressures of fluids 3 and 4 would be monitored, and in normal operation, these pressures would be maintained greater than those of fluids 1 and 2. Thus, in the event of a leak in the outer pipe wall, fluid 4 would begin to flow into fluid 2, and the leak could be detected via a decrease in the reading of the fluid-4 pressure gauge. Because fluids 2 and 4 would be compatible, heat-exchanger operation could be safely continued for a while. Similarly, in the event of a leak in the inner pipe wall, fluid 3 would begin to flow into fluid 1 and the reading of the fluid-3 pressure gauge would decrease.

A leak in the middle pipe wall would result in mixing of fluids 3 and 4, and could be detected if the set pressures of fluids 3 and 4 were different. In this event, the heat exchanger could continue in operation indefinitely because there would still be no leakage path between fluids 1 and 2. Thus, overall the proposed heat exchanger would provide indications of leaks and would be capable of operating, at least temporarily, with leaks in any two of the three concentric pipe walls.



Three Concentric Pipes and Two Pressure Gauges would add some complexity to a heat exchanger, but would provide the ability to detect leaks and to continue operation for a while in the presence of leaks.

This work was done by Jon Brett Holladay of **Marshall Space Flight Center**. *For further information,* ***write in 13*** *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; (205) 544-0021. Refer to MFS-31111.

Tetrahedral Lander Would Protect Against Impact

The proposed lander would be used instead of a parachute.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed free-fall landing device called a "tetrahedral lander" would retard the descent of a person or object and cushion the impact with the Earth. Unlike in the case of a parachute, the person or object would not be suspended vulnerably below the tetrahedral lander during descent; instead, the tetrahedral lander would surround the person or object to protect it: a landing in a forested or rocky area would thereby be made safer. Moreover, unlike in the case of a parachute, there would be no ropes or cables to become tangled. Tetrahedral landers could be used for

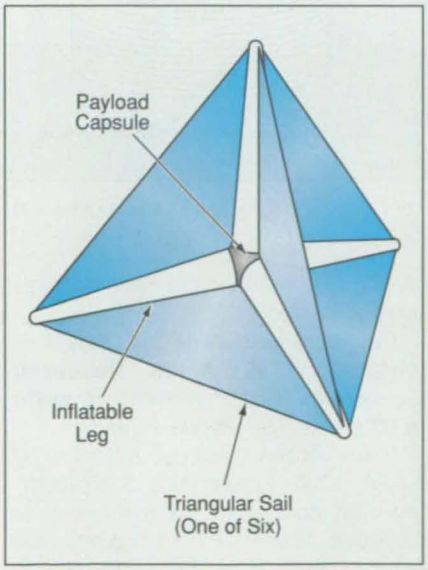
such tasks as dropping emergency supplies, landing firefighters or soldiers, and helping space vehicles return to Earth.

A tetrahedral lander would typically consist of a central payload capsule to hold the person or object, four inflatable legs in a tetrahedral configuration, and six triangular sails stretched between the four legs (see figure). Once the lander was in free fall, the legs would be inflated, deploying the sails between them. The aerodynamic drag of the sails would slow the descent. The legs would absorb the impact on the ground or body of water, and the lander would eventually come to rest on three of its legs. For additional absorption of impact, the edges of the sails could be equipped with dampers or deforming elements.

After landing, the fourth leg would stick up in the air. With three brightly colored sails attached, it should be visible to a recovery party. The sails could also be aluminized to make them radar-reflective. To keep the payload from tumbling about during descent, the payload could be held in a hemispherical cup that would rest on bearings inside the payload capsule.

This work was done by Michael Roberts of **Johnson Space Center**. *For further information,* ***write in 81*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,265,829). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22082.



Sails Would Be Stretched between legs of the tetrahedral lander. The person or payload would ride in the payload capsule at the center of the lander.

Device for Leg Exercise in Low or Normal Gravitation

This device is lightweight and collapsible.

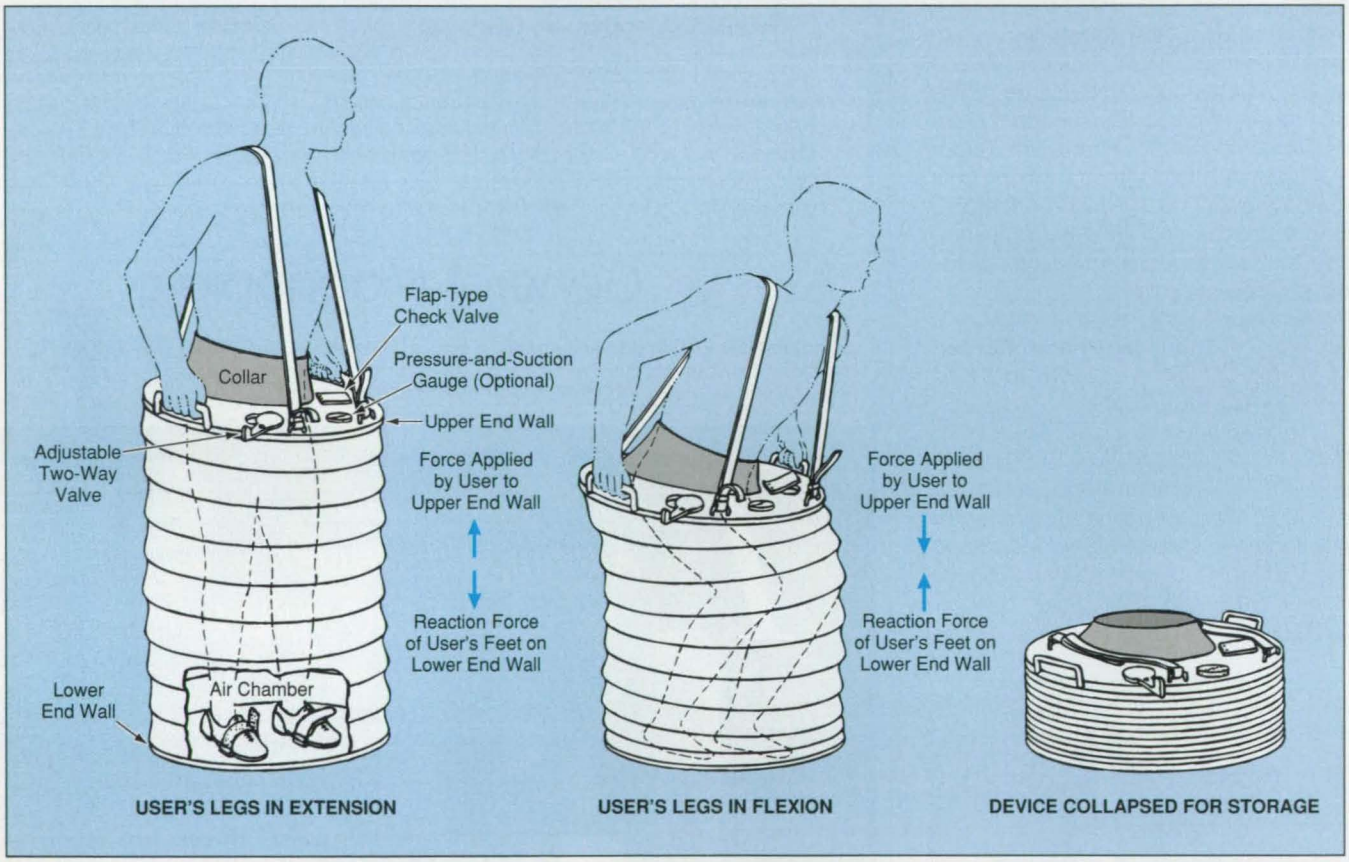
Ames Research Center, Moffett Field, California

A device provides for exercise with adjustable resistance and oscillating lower-body negative pressure. It exercises large antigravity muscle groups in the legs and back, in a manner similar to that of a standing leg press. It is also safe, inasmuch as the workload is controlled and limited entirely by the user. The device can be transported, stored, and set up easily because it is lightweight and collapsible.

The device was designed primarily for use in zero or reduced gravitation, where the oscillating lower-body suction approximates the oscillating pressure gradients experienced during leg exercise in an upright orientation in normal gravitation and thereby helps to stimulate the flow of blood in the working muscles. The device can also be used in normal gravitation and may prove useful for bedridden patients who must exercise while supine; indeed, experiments in which the utility of the device was demonstrated were performed with subjects supine to approximate the effects of zero gravitation.

Worn around the user's waist and lower body, the device consists largely of a bellowslike tube of rubberized canvas or other suitable material, reinforced with a wire helix (see figure). A flat circular wall at the upper end of the tube contains a large hole to accommodate the user. An elastic collar around this hole seals the upper end wall to the user's waist. The user can grasp handles on the upper end wall and/or can be attached to the upper end wall by shoulder straps. Another flat circular wall at the lower end of the tube includes straps for the user's feet on its interior surface.

The space surrounded by the tube and the end walls constitutes an air chamber. An adjustable two-way valve and a simple flap-type check valve are mounted in the upper end wall. Together, these valves allow air to flow out of the air chamber with relatively little resistance during flexion of the legs, thus simulating the relative ease of the down stroke in upright knee-bend exercise in normal gravitation. However, the flap closes on extension, so that the air is forced to flow into the chamber through the two-way valve. This valve is adjusted so that the resistance to inflow and the resulting suction in the air chamber provide sufficient resistance force on the upper end wall to simulate the greater difficulty of the up stroke in upright knee-bend exercise in normal gravitation. Optionally, the check-valve hole in the upper end wall can be omitted, so that the adjustable two-way valve offers resistance to flexion as well as to extension.



The **Air Chamber is Shortened and Lengthened** by flexion and extension, respectively, of the user's legs. The resistance force is governed by the valves on the upper end wall.

This work was done by Donald E. Watenpaugh at **Ames Research Center**. *For further information,* ***write in 87*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,356,361). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13380.

Multiple Fluidic Devices Provide Flow-Mixing Control

These phasing arrangements demonstrate the integration of fluidic devices.

Lewis Research Center, Cleveland, Ohio

Figure 1 illustrates an experimental fluidic oscillator of the general type known as "flip-flop nozzles." Although flip-flop nozzles have been known since the 1970s, understanding of their operation is still incomplete. The current device was constructed for use in research directed toward improving understanding of flip-flop nozzles. Their eventual use will be to control practical shear flows.

In this device, flow from the inner nozzle, issuing between the two plates of the nozzle attachment, could attach itself to either wall due to the Coanda effect. The equalization of pressure through the feedback tube causes the jet to detach from one wall and attach to the other. Two of these fluidic devices were interconnected and then operated both in and out of phase.

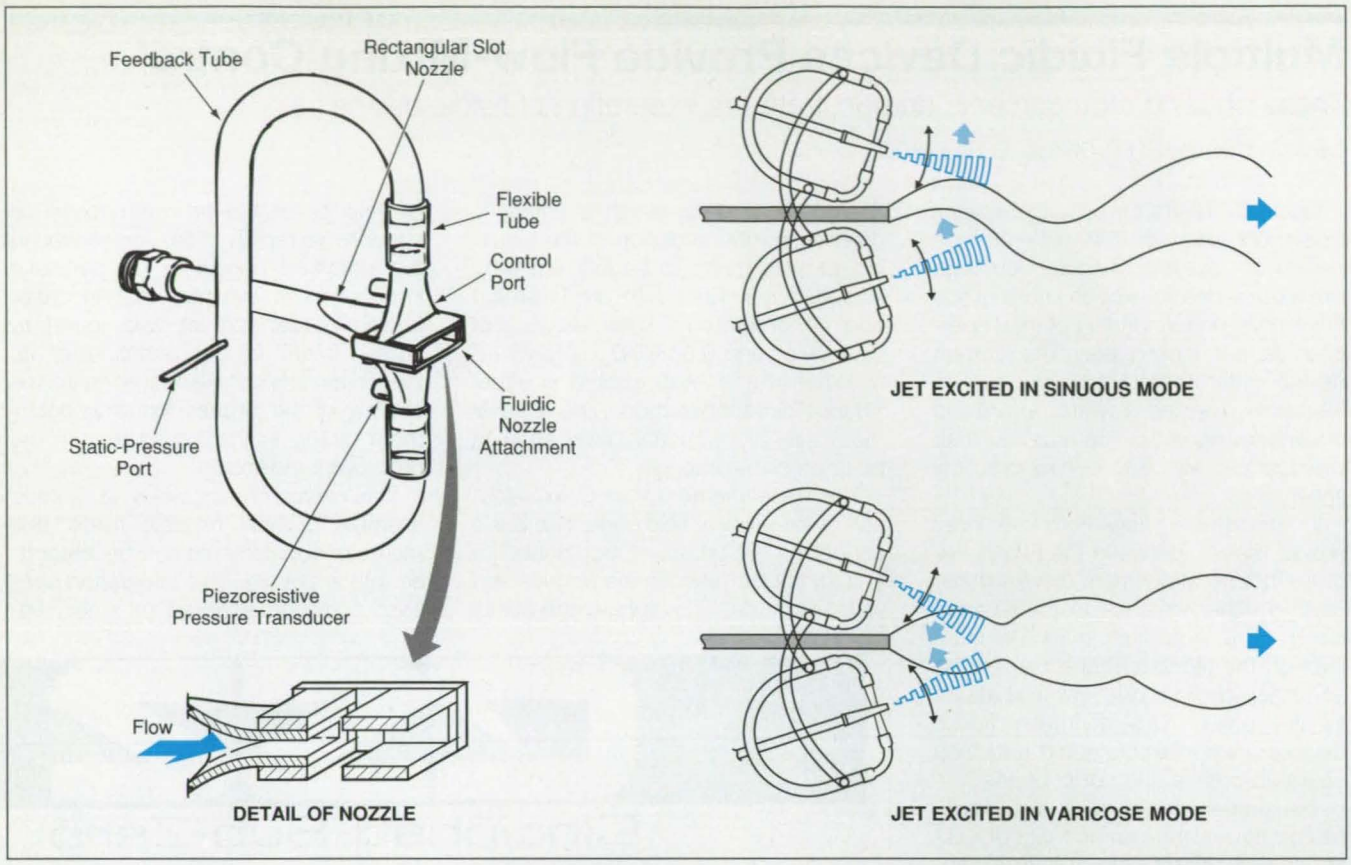
The primary rectangular slot nozzle has an equivalent diameter (D_e) of 4.37 cm and an aspect ratio of 3. In experiments, this nozzle was operated at an exit velocity of 48.76 m/s, which corresponds to a Reynolds number of 134,000. The fluidic (exciter) jet on each side was located approximately $1.4D_e$ away from the primary jet. The centerline of each exciter jet was oriented at an angle of 30° with respect to the centerline of the main jet. The supply of air flowing through each fluidic jet was approximately 12 percent of that through the primary jet. The sinuous mode was forced by operating the two fluidic jets in phase, while the varicose mode was forced by operating the fluidic jets out of phase.

Operating conditions and dimensions for the primary and fluidic jets in the experiments were deliberately selected to match the fundamental oscillations of the fluidic devices with the subharmonic of the preferred mode of oscillation of the primary jet; namely, the subharmonic that corresponds to a Strouhal number of 0.15. The fluidic oscillations in question were at a fundamental frequency of 170 Hz and, because of the on/off (square-wave) behavior of such oscillations, also produced excitation at three higher harmonics. The velocity spectrum obtained under these conditions covered the Strouhal-number range from 0.15 to 0.6. Flow-excitation levels were measured with a hot film probe located downstream of the fluidic nozzle.

The nozzle-exit boundary layer for the primary nozzle, which is critical in determining the evolution of the resulting jet, was found to be fully turbulent (shape factor 1.56) with displacement and momentum thicknesses of $0.02827D_e$ and $0.01807D_e$, respectively. When the jet was excited in either sinuous or varicose mode, the state of the nozzle-exit boundary layer showed no appreciable change.

The experiments involved examination of the velocity field under two basic conditions: (a) unforced rectangular jet and (b) the jet forced in the sinuous and varicose modes. The spread and decay of velocity of the jet were found to occur more rapidly in the forced than in the unforced condition. Of particular importance is the fact that in either forcing mode, the jet was found to spread more in the direction of its longer dimension. Also, the centerline velocity of the jet was found to decay more rapidly in the forced than in the unforced condition.

This research provides a unique example of how multiple fluidic elements or subelements can be integrated into a system. This integration concept could be adapted to other sys-



The **Single Fluidic Jet** (left) and interconnected fluidic jets (right) are being used to control primary flow.

tems in industries such as electronics, automobile engines, and environmental control where mixing and overheating control are desirable.

This work was done by Ganesh Raman of NYMA, Inc., and David M. Cornelius of Stanford University for **Lewis Research Center**. *For further information,* ***write in 68*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16100.

Adapter Converts Ultrasonic Imager to Eddy-Current Imager

The same mechanical system and electronics can be used for both types of imaging.

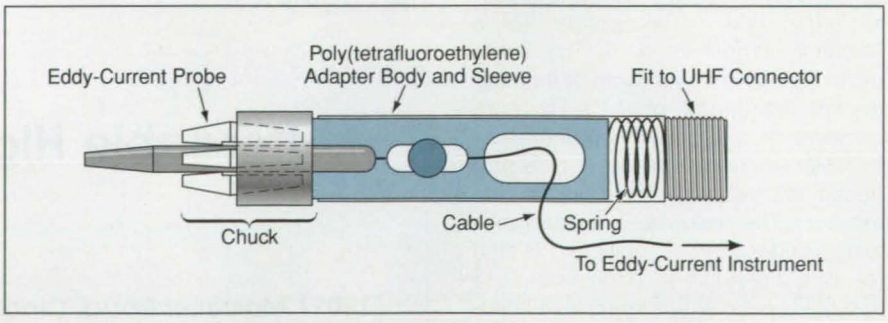
Goddard Space Flight Center, Greenbelt, Maryland

An eddy-current transducer is interchangeable with a standard ultrasonic transducer. With the interchangeable transducer, the same mechanical scanning platform can be used for either ultrasonic C-scan images or eddy-current images for nondestructive evaluation of materials and structures.

The eddy-current probe is housed in an adapter that matches the standard UHF connector of an ultrasonic transducer tube (see figure). The pencillike probe fits inside the adapter and is secured by a four-point-grip chuck. The probe cable feeds through an opening in the adapter and connects to the eddy-current instrument. A spring holds the probe on the specimen with the requisite constant contact pressure.

If the eddy-current instrument is of an analog type, its output can be directly connected to the same digital multimeter used for the ultrasonic instrument. Then the same imaging electronics as well as the same scanning mechanism can be used for both eddy-current and ultrasonic imaging.

This work was done by Engmin James Chern of **Goddard Space Flight Center**. *For further information,* ***write in 19*** *on the TSP Request Card.*
GSC-13793



An **Adapter Body and Sleeve** hold a four-jaw chuck, which in turn holds the eddy-current probe. The spring exerts constant pressure on the probe so that it maintains adequate pressure on the specimen for accurate imaging.

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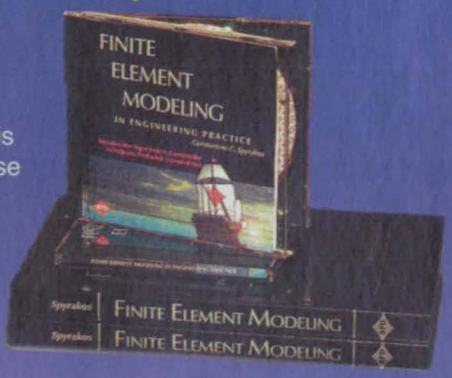

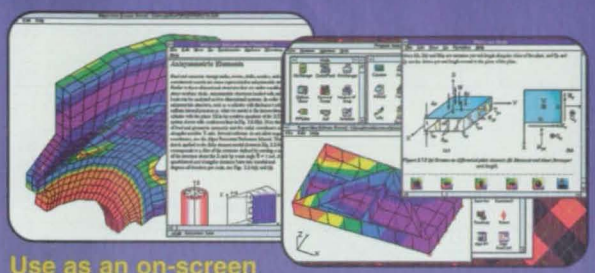

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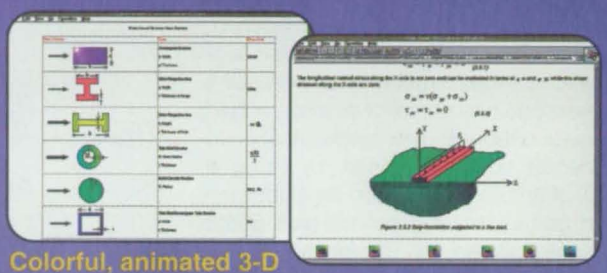

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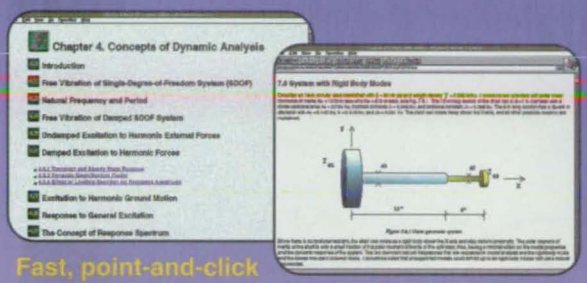

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About the Author:

Dr. Constantine Spyrakos is a Professor in the College of Engineering at West Virginia University. He holds B.S. and M.S. degrees in Civil Engineering from the Technical University of Athens, Greece. He also holds an M.S. in Engineering Mechanics and a Ph. D. from the University of Minnesota. Dr. Spyrakos is widely considered a leading authority in computational mechanics methods.

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Air-Augmented Supersonic Rocket Combustion Booster

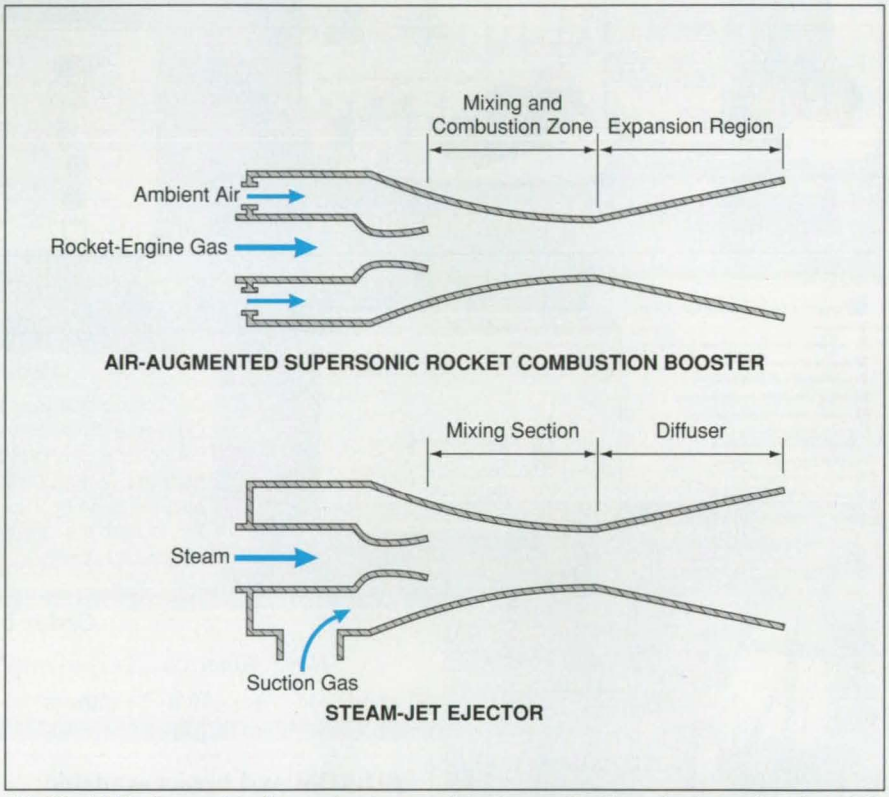
Atmospheric air would be mixed with partially burned products to obtain further combustion.

Marshall Space Flight Center, Alabama

A proposed supersonic engine designed to operate in air would incorporate an air-augmented afterburning feature to increase thrust without increasing the expenditure of fuel or of oxidizer fluid carried onboard. The basic idea is to generate additional thrust by using a flow of ambient air to burn the unburned and partially burned constituents of the gaseous stream of combustion products coming from the rocket combustion chamber.

The afterburning feature would be implemented in the engine nozzle, which would include a port through which oncoming air would be sucked into the stream of gaseous combustion products. The suction function and the configuration of the nozzle would be similar to those of steam-jet ejector nozzles used in pumping and evacuation (see figure). The resulting secondary combustion would exhibit a slightly lower flame temperature and specific impulse, but the mass flow rate would be much greater, resulting in considerably greater thrust.

This work was done by R. C. Bunker of Thiokol Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 85*** *on the TSP Request Card.*
MFS-31119



Air Would Be Drawn into the engine to complete the combustion of unburned and partially burned constituents of rocket-engine gas. In its suction aspect, the air-augmented supersonic combustion booster would resemble a steam-jet ejector.

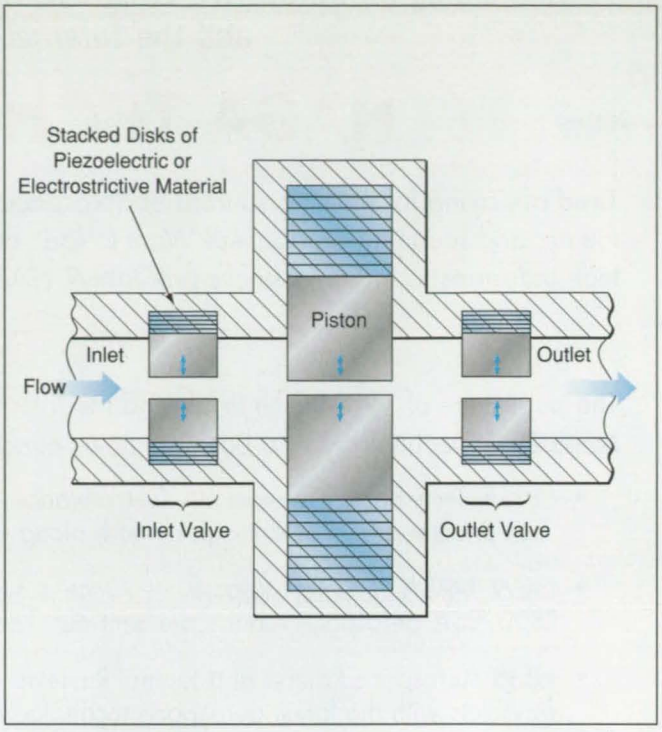
Piezoelectric Pumps Would Contain No Sliding Parts

These pumps would feature low wear.

NASA's Jet Propulsion Laboratory, Pasadena, California

Miniature pumps of a proposed type would contain no sliding parts and would be piezoelectrically or electrostrictively actuated. These pumps could handle liquids and gases at low temperatures, and would consume low power. The lack of sliding would result in minimal wear and should thus ensure long operating lifetimes.

A typical pump of this type (see figure) would include an inlet valve, a pair of opposed pistons, and an outlet valve. The valve and piston actuators would contain stacked piezoelectric or electrostrictive ceramic wafers. The voltages applied to the actuators would be phased to make them operate in a sequence to move a fluid from the inlet to the outlet. Pressure sensors in the pistons and valves would provide feedback for phase control. The pump would not leak when turned off because when no voltage was applied to the valve actuators and pistons, both valves



Contraction and Expansion of piezoelectric valve and piston actuators in a controlled sequence would result in a pumping action.

would remain closed and the pistons would be pressed against each other or it could be made to retain the position where one valve is closed.

The actuation sequence would be as follows:

1. The outlet valve would be closed.
2. The pistons would be set at their widest separation.
3. The inlet valve would be opened, allowing some fluid to flow into the gap between the pistons.
4. The inlet valve would be closed.
5. The outlet valve would be opened.
6. The pistons would be brought into contact with each other, thereby pushing some fluid out through the open outlet valve.
7. The foregoing cycle would then be repeated.

Stacked piezoelectric wafers would be used instead of thicker piezoelectric blocks in order to obtain useful amounts of piezoelectric contraction at applied potentials < 100 V. A typical actuation range of 10 to 20 μm could be realized, the exact range depending on the piezoelectric material. In one example, the gap between the pistons would be 40 μm with full voltage applied. If the pistons were 25 mm in diameter, the displaced volume would be 19.6 mm^3 per stroke. For a pump-cycle frequency ranging from 1 to 10 kHz, the pumping rate would range from 20 to 200 cm^3/s.

This work was done by Yoseph Bar-Cohen of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 53*** *on the TSP Request Card.*

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Refer to NPO-19792, volume and number of this NASA Tech Briefs *issue, and the page number.*

Industry Focus:
Motion Control/Positioning Equipment

Double-Jointed, Cable-Driven Robot Arms

Backlash and cross-coupling can be eliminated.

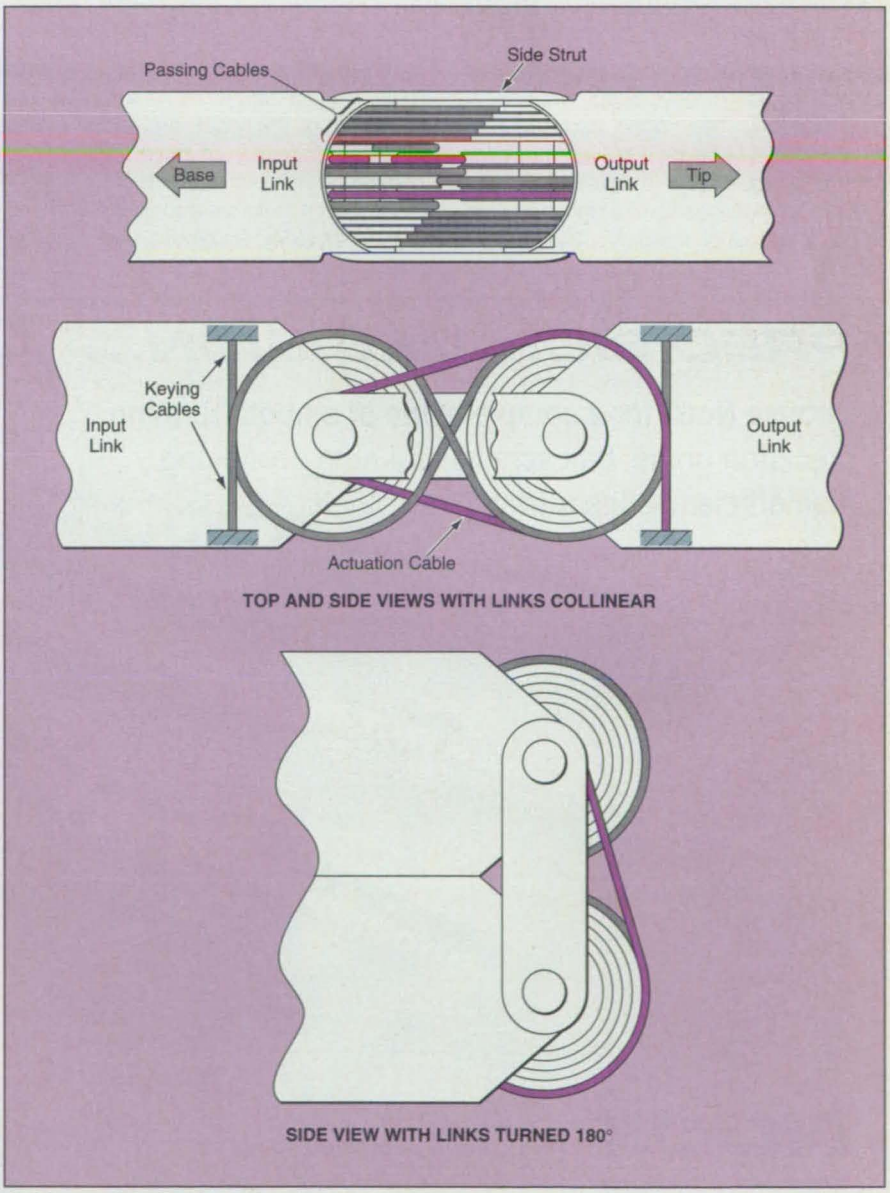
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure presents an example of a type of multiple-link, cable-driven robot arm that features revolute double joints between the links. Typically, cable-drive actuators are located in the base of a robot, and some cables pass through intermediate joints to remote joints. The cables are thus analogous to tendons that connect muscles in the forearm to finger joints. The concept of multiple-link, cable-driven robot arms is not new in itself. In the present case, the innovation lies in the particular class of double-jointed kinematic arrangements. By suitable kinematic design of cables, pulleys, and other components, it is possible to achieve a number of desirable characteristics, including (a) low or no backlash, (b) drive (torque) ratios other than 1, (c) 360° range of motion, (d) constant-length paths for cables, and (e) the ability of each intermediate joint to accommodate cables that drive other joints, without undesired cross-coupling between joints.

The input and output links shown in the figure could be any two adjacent links along a typical robot arm, the input link being the one closer to the base that contains the cable actuators. The double-jointed connection between the links is made via a pair of side struts. As is readily apparent from the bottom part of the figure, this connection is what makes possible the 360° range of relative motion between the links.

The two degrees of freedom of the double joint are reduced to one by use of two keying cables and keying pulleys. Each keying cable is stretched taut on the keying pulleys, with one end anchored on one side in the input link, the other end anchored on the opposite side in the output link. Furthermore, the keying cables cross each other between the keying pulleys. Thus, as the links rotate, each keying cable unwinds from one of the keying pulleys while winding onto the other keying pulley. The relative angular motions of the links and side struts are determined by the ratio between the diameters of the keying pulleys. In principle, the kinematic effect of this arrangement is equivalent to that of two perfectly meshing spur gears, each attached rigidly to one of the links. Of course, spur gears do not mesh perfectly in practice; they are subject to backlash, whereas in this arrangement, stretching the cables taut eliminates backlash.

The joint is actuated by a pair of actuation cables that run all the way from the cable actuators in the base to anchors on opposite sides of the output link. On the way to the anchors, the actuation cables pass over actuation pulleys mounted on the same joint axes as those of the key-



Cables and Pulleys can be designed to obtain a compact drive mechanism with minimal backlash, minimal cross-coupling between joints, and a 360° range of motion.

ing pulleys. These cables and pulleys also function somewhat analogously to a spur-gear drive. By suitable choice of different diameters for the actuation pulleys in the input and output links, one can obtain a reduction in speed and increase in torque characterized by the equivalent of a gear ratio. This effect can be utilized to increase the apparent stiffness of the joint while making the joint more compact and minimizing the lengths of cables. Shortening the cables also helps to increase the apparent stiffness.

The actuator cables that run to other joints are the ones labeled "passing cables" in the figure. These cables pass over idler pulleys mounted on the same joint axes with the other pulleys. The need to prevent cross-coupling between joints imposes two basic constraints on the passing cables and idler pulleys: (1) Like the keying cables, the passing cables must cross over between the pulleys; and (2) the ratio between the diameters of the idler pulleys in the input and output links must be the same as the corresponding ratio for the keying pulleys.

This work was done by Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 33*** *on the TSP Request Card.*

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Refer to NPO-19361, volume and number of this NASA Tech Briefs *issue, and the page number.*

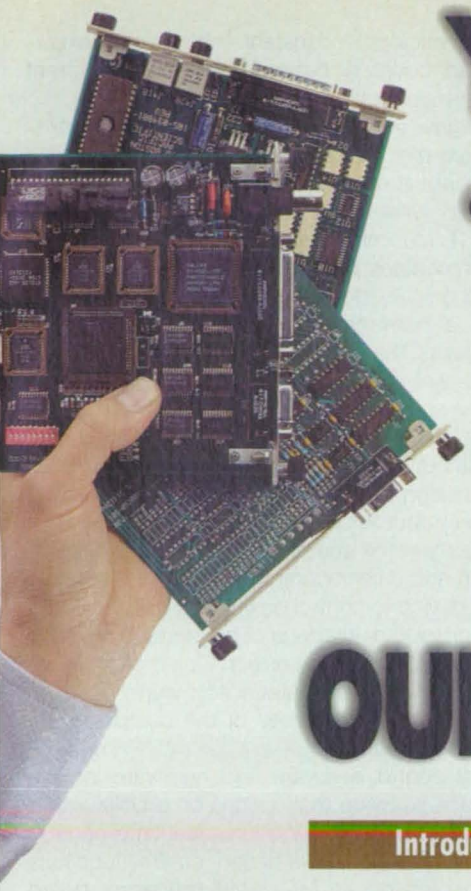
Positioning Robot for Microsurgery: Introduction

This robot accomplishes precise relative positioning and orienting in six degrees of freedom.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact, lightweight positioning robot has been developed for use in microsurgery. The robot can function throughout a large workspace, can bear relatively large loads, and is capable of precise relative positioning and orienting in six degrees of freedom. The control system of the robot implements a kinematic-based algorithm unique to the geometry of the robot, and incorporates electronic circuitry of novel design that helps to ensure safe operation.

The robot includes a torso and an arm with a shoulder, an elbow, and a nonintersecting three-axis wrist. The arm is approximately 1 in. (2.5 cm) in diameter and, when fully extended, about 10 in. (25 cm) long. Actuation of the arm is based on miniature three-axis joints, antibacklash gear trains, and tendonlike cable-drive mechanisms that, together,



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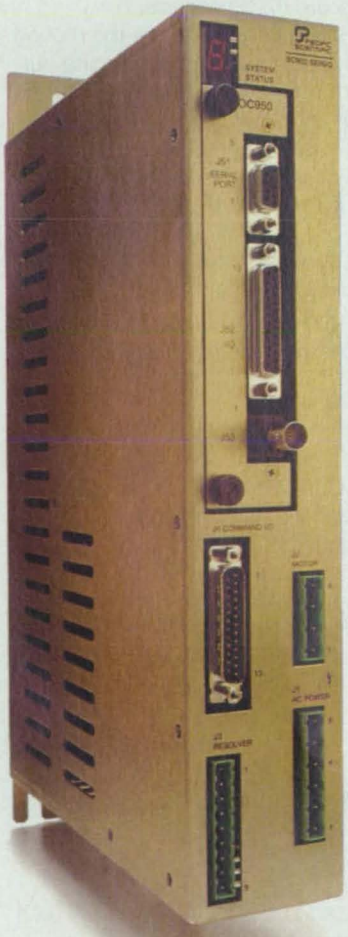

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achieve nearly zero backlash, constant-cable-length excursions, and minimized coupling between joints. The current design enables relative positioning of tools to within 25 μm.

Each antibacklash gear train features dual independent transmission paths that are mechanically coupled at the input and output only; this concept is explained more fully in the following article. The three-axis wrist joint, based on the Ross-Hime Designs OMNI-WRIST, (described more fully in the second following article) accommodates pitch, yaw, and roll motions that are completely mechanically decoupled from each other and operate throughout a hemisphere. In combination with the shoulder and elbow joints, the wrist joint provides capability for a large work volume, as well as low friction, small size, light weight, and high stiffness. The shoulder and elbow joints provide 360° of motion, and tendons can pass through either of these joints to joints farther out, without coupling to the joints through which they pass. This joint design was described more fully in "Double-Jointed, Cable-Driven Robot Arms" (NPO-19361) on page 1b.

The electronic circuitry in the control system includes a computational subsystem and a servocontrol subsystem that use a programmable logic device to control power and braking relays through an optically isolated interface. The system provides detection of faults and recovery from errors. Commercial products, including industry-standard interfaces, were used to enable rapid construction of prototypes of the computational and servocontrol subsystems.

The computational control software and hardware include graphical-user-interface software that resides on a UNIX workstation, which also serves as host to VxWorks real-time-control-environment software. The VxWorks-based control functions are, in turn, implemented on an MC68040 processor board installed in a VersaModule Eurocard (VME) chassis.

A Delta Tau Delta Systems PMAC board controls the motion of the robot in its six degrees of freedom by directly reading outputs from sensors on the robot and driving amplifiers that, in turn, drive motors that produce the motions. The graphical user interface provides the following control modes:

- A manual joint-control mode, in which the user can command motions in individual joints by selecting buttons in a control window;
- An autonomous joint-control mode, in which the control system demonstrates the workspace of the robot;
- A manual teleoperation mode, in which the user controls the robot through a mouse or by using a spaceball input device to move the robot in all six degrees of freedom simultaneously; and
- An autonomous world-space control mode, in which the control system moves the end effector (the robot hand) sinusoidally about one or more Cartesian axes simultaneously.

This work was done by Timothy Ohm, Curtis Boswell, Hari Das, Eric Paljug, Guillermo Rodriguez, Paul Schenker, Sukhan Lee, and Ed Barlow of Caltech, and Steve Charles of MDS, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 100*** *on the TSP Request Card.*

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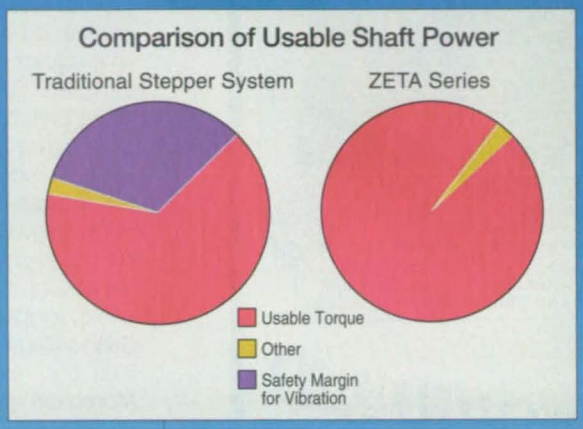

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Positioning Robot for Microsurgery: Antibacklash Drive

Two independent transmission paths are joined at the input and output ends only.

NASA's Jet Propulsion Laboratory, Pasadena, California

Antibacklash gear-train/cable drives actuate the joints of the robot described in the preceding article. These drives offer several advantages over conventional antibacklash drives, especially as regards the costs of components and the time spent performing preload adjustments.

A typical conventional antibacklash drive includes commercially available antibacklash gears, which are pairs of identical gears that must be preloaded against each other. A separate preload adjustment must be performed at each and every stage of the drive train; this is a disadvantage where the gear ratio, and thus the number of stages, is large. Moreover, conventional antibacklash gears are relatively expensive and available in a limited selection of sizes.

A drive of the present type (see figure) does not contain conventional antibacklash gears; instead, it comprises two independent drive trains that contain ordinary gears, and that are coupled at their input and output ends only. The task of preloading is greatly simplified in that all stages can be preloaded in a single adjustment, regardless of the number of stages.

The motor at the input end drives a pinion that drives both of the independent first-stage gears. A second-stage pinion is attached to each of the first-stage gears and drives one of the two independent second-stage gears. A cable spool attached to each second-stage gear drives one of the two cables, which pass to a common output spool, completing the third stage.

To preload the system, one disengages the motor from the first-stage gears, so these gears can then be counterrotated relative to each other. This rotation and the resulting preload are then passed from stage to stage until the cables become tensioned. Moreover, because the preload is passed from one stage to the next, the value of the preload is proportional to the stage ratio, as is desirable for maximum mechanical efficiency. When the desired preload tension is achieved, the motor is simply reengaged with the first-stage gears, thereby locking the preload. Although this scheme is shown here with three stages, it is applicable to any number of stages.

This work was done by Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 83*** *on the TSP Request Card.*

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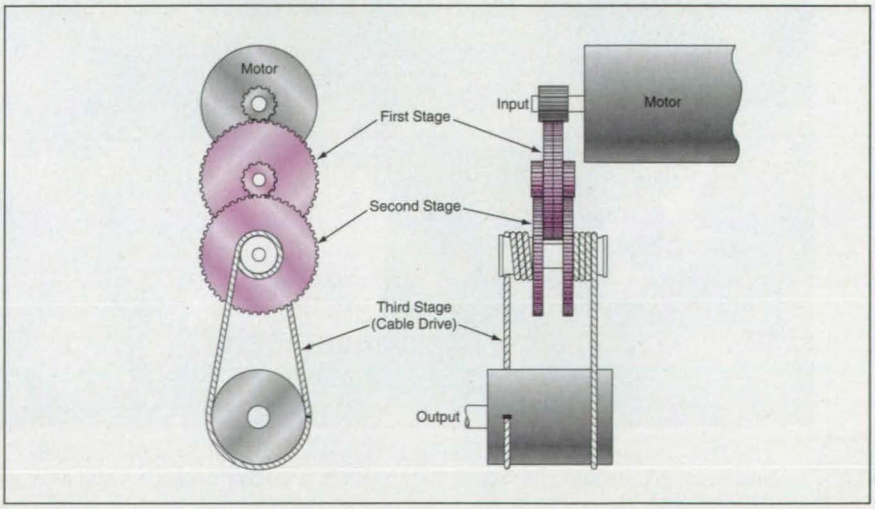

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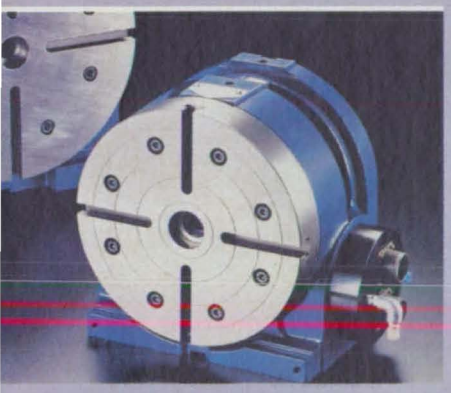

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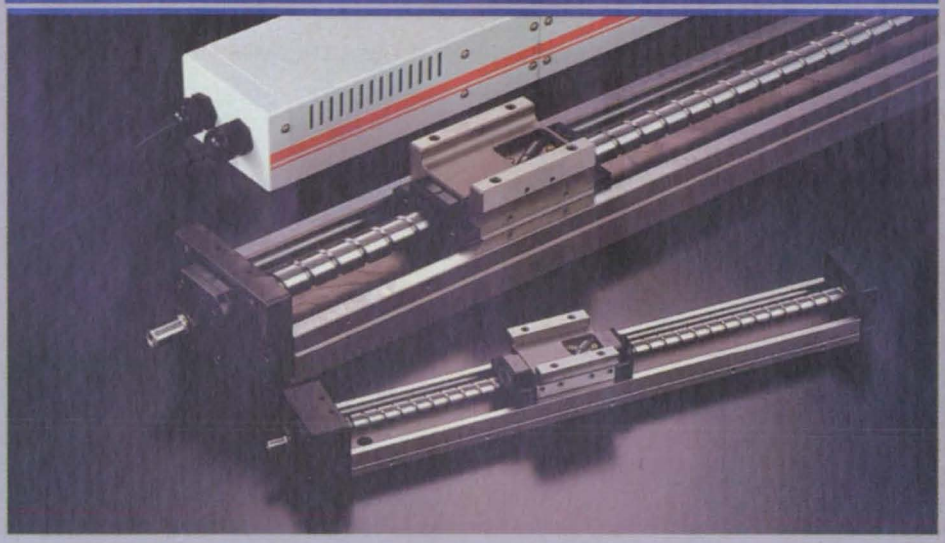

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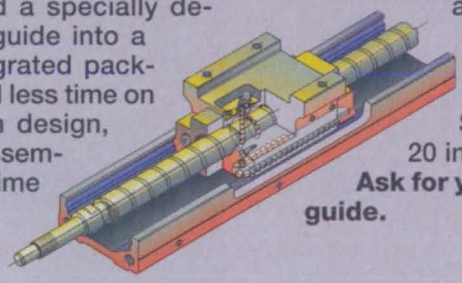

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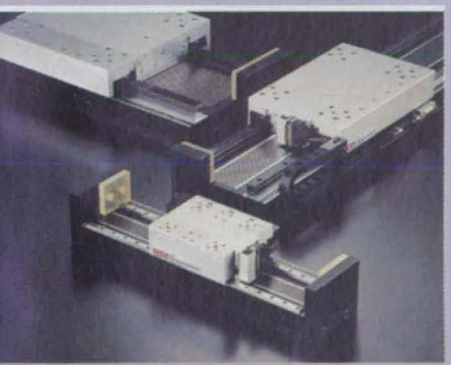

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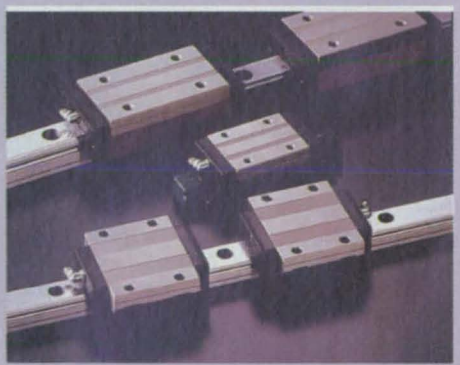

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Positioning Robot for Microsurgery: Three-Axis Wrist Joint

Modifications of a prior design reduce size, weight, and backlash.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows a miniature three-axis wrist joint that was developed to satisfy the special requirements for the microsurgical positioning robot described in the preceding two articles. The requirements include light weight, compactness, large work volume, decoupling among the rotations about the three axes, low stiction, low backlash, high stiffness, high strength-to-weight ratio, and amenability to cable (tendon drive).

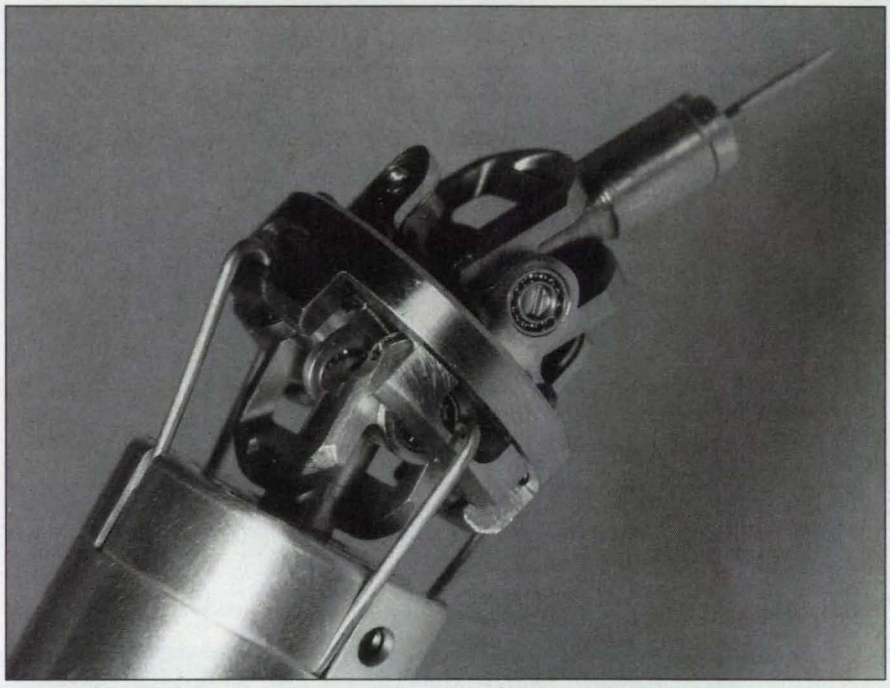
This wrist joint is a modified version of a patented commercial unit that provides motion free of singularities, along with the desired large work volume and decoupling among the rotations about the three axes. This design of this joint is kinematically identical to that of the commercial version, but incorporates modifications to reduce size and weight, minimize backlash, and add tendon drive.

The commercial unit has a diameter of about 6 in. (15 cm), a mass of about 20 lb (9 kg), and a rated payload force of about 25 lb (111 N). The present wrist joint functions throughout the same work volume (a hemisphere of motion) as that of the commercial unit but has a diameter of about 1 in. (2.5 cm), a mass of 3 oz (85 g), and a rated payload torque of about 3 lb-in. (0.34 N·m). This reduction in size and mass, while retaining considerable load capacity, was achieved through the structural modifications discussed below.

The major sources of backlash in the output of the commercial unit were minimized. These sources are in bails that guide an output shaft in one axis, in two coupled universal joints, and in two bearing rings to which actuators are attached. The source in the bails can be reduced only by careful fabrication. The source in the coupled universal joints comes from a clearance in the gear teeth that perform the coupling. The modified design replaces these gear teeth with preloaded tendons, completely eliminating backlash from this source. The source in the bearing rings was eliminated by implementing opposing tendons to drive the joint, thereby automatically preloading the bearing rings. The commercial unit operates with push/pull actuators arranged such that bearing play is in series with the actuators and does not preload them. The modifications yield zero backlash in motions about two of the three axes, with minimal backlash in motion about the third axis.

The tendon drive was incorporated into the modified design to enable the use of remote actuators (that is, actuator motors and gears in a torsolike body at the base of the robot arm). For this purpose, the commercial unit was modified by replacing asymmetric linear actuators on the pitch and yaw axes with fully symmetrical linear carriages that are positioned by use of a tendon drive of a block-and-tackle style. This drive includes a 2:1 force multiplier that counteracts a 2:1 force divider inherent to the kinematic concept. The linear carriages both (1) actuate the bearing rings to which they are attached, and (2) align the bearings. The inclusion of the 2:1 force multiplier multiplies the stiffness of the joint by a factor of 4. In the roll axis, a geared motor drive of the commercial unit is replaced with an antibacklash tendon drive.

Structural modifications that accompany the modifications of the drive mechanisms have also resulted in significant reductions in weight, size, and fabrication costs. Because the linear carriages align the bearing rings, the bails and guides of the commercial unit are eliminated; this alone reduces the weight of the joint by 50 percent, decreases the diameter of the joint by about 20 percent, reduces the fabrication cost by about 20 percent, and almost eliminates friction. Actuator rods must now be attached with a ball joint instead of a pin joint, but this is a simple modification.



This **Three-Axis Robot Wrist** is based on a prior design, with modifications to reduce size, weight, and backlash.

This work was done by Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 88*** *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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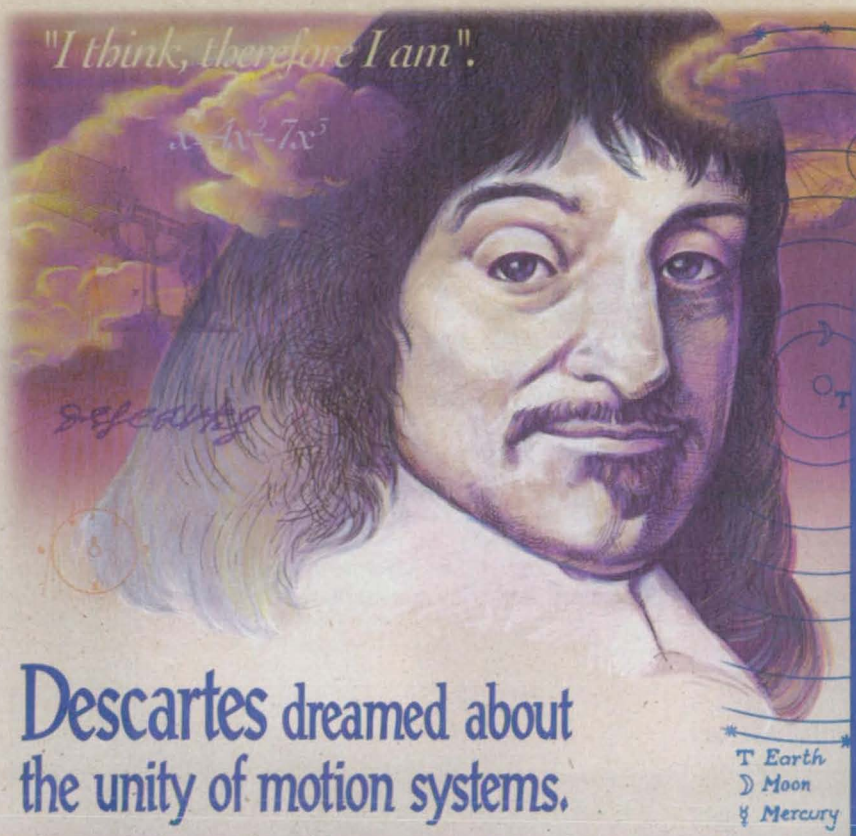
Refer to NPO-19524, volume and number of this NASA Tech Briefs *issue, and the page number.*



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Positioning Robot for Microsurgery: Conclusion

An illustration and further details are presented.

NASA's Jet Propulsion Laboratory, Pasadena, California

This is the last in the present series of articles on the microsurgical robot with tendon-driven shoulder, elbow, and wrist joints. The main purpose of this article is to present a few additional details that are significant but do not lie within the scope of the preceding, similarly titled articles, which emphasize selected parts of the robot.

The figure shows some aspects of the mechanical layout, approximately to scale. The robot includes a manipulator arm with a single-axis shoulder joint connected to a torsolike body through a single-axis rotary torso joint. The arm also includes a single-axis elbow joint and a three-axis wrist joint. Thus, altogether, there are six degrees of freedom. For more information about the joints and the cable (tendon) drives used to actuate them, the reader is referred to the preceding articles in this series and to "Double-Jointed, Cable-Driven Robot Arms" (NPO-19361), on page 1b.

The following features are particularly relevant to the microsurgical application:

- The electromechanical components, including the motors and joint-angle encoders, can be removed easily and quickly for sterilization in an autoclave.
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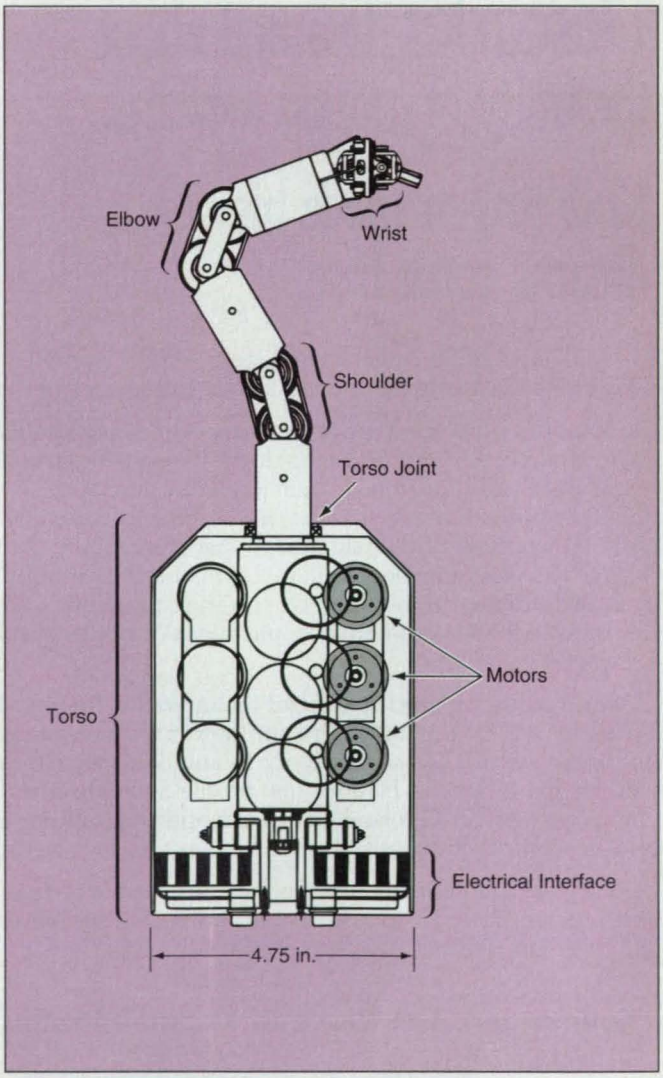
- Subject to considerations of force and stiffness, the tip of the arm can be positioned within a distance of 10 μm of a location specified relative to an initial position.

This work was done by Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 84*** *on the TSP Request Card.*



The **Positioning Robot** features tendon (cable)-driven joints. The motors and gears for the antibacklash cable drives are located in the torso and are shown here only schematically.

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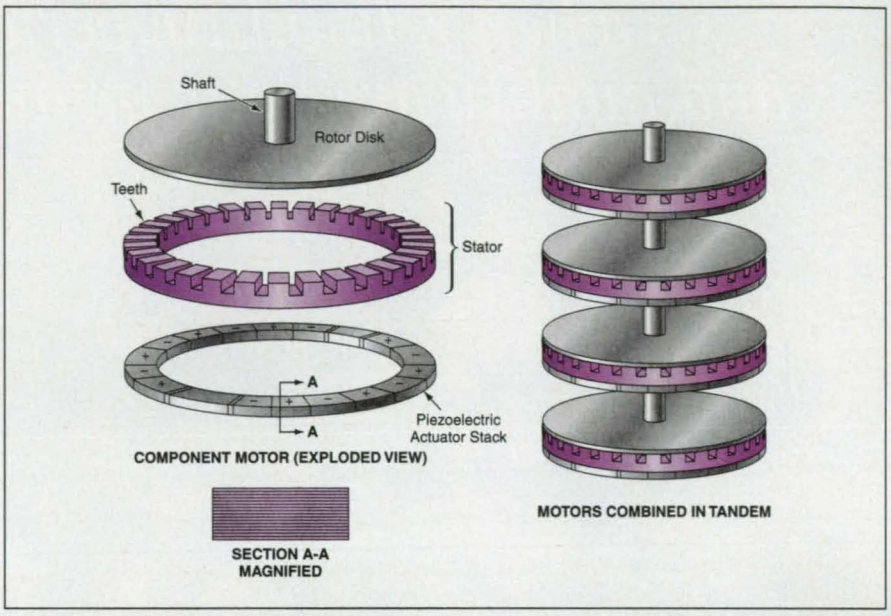
High-Torque Ultrasonic Motors

Tandem motors with redesigned actuators produce more torque.

NASA's Jet Propulsion Laboratory, Pasadena, California

Motors that comprise multiple ultrasonic piezoelectric motors in tandem are undergoing development. Each component ultrasonic motor features a drive ring (stator) segmented into multiple stacks of piezoelectric wafers. Such a drive ring produces a torque greater than that produced by the single-piezoelectric-wafer drive ring in a typical ultrasonic motor of older design. Combining motors in tandem on a single shaft in a single package makes it possible to multiply torque. Motors of this type are prototypes of lightweight, high-torque motors suitable for use as robotic actuators, whereas older ultrasonic motors are limited to such low-torque applications as watches and cameras. Moreover, in comparison with older ultrasonic motors, motors of this type can be mass-produced more easily and at lower cost.

Like older ultrasonic motors, these motors consume little power, inherently brake when power is turned off, respond quickly, and operate quietly. Each drive ring in a motor of this type contains a number of piezoelectric actuator stacks positioned at equal circumferential intervals in the required pole sequence (see figure). As in an older piezoelectric motor, the drive ring makes contact with a rotor disk attached to a shaft, piezoelectrically driven waves on the surface of the stator travel circumferentially, and these waves drive the rotor via frictional contact at the crests of the waves. Each actuator stack contains 30 or more piezoelectric layers. When energized by an applied potential of typically < 100 V, the layers of the stack collectively produce a total piezoelectric displacement of 10 to 20 μm — considerably more than the displacement obtainable from a single-layer piezoelectric actuator of equivalent thickness at the same applied voltage. The motor torque is enhanced accordingly.



Piezoelectric Actuator Stacks on the drive ring (stator) of each component motor generate an ultrasonic wave that travels around the drive ring, which is in contact with a rotor disk. Several such motors are combined in tandem to obtain high torque.

When multiple component motors are combined into a single package to obtain a high-torque motor, all of the drive rings share the same housings, all the rotor disks are connected to the same shaft, and only two end bearings are needed to support the shaft, as in a conventional motor. The combined motors also share wiring. Thus, the size and weight of the package is less than that of the multiple, individually packaged motors that would otherwise be needed to produce the same torque. Moreover, the redundancy of the multiple component motors affords some protection against failure of one of them.

This work was done by Yoseph Bar-Cohen and Shyh-Shiuh Lih of Caltech and Willem A. Grandia of QMI for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 98*** *on the TSP Request Card.*

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Refer to NPO-19835, volume and number of this NASA Tech Briefs *issue, and the page number.*

Telemanipulator With Anthropomorphic Master and Slave Hands

The robot hand is controlled via a force-sensing and -reflecting glove.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows the key mechanical parts of an experimental telemanipulation system with anthropomorphic master and slave hands mounted on nonanthropomorphic master and slave arms. The robot hand (the slave hand) shown at the left functions much like a remote extension of the hand of the human control operator. By use of the force-sensing and position-reflecting exoskeletal device (the master glove) shown at the right, the operator's hand exerts control over finger and wrist motions and forces of the slave hand. The master glove is mounted on the last gimbal axis of a six-

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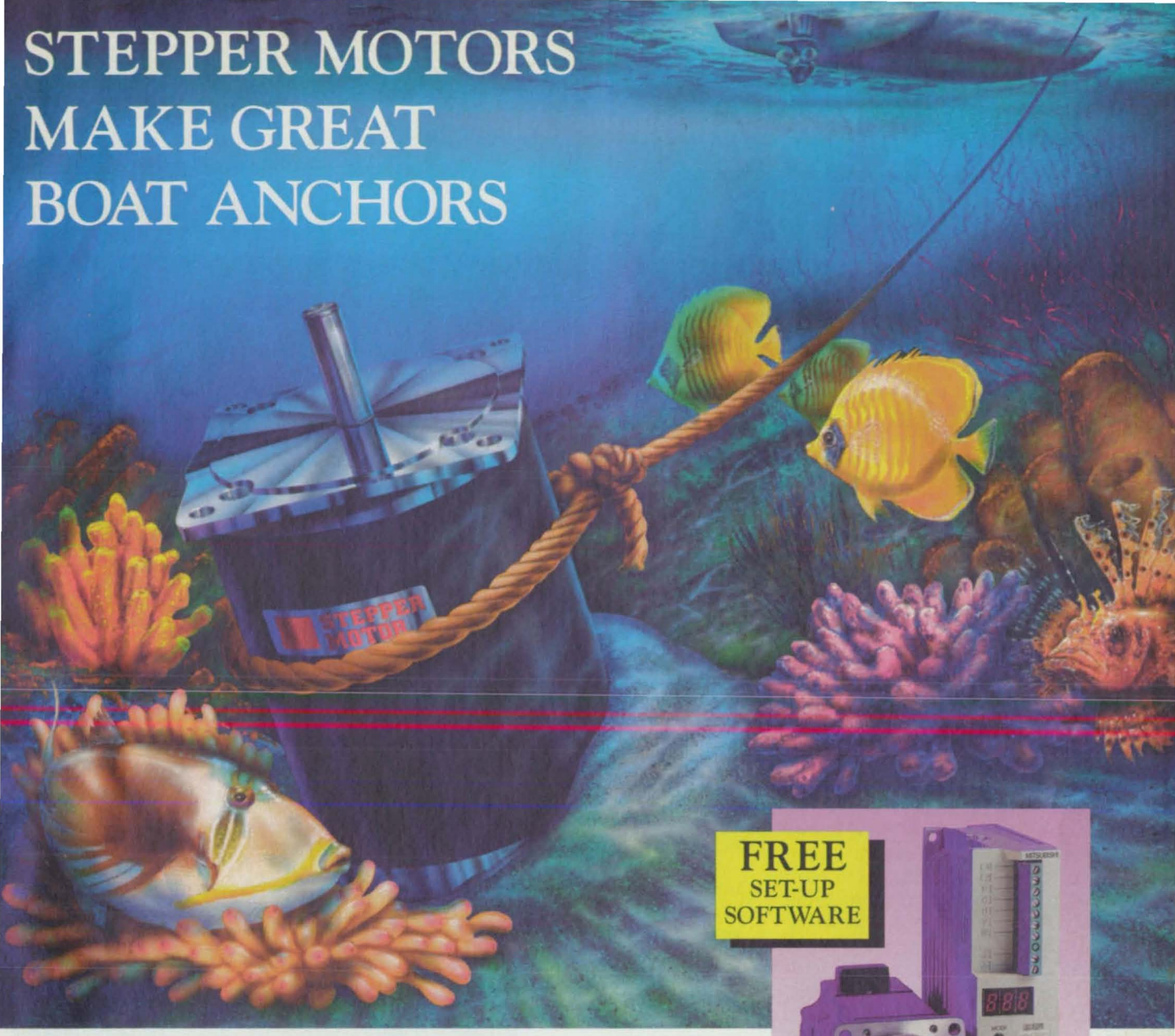

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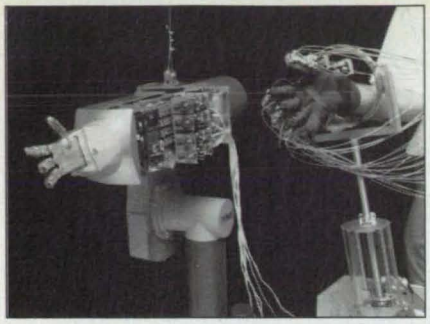


The **Human Operator Controls the Robot Hand** via force and position sensors in the master glove.

degree-of-freedom force-reflecting hand controller (the master arm). This arrangement makes it possible to map the manipulative capabilities of the human hand to the anthropomorphic robot hand without having to attach an inconvenient exoskeletal master arm to the operator's arm to derive control signals for the robot arm. The telemanipulator system includes a distributed, high-performance computer-based control system featuring custom-developed "intelligent" joint-actuator controllers built around digital signal-processing integrated circuits.

When the operator's hand is inside the master glove, the force-reflecting master arm measures the motion of the operator's arm indirectly in that it measures the motion of the base on which the master glove is mounted. The control system converts these measurements into commands for the corresponding motion of the slave arm. The control system includes an active electromechanical compliance (AEC) subsystem that provides both position and stiffness control, equivalent to the dual position/control function of muscles. The control system provides automatic hybrid position/force control and compliance control of the robot. Compliance deflection sensors detect slight joint deflections that signify contact between the robot hand and an external object, prompting the system to switch from the position-control mode to the force-control mode.

The master glove includes position and force sensors that enable hybrid position/force and compliance control of the robot hand. The glove contains 16 joints, all of which are instrumented. Remotely located actuators mechanically linked to the glove through cables provide position feedback for all 16 joints. A one-to-one kinematic mapping exists between the master glove and all of the slave-hand finger joints except those of the thumb; this reduces the computational efforts and the complexity of the part of the control system devoted to the terminus devices (the master glove and slave hand). The exception to direct mapping is that between the thumb base joints; this mapping involves kinematic transformations. The system is said to operate in a "terminus control mode." What this means is that the anthropomorphic terminus devices are regarded as belonging to a terminus subsystem that is treated somewhat differently from, but nevertheless integrated with, the rest of the manipulator system.

The fingers of the robot hand are sized and shaped similarly to those of a large male human hand, and its joints are capable of angular displacements similar to those of the corresponding human joints. As in the master glove, all joints are mechanically linked to remote actuators via cables. Each finger is controlled by its own AEC subsystem, enabling humanlike soft grasping. The kinematics of the robot hand are similar to those of a human hand, enabling such functions as manipulation of tools under the operator's control via the master glove.

This work was done by Antal K. Bejczy, Bruno Jau, and Murray A. Lewis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 111*** *on the TSP Request Card.*
NPO-19479

PC-Based Controller for a Dexterous Robot Arm

The computer is relieved of joint servo loops, freeing computing resources for other uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A control system for a seven-degree-of-freedom robot arm performs the functions of force-control trajectory generation, graphical simulation, and operator interface. Heretofore, a rather expensive computer would have been a necessary part of a control system capable of performing all of these functions. However, the present system is designed to require only a personal computer as its host processor; this is achieved by an integrated approach to the hardware and software aspects of the design. Among other things, the design of the present control system takes advantage of a state-of-the-art robot that includes its own servo controller electronic circuitry; some of this circuitry is embedded in its arm, while the rest is housed in an external control unit. The design of the robot makes it possible to remove the computational burden of all joint servo loops from the control-system computer, thus freeing computing resources that can be used to support an open control architecture and a graphical operator interface.

In addition to the personal computer, the robot arm, and the robot control unit, the system hardware (see figure) includes a six-axis force-and-torque (FT) sensor, an FT processor, and a graphical processor. The system also includes two video monitors — one connected to the personal computer, the other connected to the graphical processor for displaying the results of the simulation. The personal computer is connected to the bus of the robot control unit via a bus extender that provides a high-speed bidirectional shared-memory interface by mapping the memory locations used by the control-unit bus directly into the memory space of the computer.

The personal computer is equipped with a 486DX2, 66-MHz microprocessor, 11 MB of random-access memory (RAM), and serial and parallel input/output ports for exchanging data with the FT and graphical processors. The unusual choice of memory space is a tradeoff between the memory space addressable by the bus extender and a 1-MB minimum RAM increment allowed by the computer hardware.

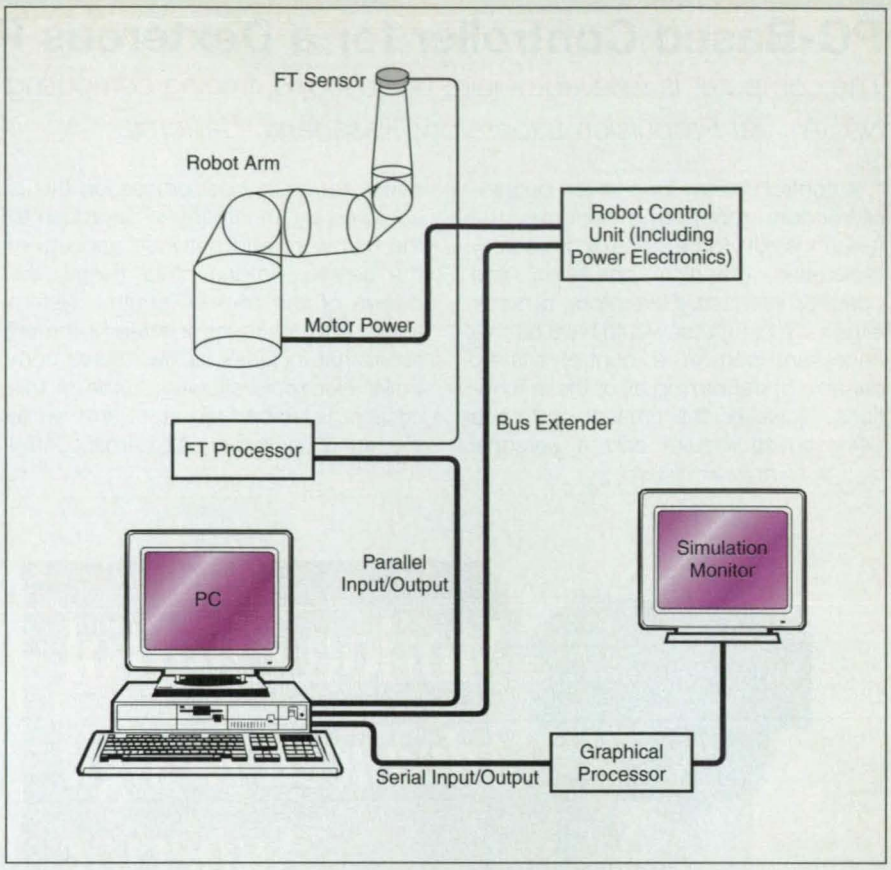
The graphical processor implements the graphical part of the operator interface. The graphical processor is designed as a 486DX4, 100-MHz single-board computer external to the personal computer with a dedicated video monitor because of limitations imposed by the speed of the central processing unit (CPU) of the personal computer and by real-time software, as explained below. The single-board computer is configured with 16 MB of RAM and 1 MB of local video memory. The personal computer and graphical processor communicate via an RS232 serial port. Motions can be simulated and displayed in real time.

The system software includes the iRMX® operating system, which provides a real-time multitasking environment in which Windows™ and DOS can be executed as separate tasks. Because the memory-management aspect of iRMX® requires the CPU in protected mode, Windows™ can run

only in standard mode, with reduced memory space and limited display capabilities. This conflicts with the need for Windows™ operating in enhanced mode to obtain a display of high quality, thus giving rise to the need for the graphical processor. For the foregoing plus other reasons, the system software utilizes only a few features of iRMX®, and is designed to be easily portable to other real-time computing environments. The software uses a programmable interval counter of a complementary oxide/semiconductor (CMOS) memory chip in the personal computer as the real-time clock of the control loop. The timer produces a hardware interrupt that neither interferes with the personal computer clock nor incurs any iRMX® overhead. The position-control part of the software is executed every 2.5 ms; an interval of 125 μs was chosen to ensure stability within the position-control cycle and prompt acquisition of FT data.

The software is divided into parts, called "tasks," that correspond to the tasks that those parts perform:

- The main task handles housekeeping functions and dispatching of messages to the other tasks.
- The operator-interface task handles the command menus and displays the trajectory parameters.
- The control task performs the trajectory-generation and kinematic computations (including processing of FT data for force control), and is activated directly by the hardware interrupt. The trajectory-generating algorithms are based on the configuration-control concept (discussed in numerous prior articles in *NASA Tech Briefs*), in which redundant degrees of freedom are exploited to achieve control objectives beyond the placement of the robot hand at the desired position and orientation.



This **Robot-Control System** features an integrated hardware/software design, with position- and force-control algorithms based on the configuration-control concept.

This work was done by Paolo Fiorini, Homayoun Seraji, and Mark Long of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 102*** *on the TSP Request Card.*
NPO-19876

Voltage-Fed Inverter for Control of Synchronous Induction Motor

Transistors in this three-phase circuit would conduct during intervals up to 180°.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed voltage-fed inverter circuit would supply power from a dc source to a three-phase synchronous induction ac motor. The circuit would provide control of the motor current (and, thereby, the motor torque) via a modified timed-switching scheme that differs from the more conventional scheme, in which each transistor is turned on during an electrical-phase-and-rotation interval of 120°. In the modified scheme, each transistor would be on during an electrical-phase-and-rotation interval of 180°. With respect to the conventional scheme, the modified scheme would extend the power deliverable to a given motor at a given dc supply voltage by a factor of 1.32.

The figure shows essential features of the circuit. The table in the figure shows which transistors would be on during each 60° interval of a full 360° cycle in which full power is applied to the motor: at any given instant, three transistors would be on. Each transistor would be on continuously for three successive intervals of 60° each. The "on" intervals of the transistors would be staggered among the six transistors in such a pattern that each motor terminal (A, B, C) would be connected alternately to the positive and negative sides of the power supply for intervals of 180°, and the electrical phases at the three terminals would be staggered by 120°.

The modified control scheme can be understood as a departure from the full-power operation described above. The torque and power could be reduced during each 60° interval by turning off, during a portion of that interval, whichever transistor would otherwise be the sole "on" transistor connected to either the positive or the negative side of the power supply. For example,

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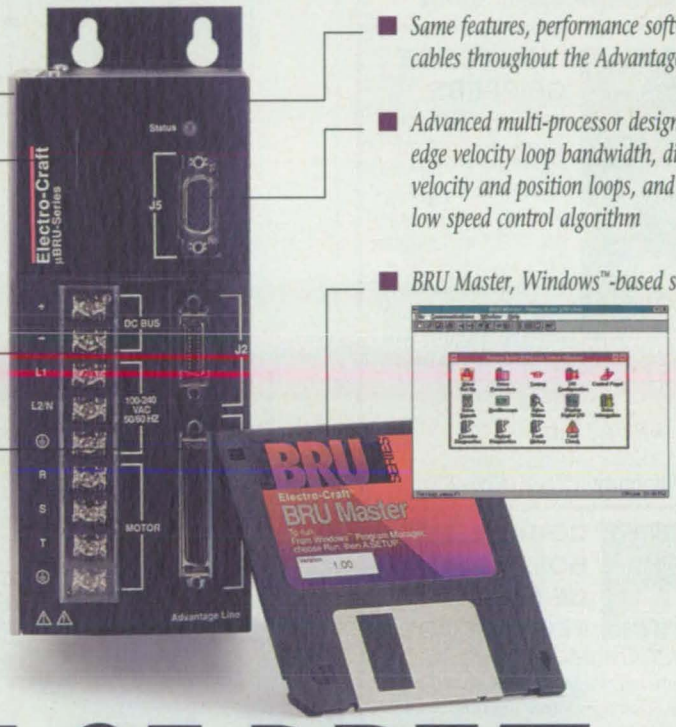

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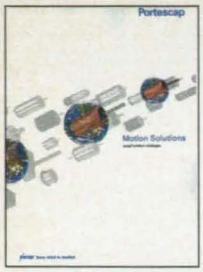

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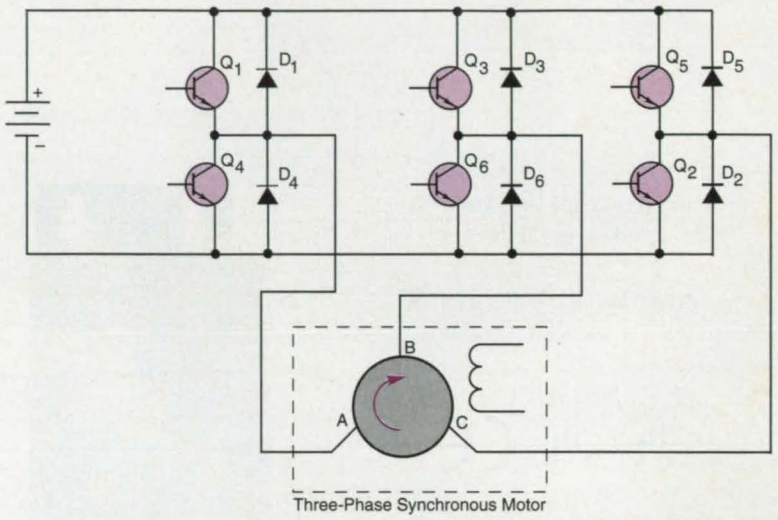
during the interval of 120° to 180°, one could reduce power by turning off transistor Q_2, which would otherwise be "on" and the sole transistor conducting current between the motor (via the C terminal) and the negative side of the power supply.

Each time a transistor was thus turned off when it would otherwise be on in full-power operation, a three-phase short circuit would occur at the motor terminals. For example, when Q_2 was turned off in the example above, the current from motor terminal C would be diverted through diode D_5 back to the positive side of the power supply, to which terminals A and B would also be connected via transistors Q_1 and Q_3, respectively. During each such short-circuit interval, the current in each phase would be reduced.

This control scheme could be the basis of the design of a new inverter circuit or of the modification of an existing 120° voltage-fed inverter to extend its power capability. An additional advantage of this scheme is that it decreases (in comparison with the 120° scheme) the distortion of voltages and currents at high powers, thereby increasing the efficiency of the motor.



Three-Phase Synchronous Motor

Intervals	Transistors On	Polarities at Terminals A	B	C
0° to 60°	Q_1, Q_6, Q_5	+	−	+
60° to 120°	Q_1, Q_6, Q_2	+	−	−
120° to 180°	Q_1, Q_3, Q_2	+	+	−
180° to 240°	Q_4, Q_3, Q_2	−	+	−
240° to 300°	Q_4, Q_3, Q_5	−	+	+
300° to 360°	Q_4, Q_6, Q_5	−	−	+

Each Transistor Would Be On during a maximum continuous interval of 180°, instead of 120° as in more conventional motor-control inverters.

This work was done by Carol Oximberg of Allied-Signal Aerospace Co. for **Johnson Space Center**. *No further documentation is available.*

Title to this invention, covered by U.S. Patent No. 5,463,300 has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to:

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Refer to MSC-21981, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Sensitivity, Absolute Optoelectronic Linear-Position Encoder

This encoder measures absolute position as well as small increments of position.

Goddard Space Flight Center, Greenbelt, Maryland

New optoelectronic linear-position encoders have been derived from recent advances in linear charge-coupled-device (CCD) array photodetectors, which have very small individual analog picture elements (pixels) numbering in several thousands. These devices make it possible to measure not only absolute position but also very small changes in position over a distance of almost 3 in. (7 cm). A representative encoder of this type includes a compact light source, attached to a moving object, which projects a small spot of light onto a linear CCD array, attached to a second object, where the array is oriented along the direction of relative motion of the two objects (see Figure 1).

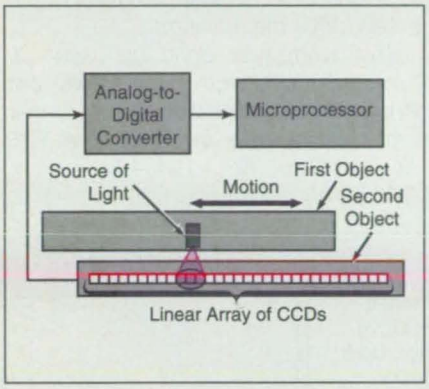


Figure 1. **The Microprocessor Calculates the Position of the Centroid** of the spot of light on the CCD array, to an accuracy of 0.005 pixel or even better.

Light-intensity values for the light spot for each light-sensing pixel of the CCD detector are recorded by a microprocessor through the use of a high-speed analog-to-digital converter. The microprocessor computes the centroid or "center of mass" of the light spot, which provides a direct measure of the position of the moving object with respect to the stationary object.

Figure 2 shows six types of misalignments, of which the following three introduce negligible errors in the position of the centroid:

- Lateral shift — offset in the *y* direction, perpendicular to the direction of motion;
- Separation — a change in the distance in the *z* direction between the source of light and the array;
- Roll — rotation of the array about the *x* axis.

Three other kinds of misalignments can be neutralized by calibration:

- Wedge misalignment — rotation about the *y* axis;
- Longitudinal offset — error in the starting *x* position;
- Twist — rotation of the array about the *z* axis; the error is very nearly proportional to the twist angle.

Because the output of an encoder of this type is based on the computation of the centroid of the light spot rather than on the locations of the edges or peak intensity of the spot, the position of the spot can be resolved to far better than the size of individual CCD pixels. Positional sensitivity of about 50 nm has been demonstrated in the laboratory using a 5,000-pixel CCD with 7-μm-wide pixels. This compares favorably with the best laser-ranging interferometers, which have resolutions of 5 to 25 nm. However, unlike this CCD-based encoder, the laser ranging interferometer provides only incremental measurements, which must be tracked continuously to ensure accuracies of computed absolute positions and is not tolerant of interruptions of either power or of its laser beam. Further, the correctness of position information from the laser interferometer depends on the temperature and humidity of the air column traversed by the interferometric beam, which complicates its operation and affects its accuracy.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center.** *For further information,* ***write in 71*** *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; (301) 286-7351. Refer to GSC-13562.

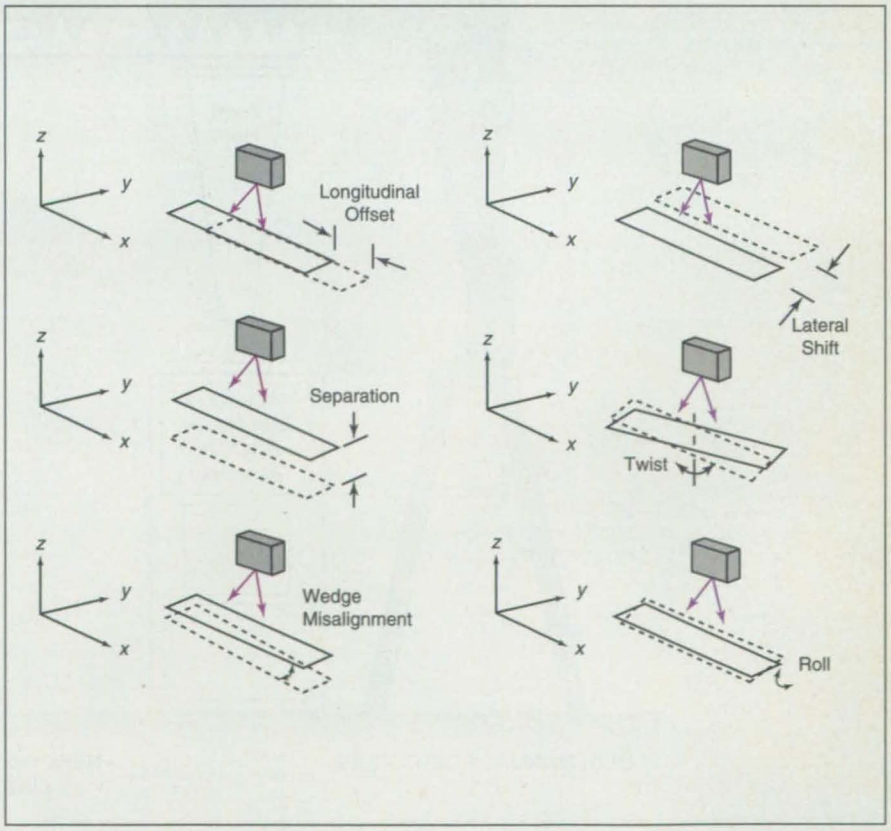


Figure 2. **Some of These Misalignments Introduce Errors**; others do not. For those that do, the errors can be corrected by calibration.

Microwave-Load Positioner Made From a Garage-Door Opener

A repetitive-positioning problem is solved inexpensively.

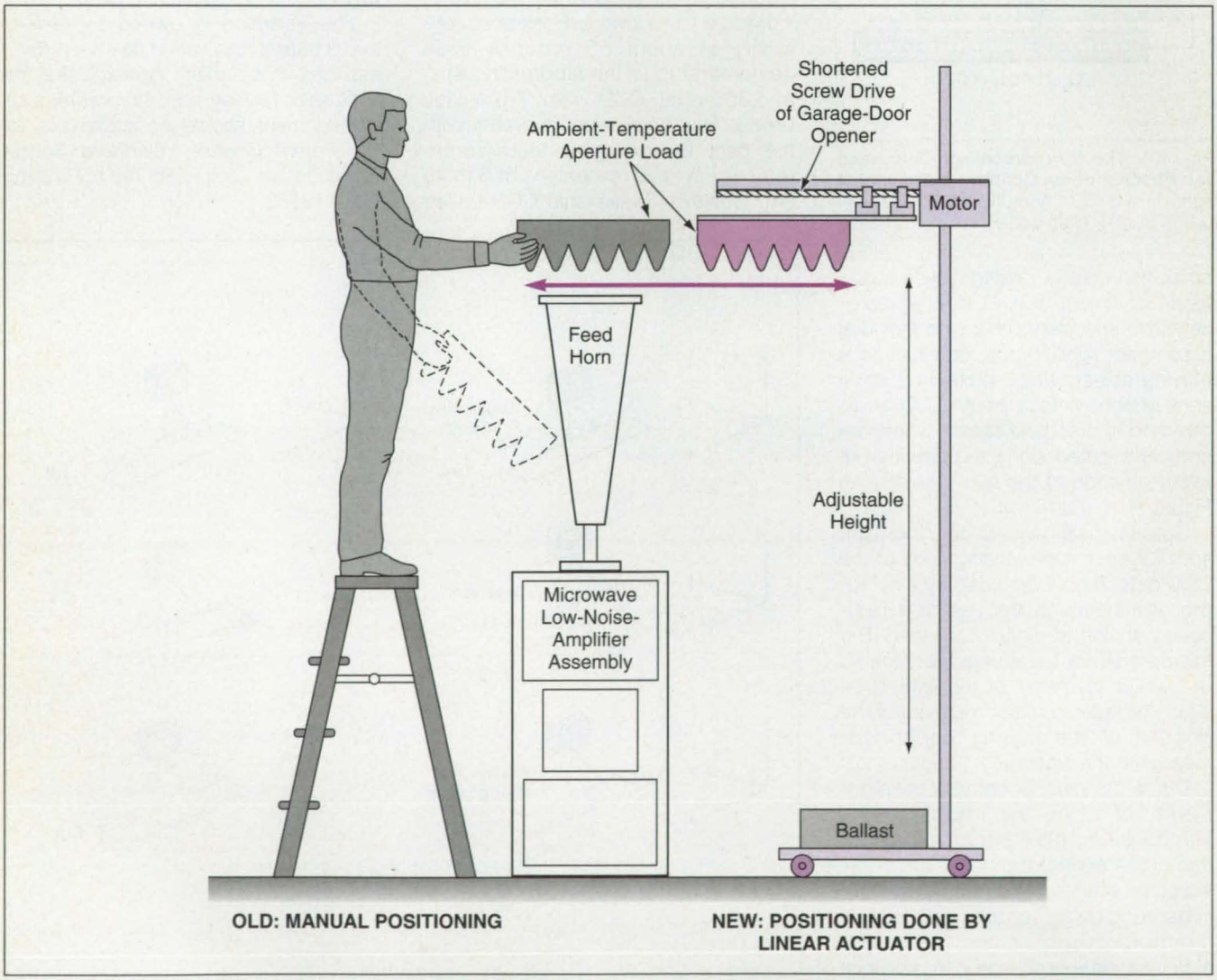
NASA's Jet Propulsion Laboratory, Pasadena, California

A commercial motorized-screw-drive garage-door opener has been modified for use as a linear actuator for repetitive positioning of a microwave ambient-temperature aperture load over a microwave feed horn, and might be useful in other applications in which similar repetitive positioning is needed. Previously, it was necessary for one technician standing on a ladder to alternately hold the microwave aperture load in place over the feed-horn aperture (see figure), then remove the load from over the aperture while another technician took calibration measurements. The modified garage-door opener provides an inexpensive and simple solution to the repetitive-positioning problem, making it unnecessary to expose one of two technicians to the risk and fatigue of working on the ladder; a single technician can readily take the measurements and control the linear actuator. Moreover, the linear actuator lends itself well to use in automated and/or remotely controlled microwave calibration measurements.

In constructing the linear actuator, the garage-door opener was modified in the following ways: (1) the range of travel was reduced by cutting the drive assembly with a hacksaw; (2) the limit switches were repositioned for the reduced range; (3) the radio-frequency-control circuit was disconnected and the manual controls extended; and (4) the garage-door safety interlock was disabled. A 555 timer integrated circuit was added to provide the pulses needed to control the motor-drive circuit.

To facilitate the use of the linear actuator on microwave horns of different heights, a portable, adjustable height-stand was fabricated, and the modified screw-drive assembly was attached to it. In use, the aperture load is attached to a cantilever bracket driven by the screw-drive mechanism.

This work was done by Jason J. Kovatch of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 91*** *on the TSP Request Card. NPO-19454*



The **Portable Linear Actuator** made from a commercial garage-door opener makes it unnecessary for a technician standing on a ladder to repeatedly position a microwave ambient-temperature aperture load.

Motion Control Industry Leaders

PARKER HANNIFIN CORP., COMPUMOTOR DIVISION

Compumotor: A Pioneer in Microstepping and Servo Motor Technologies

Incorporated in 1979, Compumotor earned its reputation for innovation by pioneering microstepping drive techniques to improve the smoothness and resolution of step motor control systems. Compumotor's innovative leadership has continued to produce a complete line of stepper motor and servo drive systems, computer bus-based and standalone controllers, and extensive applications software. Parker Hannifin's acquisition of Compumotor in 1986 fostered breakthroughs in servo technology, followed by AC brushless drives, DSP servo controller techniques, and smart drive controller combinations. Today, after a decade of innovation, Compumotor is among the largest service-oriented and most technologically advanced suppliers of electronic motion controls in the world.

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We provide more than just the products necessary for today's demanding automation requirements. An accessible network of knowledgeable worldwide support resources accompanies every product. To maintain our leadership position in the electronic motion control industry as a complete supplier of electromechanical solutions, it is mandatory that we continue to identify, invest in, and develop those technologies, products, services, and processes that will always keep our products ahead of the competition.

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Compumotor's distinguished product excellence and experience in the electronic motion control industry is as far-reaching as our global support network. Selecting a Compumotor product is much more than a decision for today – it is an investment in your future.

For more information, write to: Parker Hannifin Corp., Compumotor Division, 5500 Business Park Drive, Rohnert Park, CA 94928.

For More Information Write In No. 861

PACIFIC SCIENTIFIC'S AUTOMATION TECHNOLOGY GROUP

The Automation Technology Group was formed in 1995 to coordinate Pacific Scientific's overall business in electric motors, drives, controls, and control system integration. Consisting of four operating groups – three in the U.S. and one in Germany – this organization further strengthens Pacific Scientific's market leadership in motion control products for industrial automation.

Key markets and applications served are medical diagnostic equipment, factory automation, packaging machinery, semiconductor, electronics manufacturing, plastic extruding, and general manufacturing equipment.

The Motor Products Division produces a broad variety of standard and custom high-performance motors, including brushless servomotors, hybrid step motors and permanent magnet DC motors. New brushless servo Sentry™ Series and Powerpac™ step motors provide the highest torques per frame size in the industry.

The Motion Technology Division produces a complete line of brushless servo and step motor drives to precisely control motor torque, speed and shaft position. They recently introduced their SC950 programmable, single-axis, digital brushless servo drive and 6440 microstepping indexer/driver.

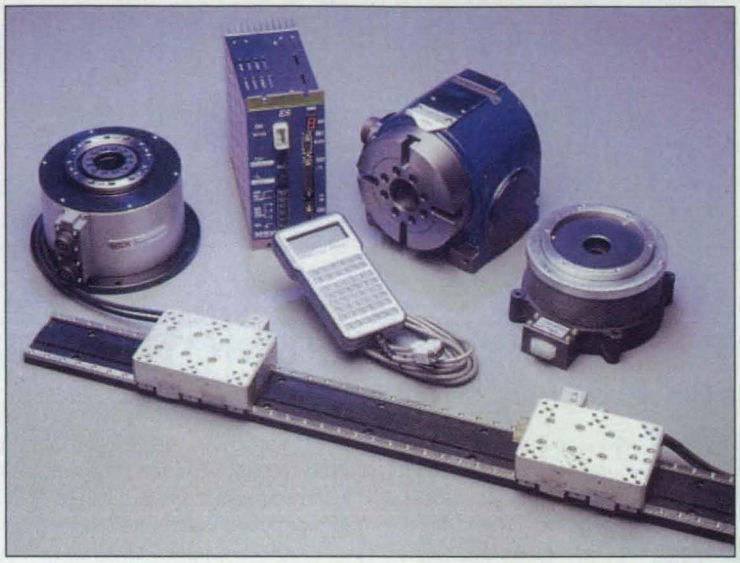
The Automation Intelligence Division designs multi-axis controllers for brushless and stepper drives to control the precise movement of multiple motors used in demanding automation equipment applications. They also design, build and install custom, turnkey machine control automation systems.

Bautz provides application engineering and is the sales office for all products and services in Germany.

For more information, contact Pacific Scientific's Automation Technology Group, 110 Fordham Road, Wilmington, MA 01887; Tel: 508-988-9800; Fax: 508-988-9940.

For More Information Write In No. 865

NSK CORPORATION, PRECISION PRODUCTS DIVISION



NSK Corporation is a world-class manufacturer of precision motion control components and systems. Product offerings include high-precision direct drive rotary and linear motors, X-Y stages, high-speed indexers, ball screws, and linear ball bearing guides. The Precision Products Division is a leading U.S. supplier of high-quality and high-accuracy mechanical and mechatronic components to many industries.

Precise positioning is achieved with both the direct drive YS Series MegaTorque® Motor System and linear Y Series MegaThrust Motor System. The MegaTorque rotary positioner is a direct drive DC brushless servo that provides high speed and extremely accurate positioning capabilities. Gearless design means zero backlash, micron level positioning, and maintenance-free operation. Permanently lubricated bearings can handle axial loads up to 4000 lbs. The system provides high reliability and comes in a variety of sizes and models including waterproof styles. Up to 360 ft./lb. of torque, speeds as high as 180 rpm, and resolution of 2.1 arc/sec. It provides ideal motion control for robots, indexers, automatic assembly, and machining applications.

The YS Series comes complete with interchangeable motor, programmable driver, and cables. It is equipped with an RS-232C interface to make programming simple and convenient. A hand pendant is used to input parameters and programs for the first time or if the motor is not connected to a personal computer.

The MegaThrust Motor is a linear positioner that incorporates the same principles of the MegaTorque motor. Direct drive eliminates backlash and loss of accuracy common in mechanical designs. Standard, multi-function digital servo driver can be interfaced with a variety of remote components and controllers for sophisticated sequencing. Motor generates up to 132 lbs. of force with speeds up to 71 in./sec. with ±1 micron repeatability. Effective stroke lengths up to 100 ft.

For more information, contact NSK Corporation, Precision Products Division, 250 Covington Dr., Bloomingdale, IL 60108; Tel: 800-255-4773; Fax: 603-924-8197.

For More Information Write In No. 862

KOLLMORGEN MOTION TECHNOLOGIES GROUP

New Kollmorgen SERVOSTAR™ Drives Multiple Motor Types

SERVOSTAR is a compact, low-cost, digital servo amplifier that can operate a wide variety of Kollmorgen brushless motor types, simplifying specification, installation, and operation in single- or multi-axis motion control systems.

Carroll Wontrop, Product Marketing Manager, says "SERVOSTAR's advanced control algorithms allow one amplifier to provide optimum machine performance with a wide variety of Kollmorgen motor types. This reduces design time, inventory, and training costs."

SERVOSTAR is well-suited for machine tool, packaging, converting, textile, electronic assembly, document handling, and defense applications. Offered with current ratings from 3 to 55 amps, feedback options include resolver and encoder with Hall effect sensors. Four power supplies with output power ratings from 0.65 to 22.5 kWatts are matched to the amplifier series.

SERVOSTAR utilizes an intuitive windows set-up environment called MOTIONLINK™. MOTIONLINK allows the user to setup and monitor the system by selecting options from a menu. Wontrop also adds, "MOTIONLINK includes an auto setup feature that walks the user through setup to have their system up and running fast." Simple or advanced control algorithms may be selected.

Maximum system performance is achieved when the SERVOSTAR is matched with a Kollmorgen motor:

SERVOSTAR and the Kollmorgen GOLDLINE™ Series are designed for rugged industrial environments. Kollmorgen GOLDLINE brushless servomotors with IP65 sealing offer continuous stall torque from 0.62 to 80.0 lb-ft. The motors are UL-classified and are available in low inertia, medium inertia, and explosion-proof designs.

SERVOSTAR and the Kollmorgen SILVERLINE™ Series are designed for light industrial environments. Mechanically equivalent to NEMA size 23 and 34 step motors, Kollmorgen SILVERLINE series offers a versatile, reliable, and cost-efficient servo solution. These motors offer continuous stall torque from 58.8 to 768 oz-in.

SERVOSTAR and the Kollmorgen Direct Drive RBE Series streamlines machine designs, eliminates mechanical transmissions, and provides faster accelerations and zero backlash for excellent position control. The Kollmorgen RBE Series offers continuous stall torque from 1.49 oz-in. to 28.9 lb-ft.

SERVOSTAR and the Kollmorgen Brushless ServoDisc Platinum XT Series offer continuous stall torque from 83 to 388 oz-in. These motion systems are ideally suited for applications where a flat package is important and ultra-smooth speed and torque control are required.

Kollmorgen Motion Technologies Group is a leading international manufacturer of precision motion control products. Kollmorgen is traded publicly on the New York Stock Exchange (KOL).

For more information, call 800-77-SERVO or fax to 540-731-0847.

For More Information Write In No. 860

MITSUBISHI ELECTRONICS AMERICA, INC.

MR-C High-Performance, Low-Cost Micro-Servo Drive

Mitsubishi Electronics' new MR-C brushless servo system is a high-function, economical alternative to 5-phase or microstepping drives. The compact size and low cost of this new series of servo motors and amplifiers virtually eliminate the need for stepper drives.

To improve the performance and meet the increasing demands of positioning applications, stepper manufacturers have added encoders and features such as damping and viscosity control – essentially pseudo-like "servo" capabilities, but without all the benefits of precise servo control. Conversely, Mitsubishi was able to develop a servo package that is easy to use, low cost, and extremely compact, yet still offers advanced servo functions that traditional stepper drives will never be able to offer.

Smallest Amplifier Yet

By incorporating a new miniaturized intelligent power module with a single microchip processing unit (CPU), Mitsubishi has produced its smallest sized servo amplifier yet. The two amplifiers, 100 and 200 Watts, are available in single-phase, 110 and 230 VAC versions. They are only 1.57 inches wide, 5.12 inches high, and 3.94 inches deep, allowing customers to mount more units in smaller spaces.

The new MR-C servo motors include advantages of innovative technologies in all three areas of motor design. The encoder is reduced in size by eliminating one of two printed circuit boards. Rotors produce more power in smaller packages by using neodymium-iron-boron magnets. Stators are specially constructed to produce even more power than before. The smallest motor, 30 Watts and 300 RPMs, is only 1.57 inches in diameter and 3.56 inches long.

The MR-C has 100% torque from zero to almost 4,500 RPM, and 400% torque available from 0 to almost 4,500 RPMs. This superior torque capability allows the MR-C to far surpass the ability of steppers to accelerate and especially decelerate from any speed.

The hardware platform is the same powerful 32-bit reduced instruction set microprocessor (RISC) used in Mitsubishi's higher function MR-H servo drive, and provides high performance with a frequency response range of 200 Hz.

The patented real-time adaptive control scheme is the heart of the system's operation, eliminating the need for any retuning following a load change. Using a 32-bit RISC processor, the algorithm provides an advanced servo that responds to the diverse and demanding needs of the motion control market. Compared to traditional systems, which required constant adjustment by hand, the MR-C servo amplifier offers a unique and efficient alternative.

As a bonus, an optional RS-232C interface kit allows use of an optional Windows-based software package that allows you to diagnose the drive and display waveforms from your PC.

For more information, contact Mitsubishi Electronics America, Inc., 800 Biermann Ct., Mt. Prospect, IL 60056-2173; Tel: 708-298-9223; Fax: 708-298-0567.

For More Information Write In No. 863

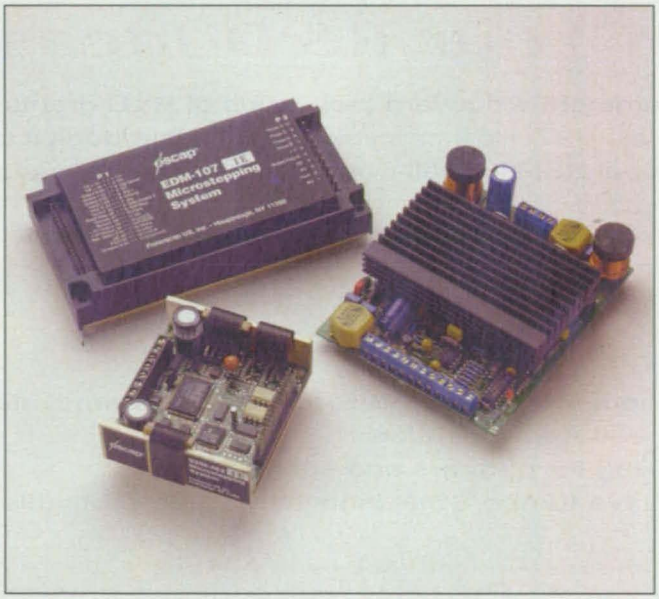
PORTESCAP US, INC.

From mind to motion.

Founded in 1931 in La Chaux-de-Fonds, Switzerland, as Universal Escapement Ltd., the company was until the end of the 50s, devoted exclusively to the manufacture of products for the clock- and watch-making industry. The most famous product was the Incabloc® shock absorber for mechanical wrist watches. In 1963, the company name was changed to Portescap. From the start, innovation, progress, and the mastering of microtechnology led to numerous developments in new, emerging markets. With modern technologies and outstanding products, Portescap has become one of the world's leading specialists in the field of high performance electromechanical drive systems.

As a result of modern microtechnology escap® Ironless Rotor DC motors, Disc Magnet Stepper Motors, and their complementary products such as gearboxes, tachometers, optical and magnetic incremental encoders and motor drive circuits provide an extensive range of motion control solutions. Through continuous research and development, they satisfy the numerous requirements of an ever-faster-moving industrial world.

There are always certain specific problems which require a fully custom-made solution. With its knowledge of electronics, electromagnetism, and high precision micromechanics, Portescap, working closely with the customer, is able to develop solutions to meet individual needs.



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For More Information Write In No. 864

ROCKWELL AUTOMATION/ELECTRO-CRAFT

Rockwell Automation announces the introduction of a new Electro-Craft brand drive product.

The BRU-Series Advantage Line family of universal drives has been extended to include three new micro versions. With the addition of the micro drives, Rockwell Automation/Electro-Craft becomes the first U.S. manufacturer of a compact digital servo drive. This highly anticipated entry into the Japanese-dominated market for fully functional small servo drives places the Advantage Line in front when graded on performance, functionality, and ease-of-use.

The new Advantage Line micro-size drives pack virtually the same functionality and performance of its larger counterparts into a package 25% of their volume. With BRU Master, its Windows-based software, or the optional TouchPad MMI, the Advantage Line can be configured to accept a variety of control commands. These include analog velocity input, preset velocities and positions, step and direction, master encoder following and direct digital commands via the serial port using the Advantage Line host language. The small size and exceptional performance make it an attractive solution for traditional servo markets and a high-performance alternative for stepper applications.

The BRU-Series Advantage Line drives, now available in seven power ratings from 0.5kW to 7.5kW, are designed for reliability and performance by making extensive use of large-scale integration with third-generation intelligent power modules and high-density custom ASICs. Advanced multi-processing provides leading-edge velocity loop update rates and all digital current, velocity and position loops, and an advanced, low-speed control algorithm. BRU Master, the Advantage Line's productivity tool, is not only an effective setup interface, but it also provides a comprehensive set of diagnostic and system integration tools, data displays such as on-screen digital oscilloscope, quick set-up screens, and on-line help. With UL and C-UL listings, and the CE mark for compliance with the European Directives, the BRU-Series Advantage Line is a drive family that is designed for global markets to meet global standards.

For more information, contact Rockwell Automation/Electro-Craft, 6950 Washington Ave. South, Eden Prairie, MN 55344; Tel: 612-942-3789; Fax: 612-942-3711.

For More Information Write In No. 866

Improved Plasma-Spraying Thermal-Barrier Coating Technique

Low-pressure inert-gas plasma spraying results in less spalling and longer life.

Marshall Space Flight Center, Alabama

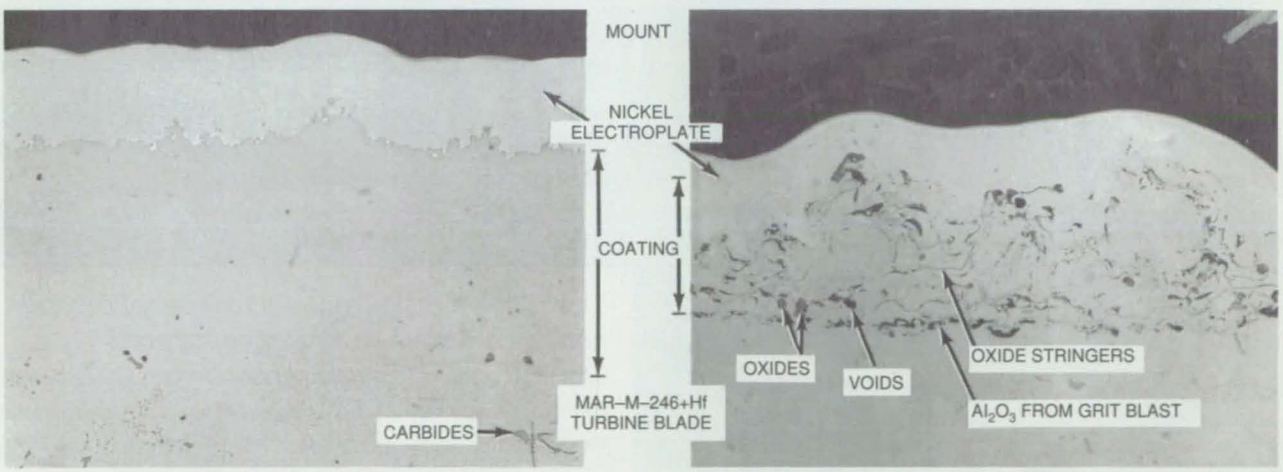
A vacuum plasma-spraying process (more precisely, a low-pressure argon plasma-spraying process) applies improved thermal-barrier coatings to turbine blades. A coating of this type (see figure) comprises (a) a thermal-barrier layer of 92 weight percent Z_rO_2 mixed with 8 weight percent Y_2O_3 on top of (b) a bonding layer of NiCrAlY. These thermal-barrier coatings have been developed for the turbine blades of the high-pressure fuel turbopump of the main engine of the space shuttle; they could also be used to prolong the service lives of turbine blades and other thermally stressed components in terrestrial gas turbines, jet engines, and automotive engines.

Prior to the development of the present vacuum plasma-spraying process, the thermal-barrier coatings in the space shuttle application were applied in an air plasma-spraying process. The coatings were observed to spall after limited numbers of engine start/stop thermal transients. Coatings applied by the vacuum plasma-spraying process endured five times as many cycles. The early spalling in the case of the air-plasma-sprayed coatings has been attributed to the formation of oxides at the surfaces of the blades and throughout the NiCrAlY layers. The oxides are brittle and weak, leading to premature failure of entire coatings.

Such oxidation does not occur in the vacuum plasma-spraying process. Because the powders used in the vacuum plasma-spray process are finer than those used in the air plasma-spraying process, the vacuum-plasma-sprayed coatings are less rough. As a result, turbine efficiencies are improved and rates of heat transfer to the coated turbine blades are reduced. The vacuum plasma-spraying process also enables the use of preheated substrates (the turbine blades) and of negative-transfer-arc cleaning of the substrates prior to deposition to achieve dense, strongly bonded coatings (see figure).

This work was done by Richard Holmes and Frank Zimmerman of **Marshall Space Flight Center** *and Timothy N. McKechnie of Plasma Processes, Inc. For further information,* ***write in 32*** *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; (205) 544-0021. Refer to MFS-30081.



This **Photomicrograph Shows a Cross Section** of a thermal-barrier coating that was (a) vacuum plasma sprayed onto a turbine blade made of MAR-M-246+Hf alloy and (b) air plasma sprayed on the same alloy.

Eliminating Greasing of Steel Parts for Storage

The subsequent use of harmful degreasing solvents can be minimized or eliminated.

Marshall Space Flight Center, Alabama

Experiments have shown that in at least some applications, specially designed flexible covers can prevent rusting of steel parts in storage. Thus, the covers eliminate the need for the traditional technique of coating steel parts with grease to protect them against corrosion during storage. In so doing, the covers also reduce or eliminate the need for harmful degreasing solvents like 1,1,1-trichloroethane to remove grease after storage in preparation for painting, application of adhesives, or other subsequent treatment.

In the original application for which the technique of using the covers was devised, the steel parts are components of rocket-motor cases that are undergoing refurbishment. In this application, the covers are used to store the parts between grit blasting and subsequent painting and bonding processes. A cover is fitted on the part (see figure)

A **Flexible Cover** prevents rusting of a large steel cylinder (part of the case of a solid-fuel rocket motor) by enclosing it in dry air.

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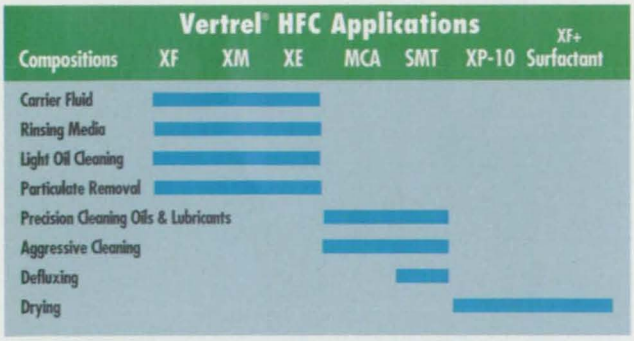

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and purged with dry air. A desiccant inside the cover absorbs moisture during storage.

This work was done by Neil W. Sagers of Thiokol Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 77*** *on the TSP Request Card.*
MFS-31000

Analyzing Data From On-Machine Inspection

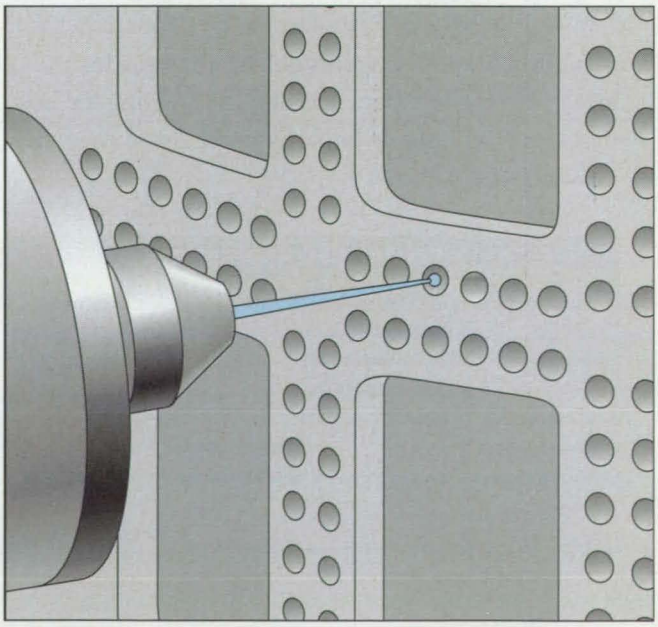
Software automatically processes data from many machines.

Marshall Space Flight Center, Alabama

A modified version of the GEOMET 300/PC* computer program collects dimensional inspection data from a group of machine tools, analyzes the data, and presents the analyses in a standardized format. The data are generated during on-machine inspection, in which electronic touch probes measure the coordinates of points on the surface of a workpiece while the workpiece is still on the machine tool (see figure). The software eliminates the need for manual calculations and makes it unnecessary to develop special software to analyze dimensional inspection data for each distinct workpiece size and shape.

The software implements a data format that ensures that a data file that pertains to a given workpiece contains enough information to enable completion of an analysis cycle, without intervention by a machine operator or an inspector. The software also ensures that the data remain traceable, even if part of the overall machining/inspection/computing system should fail.

The software was installed in a 386 personal computer connected to a factory distributed-numerical-control computer network so that it can communicate with computers on the shop floor and with the network file server. Coordinate data are uploaded from each machine tool to the file server. A control program detects the presence of new data on the file server and orders the execution of GEOMET 300/PC, indicating to the 386 personal computer the name of the set of data, the inspection program to be used, and the destination for the results of the analysis. (Usually, the results are sent to the inspector on



A **Touch Probe** on a machine tool measures the positions and diameters of drill pilot holes on a workpiece.

the shop floor, but interested engineers can also request the results through the network file server.) With the control program running continuously, analyses are performed automatically.

* "GEOMET" and "GEOMET 300/PC" are registered trademarks of the GEOMET SYSTEMS Software Division of Helmel Engineering Products, Inc.

This work was done by Thomas A. Koehnlein of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 73*** *on the TSP Request Card.*

MFS-30007

Closing Out Edges of Fibrous Silica Insulating Blankets

Surface fabrics or foils are attached to segmented ceramic frames.

Ames Research Center, Moffett Field, California

In an improved method of finishing the edges of thermally insulating blankets made largely or entirely of fibrous silica, surface fabric, or foil layers are attached to segmented ceramic frames. Typically, such a blanket includes a fabric or foil layer on one surface designed to be exposed to high temperature, a bulk filling of fibrous material, and a fabric layer on the opposite, cooler surface, which is designed to be adjacent to an object to be protected against high temperature.

In the prior method of finishing (closing out) the edges of such a blanket, flaps of the fabric layer of the surface designed to be hotter in use were wrapped around the edges of the blanket onto the fabric layer of the surface designed to be cooler in use; in the overlap, the two fabrics were either stitched together or bonded by use of a flexible adhesive like room-temperature-vulcanizing (RTV) silicone rubber. In comparison with the prior method, the improved method offers better edge definition plus reduced flow of heat from the hotter to the colder surface in a convective environment. Moreover, the segmentation of the frame enables the blanket to retain much of its flexibility.

Figure 1 illustrates a version of the method that is suitable for a blanket with a metal foil layer on the surface designed to be hotter in use, and a ceramic fabric layer on the surface designed to be colder. The segments of the frame are preferably machined from tiles of a fibrous refractory composite insulating material. Prior to attachment of the blanket, a protective ceramic material that contains colloidal silica is applied to the segments of the frame and baked on. This coating provides (1) densification to enhance the subsequent attachment of the fabric surface layer(s) with an adhesive and (2) increases the thermal emittance of the exposed exterior portions of the frame.

In preparation for insertion of the blanket in the frame, a peripheral strip of the bulk fibrous filling is removed to expose edge strips of the foil and fabric surface layers. The bottom surface of the frame is coated with RTV or other suitable flexible adhesive, placed around the blanket, and pushed down onto the edge strip of fabric with a pressure of about 3 psi (21 kPa). After the adhesive has cured, clips made of a metal alloy compatible with the foil are inserted in grooves on the frame segments to hold the foil in place by pushing it against the

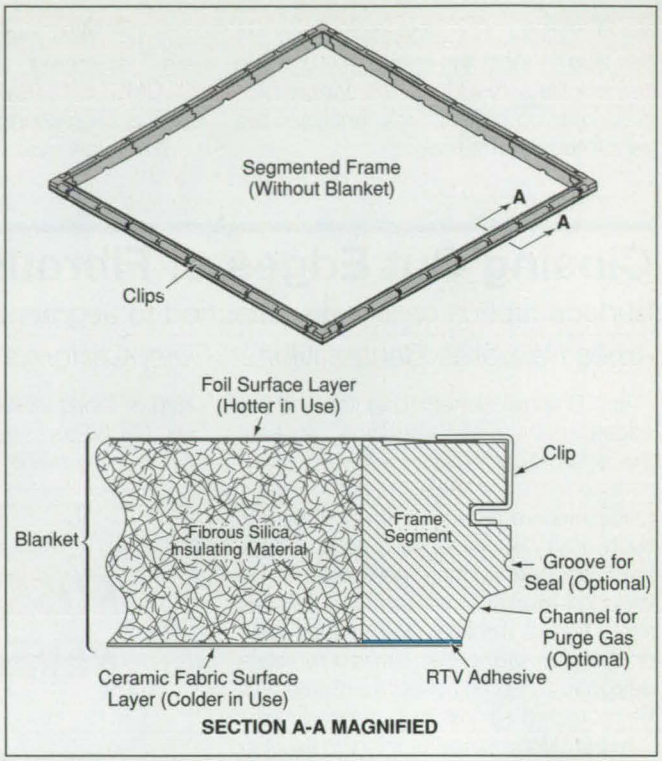


Figure 1. **Clips and Adhesive** are used to bond the foil and ceramic-fabric surface layers, respectively, to the segments of the frame.

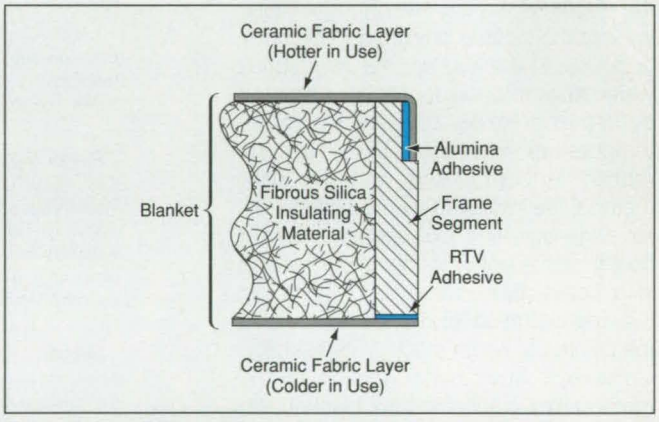


Figure 2. **Two Different Adhesives** are used to bond the hotter- and colder-surface ceramic fabric layers to the segments of the frame.

top surface of the frame. A ceramic adhesive is then applied to secure the clips in the grooves.

Figure 2 illustrates another version of the method that is suitable for a blanket with ceramic fabrics on both surface layers. This version is similar to the preceding one in that it involves similar coating of the frame segments and similar adhesive bonding between the lower surface of the frame and the ceramic surface layer designed to be cooler in use. However, clips are not used in this version; instead, the fabric layer on the surface designed to be hotter in use is folded over the top outer edge of the frame, where it is bonded in a shallow recess by use of an alumina adhesive.

This work was done by D. J. Rasky and D. A. Kourtides of **Ames Research Center.** *For further information,* ***write in 7*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,545,273). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-14027.

Dispenser for Liquid Corrosion Inhibitor

Marshall Space Flight Center, Alabama

A simple dispenser has been designed to enable fast, easy, leak-free application of a liquid corrosion inhibitor in tight-tolerance crevices. This device is needed because considerations of safety in the use of the particular corrosion inhibitor dictate that the substance remain in liquid form and not be atomized. Satisfying all applicable health, safety, and environmental requirements, the dispenser can be made from off-the-shelf parts. It is composed of a hand-pump sprayer, connected via a polytetrafluoroethylene tube to a syringe with a blunt-tip needle. The dispenser might also be useful for dispensing paints, glues, lubricants, fuels, cleaning solutions, and other hazardous and nonhazardous liquids into confined spaces.

This work was done by Gene E. Morgan, Carole A. Elm, and S. Rachel Khoshbin of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 57*** *on the TSP Request Card.*
MFS-30094

Removal of Residual Forming Oil

Marshall Space Flight Center, Alabama

A process for removing residual forming oil from metal tubes has been developed. In the first step, the tubes are presoaked in a mild akaline cleaning liquid at ambient temperature for two hours or longer: the long soak increases the fluidity of the forming oil sufficiently that subsequent internal flushing causes most of the oil to be dislodged from the insides of the tubes. The oil sludge is separated from the cleaning liquid by use of a centrifuge, so that the liquid can be reused and the amount of hazardous waste is minimized.

This work was done by Benjamina G. Montoya and Michael L. Cassidenti of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 44*** *on the TSP Request Card.*
MFS-30040

Technique for Inspecting Partial-Penetration Welds

Lyndon B. Johnson Space Center, Houston, Texas

A technique for nondestructive inspection of partial-penetration welds involves the use of computed x-ray tomography to obtain cross sections. In a demonstration of the technique, an x-ray source with a 0.010-in. (0.25-mm) aperture was used to take pictures of a part at intervals of 0.005 in. (0.13 mm). It was found that the depth of penetration of a weld in the part could be measured accurately by use of this technique.

This work was done by John T. Litwinski of Rockwell International Corp. for **Johnson Space Center.** *For further information,* ***write in 78*** *on the TSP Request Card.*
MSC-22348

Software for Parallel Simulation of Discrete Events

A simulation analyst need not be concerned with details of computing equipment.

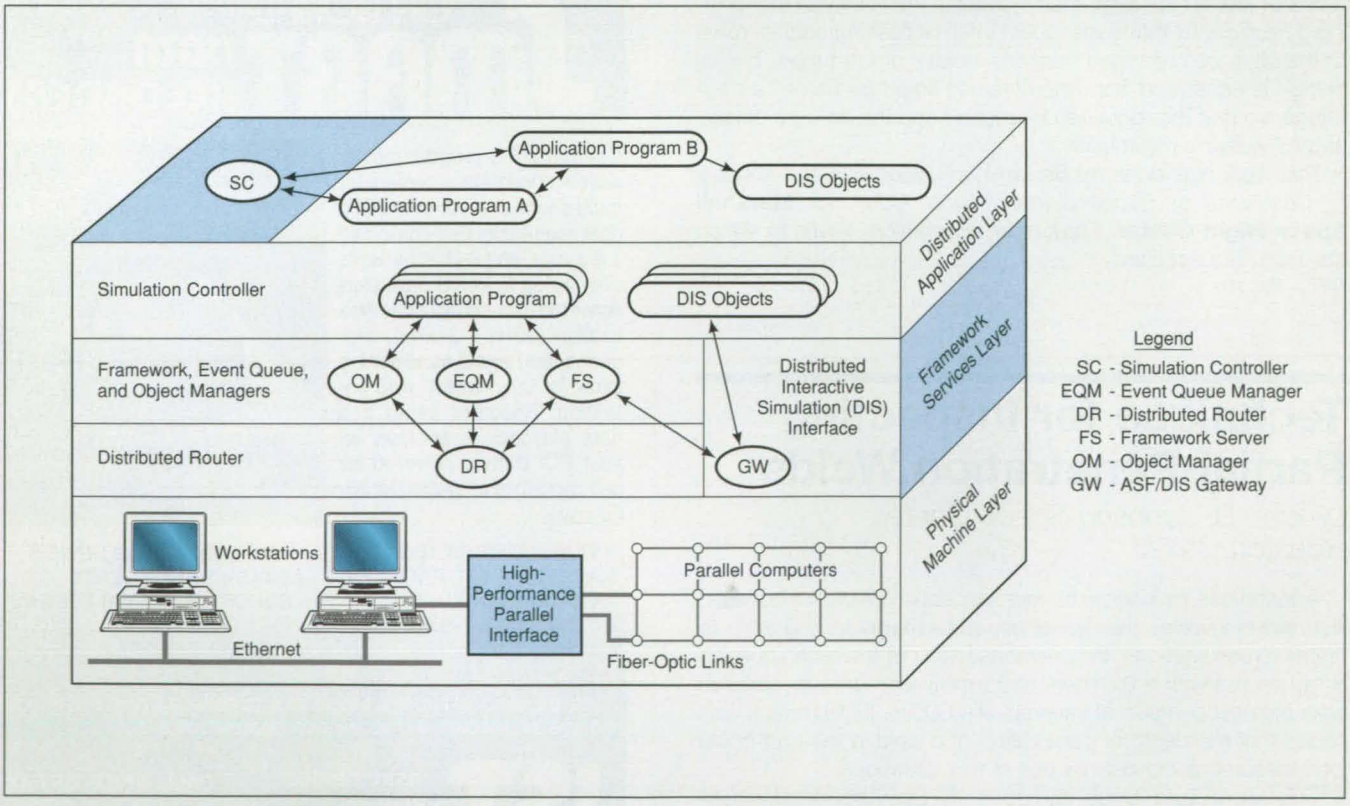
NASA's Jet Propulsion Laboratory, Pasadena, California

The Advanced Simulation Framework (ASF) is a system of software that provides a programming environment for simulation of discrete events on a network of multiple computers operating in parallel. Parallel processing (as distinguished from serial processing on single computers) can increase the achievable scale and scope of a simulation. Heretofore, parallel simulation of discrete events has been inhibited by the difficulty of developing parallel-simulation software, and simulation analysts had to take account of limits of performance of available computers. The ASF facilitates the development of software for specific simulations and enables an analyst to concentrate on the simulation and analysis, without concern for the details of the computing equipment.

The ASF enables the simulation of discrete events by use of interconnected UNIX-based workstations and distributed-memory parallel computers. From the analyst's perspective, a simulation application program consists of a set of C++ language objects and a simulation scenario. The scenario describes the available workstations and parallel computers, the initial state of each simulation object, and one or more initial events. When the objects and scenario are placed in the ASF, the application programs of the simulation are executed by parallel processing.

The ASF includes the Simulation Controller program, which serves as an interface between the user and the ASF-based simulations. The Simulation controller program provides an X-window/Motif-based control-panel display that enables the user to monitor and control a simulation; the user can start or stop a simulation, monitor the states of the application programs in the simulation, and change the simulation by scheduling simulation events.

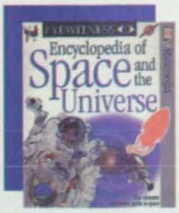
Time-stamped messages between nodes (that is, computers) serve as part of the means for enforcing causality of events simulated on different nodes. The ASF includes two alternative algorithms for enforcing causality. One is called the Fixed Time Bucket algorithm and implements a conservative approach in which all events in one



A **Computing System for Parallel Simulation of Discrete Events** as implemented by the ASF can be represented schematically as a layered software/hardware structure.

From the publishers of *NASA Tech Briefs*

Holiday Gift Ideas



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period of simulated time (called a "time bucket") are completed on all nodes before proceeding to the next time bucket. The other, called the Breathing Time Bucket Algorithm, implements an optimistic approach, in which events are processed by all computers until one of them generates an event that must be taken into account by another computer. At that point, all computers must be synchronized in simulated time, and those that have processed ahead of the synchronized time must roll back their simulations to that time. The simulation then resumes.

ASF server software resides at each node. This software initializes simulation services and maintains information on the current status of the simulation application program running at that node. The server software at each node also cooperates with the simulation controller software at the user's node to provide monitoring and control of the overall simulation process. This cooperation includes a network-wide event-management service that operates through an event-queue management component of the software at each node. Similarly, a network-wide object-management service operates through an object-management component of software at each node. ASF also provides an interface to the IEEE Standard Distributed Interactive Simulation (DIS) protocol. This interface permits ASF hosted constructive simulation applications to interact with virtual simulations.

This work was done by Peggy Li, Raymond Yeung, D'arcy Tyrrell, and Nadia Adhami of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 61*** *on the TSP Request Card. NPO-19341*

Planning Optimal Collision-Avoiding Trajectories

Obstacles, dynamics, and constraints are taken into account.

NASA's Jet Propulsion Laboratory, Pasadena, California

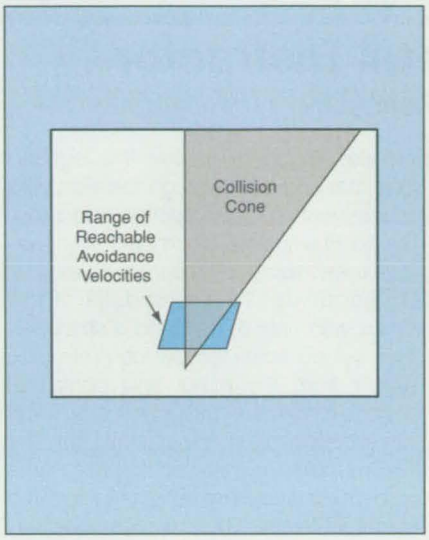
A method of automated planning of the trajectory of an object equipped with control actuators involves (1) taking account of the trajectories of other objects (obstacles), (2) taking account of the dynamics of the controlled object and of the constraints upon the actuators, and (3) optimizing the trajectory in the sense of minimizing the time it takes the controlled object to travel from an initial location to a goal. In a typical application, the controlled object would be a robot and the obstacles would be other moving and/or stationary objects (possibly including other robots) in a factory. The method could also be used in other applications like controlling land, air, or sea traffic.

This method is built on the method described in "Planning Motions To Avoid Moving Obstacles" (NPO-19031), *NASA Tech Briefs*, Vol. 19, No. 4 (April 1995), page 70. To recapitulate: With respect to the controlled object and one of the obstacles at their present positions, the collision cone (in velocity space) is defined as the conical range of velocities at which continued motion will eventually cause the object and obstacle to collide. Thus, to prevent a collision with a given obstacle, the object

must avoid the collision cone, which can be regarded as a velocity obstacle. In the case of a single obstacle moving at constant velocity, one can prevent a collision by choosing a simple straight-line trajectory outside the collision cone.

When multiple obstacles are present and/or the obstacle(s) accelerate(s), a simple constant-velocity, straight-line trajectory may not suffice to prevent a collision. Then it becomes necessary to plan a multiple-segment trajectory, such that on the ith segment (which is of duration Δt_i and begins at time t_i), the controlled object can avoid the collision by maneuvering to a safe velocity, called an "avoidance velocity," that lies outside the collision cone at t_i. In planning the collision-avoidance maneuver, it is necessary to consider the range of feasible accelerations at time t_i, given the dynamics of the controlled object and the constraints upon the control actuators at that instant. The range of feasible accelerations determines the range of reachable avoidance velocities — the range of velocities that can be reached between t_i and $t_i + \Delta t_i$ and that lie outside the collision cone at time t_i (see figure).

The state space of the controlled object is represented by a tree of all such avoidance maneuvers at discrete times t_i. The nodes on this tree correspond to the positions of the robot at these discrete times. The operators that expand a node at time ti into its successors at time $t_i + \Delta t_i$ are the velocities in the ranges of reachable avoidance velocities. The edges of the tree correspond to the avoidance maneuvers.



A **Collision Cone in Velocity Space** at time t_i contains a range of velocities that would eventually lead to a collision. The reachable avoidance velocities are those velocities outside the collision cone that can be reached in the short time between t_i and $t_i + \Delta t_i$, given the range of feasible accelerations.

An initial, approximate version of the multiple-segment trajectory is chosen by a global search over the tree. In this initial trajectory, the velocity is represented as changing abruptly from segment to segment; this is physically unrealistic, and thus unsuitable for optimization. Accordingly, prior to optimization, the initial trajectory is smoothed over all the segments by a polynomial interpolation. The smoothed trajectory is then refined by use of a dynamic optimization algorithm that accounts for the dynamics, constraints, and obstacles. In the optimization algorithm, which is of the steepest-descent type, the state inequality constraints are transformed into state-dependent control constraints.

This work was done by Paolo Fiorini of Caltech and Zvi Shiller of UCLA for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 72*** *on the TSP Request Card.*
NPO-19831

Intramedullary Skeletal Distractor

John F. Kennedy Space Center, Florida

The intramedullary skeletal distractor (ISKD) has been proposed as an improvement over the fixture that, heretofore, has been used in surgically extending a femur that has been damaged and fails to grow as fast as does the femur in the opposite leg. The basic strategy of such extension is to make a cut across the femur at about its midlength, then to install a fixture and use it to push the two pieces of the femur apart lengthwise at a controlled rate to maintain a slight gap, preventing the two pieces from growing back together until the desired overall length is achieved. The fixture used heretofore includes portions outside the leg and rods that protrude through the skin, with consequent risks of infection and injury. The ISKD would be a compact stainless-steel telescoping-rod mechanism mounted lengthwise in the medulla of the femur, with only screws and a small bellows-button actuation device protruding slightly from the femur and contained entirely within the patient's body. With the exception of the midlength cut, the ISKD would be installed by the same procedure used to install a metal rod in a fractured femur. The extension mechanism within the ISKD would include a drive screw driven by a gear train with an input ratchet wheel. Pressing the bellows button through the skin would advance the ratchet, turning the gears and drive screw and thereby extending the telescoping rods. A metal bellows would maintain a seal between moving components to ensure reliable operation.

This work was done by Fred Jankowski and Alan C. Littlefield of **Kennedy Space Center**. *For further information,* ***write in 14*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11708.

Therapeutic Oxygen System for Use During Rescues

John F. Kennedy Space Center, Florida

A gas-supply manifold system with a pressure regulator, flowmeters, hoses, valves, and water (bubbler) bottles supplies humidified oxygen from a liquid-oxygen source to as many as four patients during a long medical-evacuation flight. The present system, designed for use aboard a C-130 aircraft, is based on an older system designed to supply oxygen to as many as three patients aboard a C-141 aircraft. Advantages of the present system over the older system include more accommodating dimensions and layout, easy-to-locate flowmeters, and nonrebreathing oxygen masks for conservation of oxygen. When not in use, the present system can be stored and carried in a case half the size of the large suitcase used to store and transport the older system. The present system can readily be adapted for use in other medical-evacuation situations on land or aboard aircraft or boats.

This work was done by Barry C. Slack of **Kennedy Space Center**. *For further information,* ***write in 86*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11771.

Low-Spillage Metabolic Feeder

Most of the unconsumed food remains in the feeder.

Ames Research Center, Moffett Field, California

An improved feeder has been developed for use in experimental studies of the metabolism of small animals. The feeder is an integral part of a cage (called a "metabolic cage") in which an animal is confined for experiments on its nutritional state and its gastrointestinal and renal functions. In addition to the feeder, the metabolic cage includes a funnel below a floor grate for collection of urine and feces.

In principle, the amounts of feces and urine produced can be measured directly, while the amount of food consumed can be calculated as the difference between the amount supplied and the amount that remains at the end of the observation period. However, the calculation of the amount of food consumed is distorted by the amount spilled; moreover, some of the spilled food can become mixed with urine and feces, with the result that both quantitative and qualitative analyses of these products also yield distorted results. Thus, minimization of spillage is necessary for accurate metabolic studies.

Unlike older feeders, the present feeder is designed to minimize spillage. The feeder is attached to the cage via a hole in one wall (see figure). To gain access to the feeder, the animal crawls through the hole and through a short tunnel to a food cup. The food cup is held by guides attached to the tunnel; the guides and the food cup are tilted away from the tunnel so that food in the cup gravitates away from the opening between the tunnel and the cup.

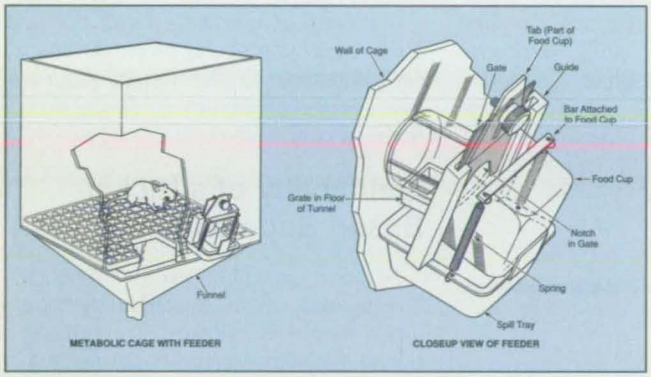
The opening between the tunnel and the food cup is partly obstructed by a notched gate, the height of which is

adjusted for the specific animal so that only the animal's head (and not the rest of its body) can enter the cup. The tunnel is made narrow enough that the animal cannot turn around; after eating, it must back out of the tunnel. These features minimize spillage during feeding by preventing the animal from entering the cup and kicking food out.

Of course, the animal might still throw some food out of the cup while eating, and/or it might drop some food while backing out of the tunnel after eating. To catch this food, a grate in the floor of the tunnel with a spill tray is placed below the tunnel, held in place by springs. The amount of food caught in the spill tray can be added to the amount remaining in the food cup to obtain a more accurate measure of the amount of food that remains unconsumed.

This work was done by JuliAnn Evans, Daniel P. Gundo, Jennifer S. Harper, Gerald M. Mulenburg, and Thomas L. Skundberg of **Ames Research Center.** *For further information,* ***write in 36*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,499,609). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-12063.



The **Tunnel and Gate** allow little maneuvering room, preventing the animal from throwing food out while eating. Food spilled through the grate in the floor of the tunnel is caught in the spill tray.

Isokinetic-Exercise Test of Proprioception

Ames Research Center, Moffett Field, California

A test of human proprioception involves the use of a computer-controlled isokinetic ergometer. A subject with an arm or leg connected to the ergometer watches a video monitor that displays a bar graph indicative of the position of the arm or leg, and a horizontal line (goal) indicative of unexpected pseudorandom variations of the variable torque (load) applied by the ergometer to the subject's limb. During these load variations, the subject strives to keep the position of the bar graph coincident with the goal, depending on the specific test. The subject's responses are recorded and processed; a score is derived from the deviation of the subject's arm or leg position from the goal. A perfect proprioceptive response, where there is perfect tracking by the bar graph on the goal, is set at 100.

This work was done by J. E. Greenleaf of **Ames Research Center,** *P. T. Dempster and M. Bond of Loredan Biomedical, Inc., and E. M. Bernauer of the University of California. For further information,* ***write in 89*** *on the TSP Request Card.*
ARC-13389

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited.

Manufacturing/ Fabrication

Development of a Method for Depeaking Thick Butt Welds

Two reports address the issue of peaking in butt welds between thick structural members, with a view toward developing a method for depeaking. Typically, butt welding of two thick members starts with fusion tack welding of mating tabs on the members, followed by weld passes in which filler material is laid down in the spaces that remain on either side of the fused tabs. Further passes are made on both sides until the joint between the two members is solid through the thickness. Peaking is an unintended angular displacement about the weld line, caused by asymmetry of residual stresses from thermal contractions of the filler and parent materials.

This work was done by Vincent Verderaime and Robert Vaughan of **Marshall Space Flight Center.** *To obtain copies of the reports, "Weld Depeaking Process Through Depeaking Index Model" and "Aluminum U-Groove Weld Improvements Based on Experimental Stress Behavior,"* ***write in 51*** *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; (205) 544-0021. Refer to MFS-31099.

Machinery/Automation

Influence of Contact Ratio and Tooth Form on Gearbox Noise

Two reports describe experiments that were conducted to determine levels of gear-mesh noise associated with various gear-tooth geometries. The experiments were conducted on nine sets of gears that were as nearly identical as possible in all respects except for tooth forms and contact ratios. All measurements were taken in the same gearbox under nominally identical conditions. For each set, noise measurements were performed at various combinations of load and speed.

This work was done by Fred B. Oswald of **Lewis Research Center**; *Joseph W. Lenski, Jr., Robert H. Spencer, and Raymond J. Drago of Boeing Helicopters; and Mark J. Valco of the Vehicle Propulsion Directorate of the U. S. Army Research Laboratory. To obtain copies of the reports, "Influence of Gear Design Parameters on Gearbox Radiated Noise" and "The Relative Noise Levels of Parallel Axis Gear Sets With Various Contact Ratios and Gear Tooth Forms,"* ***write in 24*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16299.

Materials

Cleaning Soot From Oil Paintings With Monatomic Oxygen

A report presents information on the topic of "Atomic Oxygen Removes Varnish and Lacquer From Old Paintings" (LEW-16031), *NASA Tech Briefs*, Vol. 20, No. 4 (April, 1996) page 61. Additional information is available, which includes (1) discussion of the retardation of attack by atomic oxygen on oxide-based pigments, (2) the ability of the atomic oxygen to attack low as well as high spots, (3) mention of some pigments (alizarin crimson, sap green, and prussian blue) as being considered by conservators to be difficult to maintain during restoration by conventional swabbing with solvents but being unaffected by atomic oxygen, (4) mention of other materials (e.g., silver) that cannot be cleaned by atomic oxygen because they form friable oxides, (5) a proposed concept for rastering of atomic oxygen beams to clean large paintings, (6) using monatomic oxygen to clean objects other than paintings (e.g., to sterilize medical instruments or remove excess adhesive materials from aircraft engine nacelles), and (7) the need for research on ancillary issues like the effect of the cleaning process on aging and the shrinkage induced by dehydration of large paintings in a vacuum.

This work was done by Bruce A. Banks and Sharon K. Rutledge of **Lewis Research Center.** *To obtain a copy of the report, "Process for Noncontact Removal of Varnish and other Protective Organic Coatings from the Surface of Paintings,"* ***write in 70*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-15896.

Weldability of a Nickel-Based Superalloy

A report describes an experimental investigation of the susceptibility of a nickel-based superalloy to cracking during and after electron-beam welding. The alloy in question is Udimet 720LI — a modified form of the alloy Udimet 720, which contains reduced concentrations of such interstitial elements as boron, silicon, and carbon. Alloy 720LI consists of nickel with the following weight percentages of other elements: 16.15 Cr, 14.7 Co, 5.0 Ti, 2.5 Al, 3.0 Mo, and 1.25 W. The history of high-strength superalloys like this one suggests that welding will be difficult because of their tendency towards hot cracking during the welding process or strain-age cracking during the postweld aging process. It was found that the alloy was not susceptible to hot cracking unless it had previously been subjected to a four-step aging heat treatment recommended by the manufacturer.

This work was done by Joseph M. Kalinowski of NYMA, Inc., for **Lewis Research Center.** *To obtain a copy of the report, "Weldability of a Nickel-Based Superalloy,"* ***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, Lewis Research Center; (216) 433-2320. Refer to LEW-16322.

Penetration of Cracks Into Composites During Thermal Aging

A report describes an experimental study of the penetration of cracks from cut surfaces into the depths of polymer-matrix/carbon-fiber composite materials during thermal aging. Such cracks are of concern because they can accelerate thermo-oxidative degradation by exposing additional surface area to the environment. In the experiments, specimens of PMR-15 polyimide reinforced with carbon-fiber fabric were prepared with both molded and cut surfaces, then aged in air at temperatures of 288, 316, and 343 °C. At intervals, aging was interrupted for weighing the specimens, both before and after immersion in water. The amount of weight gained during immersion was assumed to be indicative of the volume (and assumed to be proportional to the area) of cracks that had penetrated from the surfaces.

This work was done by Kenneth J. Bowles of **Lewis Research Center** *and John E. Kamvouris of National Research Council. To obtain a copy of the report, "Penetration of Carbon-Fabric-Reinforced Composites by Edge Cracks During Thermal Aging,"* ***write in 30*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center; (216) 433-2320. Refer to LEW-16305

Electronic Components and Circuits

Optimizing Operation of Ni/Cd Batteries by Taguchi Methods

A report describes an effort to extend the operational lives of spacecraft nickel/cadmium rechargeable batteries by applying Taguchi methods of robust design to optimization of battery operating parameters. Battery experts identified the recharge fraction as the key parameter that must be controlled to maintain nominal performance. The recharge fraction is one of the parameters used to determine battery overcharge. There are five operating parameters that affect the recharge fraction. The five parameters, which were chosen for optimization, were: peak charge current, depth of discharge, temperature, duration of orbit, and charge voltage level.

This work was done by Julian O. Blosiu, Frank Deligiannis, and Salvador DiStefano of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Nickel-Cadmium Battery Operation Management Optimization Using Robust Design,"* ***write in 65*** *on the TSP Request Card.*

NPO-19942

ASICs for Spacecraft Data Communications

A paper describes four application-specific integrated circuits (ASICs) that have been developed for the Cassini spacecraft, which is scheduled to be launched in 1997 on a 12-year mission to Saturn. These ASICs are used in the command and data subsystem of the spacecraft to receive uplink data, transmit downlink data, and provide intercommunications among spacecraft subsystems via a military standard 1553B bus.

This work was done by James A. Donaldson, Huy H. Luong, Donald R. Johnson, and Steven H. Wood of Caltech for **NASA's Jet Propulsion**

Laboratory. *To obtain copies of the report, "Cross Strap Bus Adaptor/Bus Controller (XBA/BC) ASIC" and the paper, "Spacecraft Uplink, Downlink, and Intercommunications in a Space-Qualified ASIC Chip Set," **write in 92** on the TSP Request Card.*
NPO-19955

Physical Sciences

Using NIR Measurements To Analyze Surface Contaminants

A report discusses an application of a method that combines near-infrared (NIR) spectrometry and multivariate analysis for identifying and quantifying trace amounts of greases, waxes, and other contaminants on surfaces that are required to be clean in preparation for subsequent adhesive bonding. The method was described previously in "Infrared Spectral Measurement of Surface Contaminants" (MFS-26342) *NASA Tech Briefs*, Vol. 20, No. 7 (July 1996), page 62. To recapitulate: a surface to be inspected is scanned by use of a fiber-optic probe coupled to an infrared spectrometer. A computer processes the spectral data for each increment of position along a scan. Although the raw spectral scan data are complicated by intricate reflection, absorption, and scattering interactions at the inspected surface, computer processing using techniques of multivariate analysis makes it possible to extract spectral features indicative of the contaminant molecular species, even when some of the spectral peaks from different contaminant materials overlap. In the application described in the report, the method was demonstrated to provide the capability to distinguish between thin surface layers of a grease and a similar thin surface layer of a silicone release agent and to measure the quantities of these contaminants on aluminum and steel surfaces.

This work was done by G. L. Workman, W. F. Arendale, and C. Hughes of the University of Alabama in Huntsville for **Marshall Space Flight Center.** *To obtain a copy of the report, "Quantitative Analysis of HD2 and Silicone Contaminants on Solid Rocket Motor Components," **write in 9** on the TSP Request Card.*
MFS-26295

Mechanics

Enhancing Butt Welds on Basis of Stress Analysis

A report addresses the problem of peaking in thick butt welds, with a view toward developing a method to reduce peaking and increase weld strength. The report is an updated version of the reports described in "Development of a Method for Depeaking Thick Butt Welds (MFS-31099), which appears earlier in this section. To recapitulate: butt welding of two thick members typically starts with tack welding of mating tabs on the members, followed by weld passes in which filler material is laid down in grooves that remain between the members on both sides of the joined tabs. Weld passes are made on both sides until the grooves are filled.

This work was done by Vincent Verderaime and Robert Vaughan of **Marshall Space Flight Center**. *To obtain a copy of the report, "Aluminum U-Groove Weld Enhancement Based on Experimental Stress Analyses," **write in 11** on the TSP Request Card.*
MFS-27327

Tutorial Paper on Universal First-Order Reliability Method

A NASA technical paper has been written to promote a recently developed universal first-order reliability method for designing structures. Various aspects of the method were described in several previous articles in *NASA Tech Briefs*; namely, "Study of Structural-Load Safety Factors" (MFS-27285), Vol. 18, No. 1 (January 1994), page 74; "Improved Selection of Structural-Load Safety Factors" (MFS-28825), Vol. 19, No. 3 (March, 1995), page 86; and "First-Order Reliability Method for Semistatic Structures (MFS-31034), Vol. 20, No. 9 (September 1996), page 84. The paper describes the universal first-order reliability method, presents guidelines to assist engineers in applying the method, and illustrates the application of the method with examples.

This work was done by Vince Verderaime of **Marshall Space Flight Center.** *To obtain a copy of the paper, "Illustrated Structural Application of Universal First-Order Reliability Method," **write in 12** on the TSP Request Card.*
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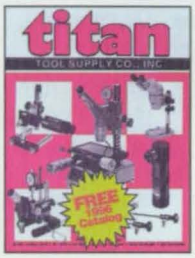

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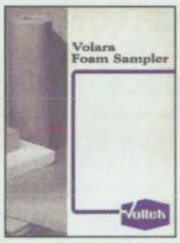

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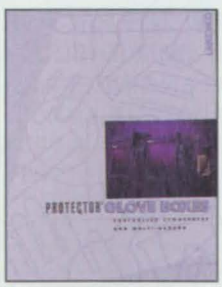

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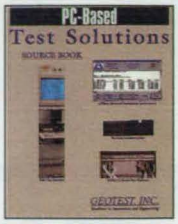

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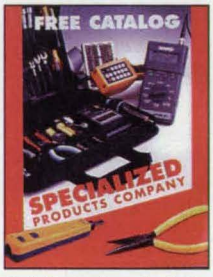

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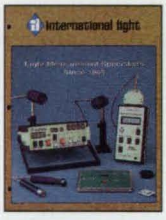

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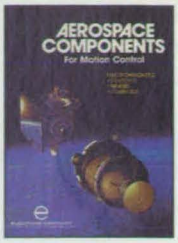

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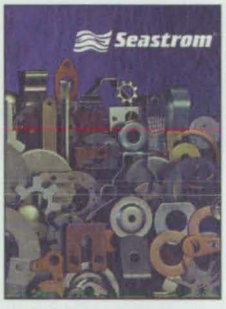

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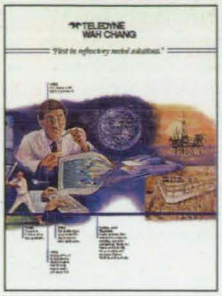

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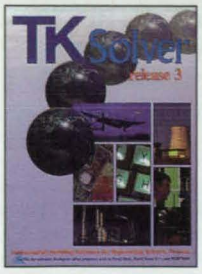

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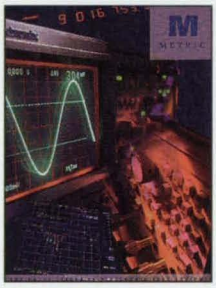

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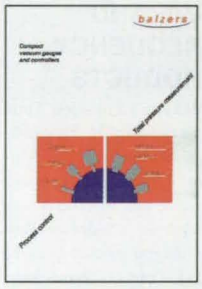
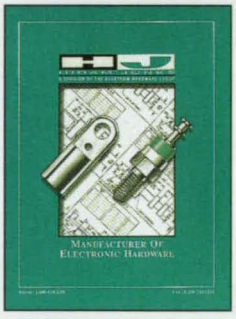


LOW-COST COMPACT GAUGES

Pfeiffer Vacuum offers a complete line of low-cost, compact gauges and controllers to meet all total pressure measurement needs. It includes capacitance, piezo, pirani, cold cathode, and FullRange™ gauges. The popular FullRange gauge combines two gauges in one compact housing to measure from atm to UHV with or without a controller. Contact: Julie Giambartolomei, Pfeiffer Vacuum Technology, Inc., 8 Sagamore Park Rd., Hudson, NH 03051; Tel: 603-595-3200; Fax: 603-595-3250.

Pfeiffer Vacuum Technology, Inc.

For More Information Write In No. 340



Hiram Jones Electronics, Inc./A Division of the Seastrom Hardware Group manufactures a complete line of standard miniature and subminiature terminals including: insulated test jacks, assembled standoffs and press-type terminals. All standard catalog items are available for immediate pricing and delivery. Call today for your free 27-page catalog: 800-634-2356.

Hiram Jones Electronics, Inc.

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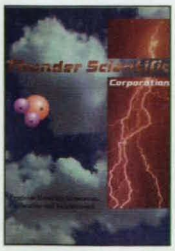


HUMIDITY GENERATION, CALIBRATION & MEASUREMENT

Thunder Scientific's NEW catalog for 1996 includes high-accuracy, two-pressure humidity generators at ±0.3% RH and NIST-traceable humidity standards. Thunder offers complete calibration service of hygrometers and dew point instruments. HumiCalc® humidity conversion software is priced right at $99. Call 800-872-7728 or fax your business card to 505-266-6203 for a copy of Thunder Scientific's Precision Humidity Generation, Calibration, and Measurement catalog.

Thunder Scientific

For More Information Write In No. 342

CONTROL THE WORLD WITH VISSIM/ FUZZY-TECH

VisSim/fuzzyTECH works seamlessly with VisSim™ to create an ideal environment for fuzzy control development and simulation. Additional VisSim add-ons include C code generation, communication design, real-time I/O, neural networking, constrained optimization, and frequency domain analysis. VisSim is used for 6-DOF guidance, anti-lock braking, servo and drive motor control, web processes, winders, gas turbines, and data communications.

Visual Solutions, Inc.
487 Groton Road
Westford, MA 01886
Tel: 508-392-0100 Fax: 508-692-3102

For More Information Write In No. 343

STATIC ELIMINATORS

EXAIR-Ionizers improve static and dust removal in many applications and contain no radioactive element. Air delivered ions neutralize static and clean surfaces at distances up to 20 feet. Three styles, including ionizing air knife and blowgun, are available. Applications include web cleaning, pre-paint auto body blowoff, and neutralizing plastic parts. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com.

EXAIR Corp.

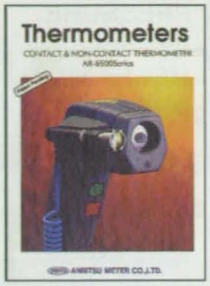
For More Information Write In No. 344

NEW MECHANICAL STRENGTH TESTER

Romulus III uses a single workstation programmed to operate any of four platforms (to accommodate 1 gram to 1 ton force). Twelve interchangeable modules execute 52 tests (30 strictly microelectronics). Choose adhesion by stud pull, scratch, blade cutting, shear, tear, flexure, 90 and 180 degree peel. Tensile and flexure stress/strain, micro-wire, TAB, ball bond & more. Quad Group; E-mail: quadgroup@spokane.net; http://www.spokane.net/quadgroup.

Quad Group

For More Information Write In No. 345



PRECISION TEMPERATURE MEASUREMENT

Over 5,000 models are detailed in a 90-page catalog. Accuracy of 0.2% and response time down to 200 msec. Temperature of fluids and gases, stationary and moving surfaces. Anritsu Meter Co., 795 Franklin Ave., Franklin Lakes, NJ 07417; Tel: 800-457-2999 or 201-848-0033.

Anritsu Meter Co.

For More Information Write In No. 346

REMOTE VIEWING INSTRUMENTS

Inspecting inaccessible areas or hostile environments is easy with ITI's 1800+ rigid & flexible instruments, specially built to suit aviation & aerospace needs. Custom work a specialty. Instrument Technology, Inc. - The Leader in Remote Viewing, PO Box 381, Westfield, MA 01086; Tel: 413-562-3606; Fax: 413-568-9809; E-mail: iti@scopes.com; http://www.scopes.com.

Instrument Technology, Inc.

For More Information Write In No. 347

COMBAT® BORON NITRIDE FOR DESIGN APPLICATIONS

Carborundum Corporation, Boron Nitride Division, offers an 8-page, full-color brochure detailing Combat Boron Nitride, available in solid, powder, coating, and aerosol spray forms for a variety of design applications. Four-page insert provides technical data. Carborundum Corporation, Boron Nitride Division, 168 Creekside Drive, Amherst, NY 14228; Tel: 716-691-2052; Fax: 716-691-2090.

Carborundum Corporation

For More Information Write In No. 348

BROCHURES AVAILABLE FOR FIRESTONE AIR-PICKER®/AIR-GRIPPER™ AND AIR SPRINGS

Firestone Industrial Products Company has prepared product specification brochures on its Airstroke® actuators/Airmount® isolators, and its Airpicker® and Airgripper® pneumatic devices. For free copies, contact: Firestone Industrial Products Co., 701 Congressional Blvd., Carmel, IN 46032; Tel: 800-888-0650; Fax: 317-580-2345.

Firestone Industrial Products Co.

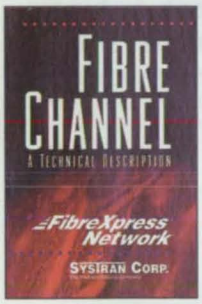
For More Information Write In No. 349

METALS & MATERIALS FOR RESEARCH

A large selection of research metals and materials are available in small quantities, ready for immediate shipment. Almost 4,000 items are listed, along with technical specifications and comparative data. Featured are pure metals, alloys, polymers, ceramics, composites, and honeycombs. 48-hour delivery. Custom services are also available. Goodfellow Corporation, 800 Lancaster Ave., Berwyn, PA 19312-1780; Tel: 800-821-2870; Fax: 800-283-2020; E-mail: info@goodfellow.com.

Goodfellow Corp.

For More Information Write In No. 350

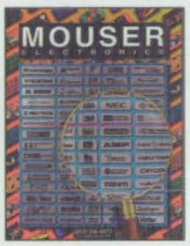


NETWORK FOR DSP APPLICATIONS

Introducing FibreXpress™, SYSTRAN Corp.'s new line of Fibre Channel host bus adapters. FibreXpress is ideal for very-high-speed mass storage and high-throughput, data-intensive DSP applications such as radar, sonar, medical scanners, and OCR. Request your free tech overview today! SYSTRAN Corp.; Tel: 937-252-5601; Sales: 800-252-5601; Fax: 937-258-2729; E-mail: info@systran.com; WWW: http://www.systran.com.

SYSTRAN Corp.

For More Information Write In No. 351



FREE ELECTRONIC COMPONENTS CATALOG

332-page catalog featuring complete product and pricing data for 67,000+ products from 125+ leading manufacturers. Complete line of semiconductors, passive components, electromechanical devices, resistors, capacitors, switches, wire/cable, connectors and more. Same-day shipping. Mouser Electronics, 958 N. Main St., Mansfield, TX 76063; Sales Tel: 800-346-6873; Catalog Tel: 800-992-9943; Fax: 817-483-0931; http://www.mouser.com; E-mail: catalog@mouser.com.

Mouser Electronics

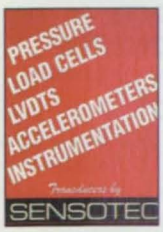
For More Information Write In No. 352

ANORAD'S NEW PCLM SERIES BROCHURE

Anorad Corporation has a new 20-page brochure packed with information on its latest introduction, the Anoline PCLM Series – a new motor technology utilizing Piezo Ceramics. The Series complements an already existing product line of linear motors and stages that focus on high performance motion control. Contact the leader in motion control for your free brochure. Anorad Corporation; Tel: 516-231-1995; Fax: 516-435-1612; http://www.anorad.industry.net.

Anorad Corporation

For More Information Write In No. 353



FREE TRANSDUCER CATALOG

Sensotec's 195-page full-line catalog contains transducers, including intrinsically safe, clean-in-place, miniature, liquid level, and other models. Featured are pressure transducers for gage, absolute, vacuum, and differential with millivolt, 0-5V, 0-10V, and 4-20 mA outputs; load cells for tension, compression, or universal applications, strain gauge and piezoelectric accelerometers with single or multiple axis configurations; free and captive guided LVDTs. Amplifiers and support instrumentation are available. Sensotec, Inc., 1200 Chesapeake Ave., Columbus, OH 43212; Tel: 800-848-6564; Fax: 614-486-0506; http://www.sensotec.com.

Sensotec, Inc.

For More Information Write In No. 354

MATRIX$_X$ FROM INTEGRATED SYSTEMS

The MATRIX$_X$ product family features: SystemBuild™, the industry's leading graphical modeling and simulation environment; Xmath™, the first object-oriented mathematical analysis and visualization tool; AutoCode®, the first and most sophisticated automatic C and Ada code generator; DocumentIt™, the first automatic documentation generator; and the RealSim Series™ of rapid prototyping computers. Integrated Systems Inc., 201 Moffett Park Drive, Sunnyvale, CA 94089; Tel: 408-542-1500; Fax: 408-542-1950.

Integrated Systems Inc.

For More Information Write In No. 355

FREE CATALOG OF TOOLING COMPONENTS

National mail order catalog of over 25,000 items offers a full range of tooling components and equipment. Items include clamps, handwheels, handles, knobs, spring & ball plungers, latches, leveling pads, set-up accessories, locating devices, springs, thread inserts, and metric items. All items are in stock for same-day shipment with no minimum order requirement. Reid Tool Supply Co., 2265 Black Creek Rd., Muskegon, MI 49444; Tel: 800-253-0421; Fax: 800-438-1145; http://www.industry.net/reidtool.supply.

Reid Tool Supply Company

For More Information Write In No. 356

LITERATURE SPOTLIGHT

PRESSURE VESSEL MECHANICAL INTEGRITY

PC software analyzes mechanical integrity of installed pressure vessels to insure compliance with OSHA regulations – Process Safety Management of Highly Hazardous Chemicals. Created by engineers experienced with vessel inspection, program utilizes ASME B&PV Code, NBIC and API 510 guidelines. Free demo disk. Tel: 816-228-2976; Fax: 816-228-0680.

Computer Engineering, Inc.
For More Information Write In No. 357

INNOVATIVE APPROACHES TO MACHINE SAFEGUARDING

This colorful 8-page brochure provides an overview of noncontact opto-electronic safeguarding controls available from SICK Optic-Electronic, including application diagrams and photos. Products include point-of-operation devices, optical perimeter and area guards with advanced functions like blanking, Presence Sensing Device Initiation (PSDI) and multiple configurable muting controls. Tel: 800-325-7425; Fax: 612-941-9287; Web: http://www.sickoptic.com; E-mail: info@sickoptic.com.

SICK Optic-Electronic
For More Information Write In No. 358

Evans Capacitor Company is a spin-off from Evans Company, known for the Capattery®. Specializing in electrochemical and high energy density electrolytic capacitors, Evanscap has new literature, describing not only the Capattery, but the Capattery II®, a larger electrochemical capacitor with a polymeric case, and a new high energy density electrolytic capacitor, the Evans Hybrid® – half the weight and 1/10th the volume of aluminum capacitors. Evans Capacitor Company, 33 Eastern Ave., East Providence, RI 02914-2107; Tel: 401-434-5600; Fax: 401-434-6908; http://www.evanscap.com.

Evans Capacitor Company
For More Information Write In No. 359

THE NEW WYKO NT-2000

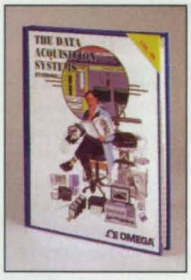
WYKO NT-2000 Surface Measurement System is designed to measure 3D surface roughness from 0.1 nm to 2 mm. Outstanding automation capabilities provide hands-off, high throughput inspection. The system offers best-in-class precision, resolution, and gauge capability. Extensive analysis software operates on the latest Pentium Pro PC under the Microsoft Windows NT™ operating system. The WYKO NT-2000 is flexible enough for R&D, yet robust enough for manufacturing process control and quality inspection. WYKO; Tel: 520-741-1297; E-mail: sales@wyko.com.

WYKO
For More Information Write In No. 360

NEW 1996 CATALOG & TECHNICAL MANUAL

Advanced Motion Controls is pleased to announce the publication of our new 1996 catalog describing our complete line of DC brush type and DC brushless PWM high-efficiency servo amplifiers. In addition to technical data for all products offered, this 230-page book features a product summary, application notes, set-up instructions, and a trouble-shooting guide. Pricing also is included. Advanced Motion Controls, 3629 Vista Mercado, Camarillo, CA 93012-8055; Tel: 805-389-1935; Fax: 805-389-1165.

Advanced Motion Controls
For More Information Write In No. 361



DATA ACQUISITION SYSTEMS

New OMEGA Complete Data Acquisition and Computer Interface Handbook and Encyclopedia® offers over 650 full-color pages with products including communications-based systems and plug-in cards for IBM, Apple, PS/2, and Macintosh computers. Includes newest prices (U.S. Dollars) and specifications, plus software for data acquisition and control. Over 40 pages of valuable technical information. Omega Engineering, Inc.; Tel: 202-359-7874.

Omega Engineering, Inc.
For More Information Write In No. 362

THE SPECIALTY BULB CO. INC.

Call us to interchange and identify any lamp. We are a highly specialized light source distributor with the technical ability to meet the individual requirements of its customers and research institutes. We stock European, Domestic, and Far Eastern bulbs for all industries. The Specialty Bulb Co. Inc.; Tel: 516-589-3393 or 800-331-BULB (2852); Fax: 516-563-3089 (24 hrs.)

The Specialty Bulb Co., Inc.
For More Information Write In No. 363

PRECISION POSITIONING & MOTION CONTROL CATALOG

FREE, detailed 160-page catalog covers NEAT's expanding line of Precision Positioning and Motion Control Systems. Featured are single-axis, X-Y, multi-axis, rotary, high-vacuum, and air bearing positioners, along with NEAT's complementary line of stepping and servo motors, encoders, drives, and controls. Catalog includes an Engineering Considerations guide, an overview of Custom Designs, and a Glossary for reference. Visit our Web Site at: www.neat.com. New England Affiliated Technologies, 620 Essex St., Lawrence, MA 01841; Tel: 800-227-1066 or 508-685-4900; Fax: 800-523-8201 or 508-688-8027.

New England Affiliated Technologies
For More Information Write In No. 364

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- 60,000 sq. ft. of exhibits showcasing licensable technologies and cutting-edge products from U.S. government labs, industry, and universities. Exhibit hall admission is FREE for all registrants.
- Top speakers including NASA Administrator Daniel Goldin, Netscape CEO James Barksdale, and DIRECTV Executive Vice President L. William Butterworth.
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Awards dinner guest speaker: L. William Butterworth of DIRECTV, producer of the nation's premier high-power direct broadcast satellite (DBS) system.

Be one of the first 5,000 registrants and get a coupon for a FREE NASA Technology CD-ROM, a $250 value, redeemable inside the NASA Exhibit Pavilion.

Two world-class events under one roof: Technology 2006, the world's largest technology transfer conference, is being held concurrently with TeleCon XVI, the world's largest conference and trade show on teleconferencing, videoconferencing, desktop videoconferencing, and collaborative systems. Combined, the events offer 150,000 square feet of exhibits in the Anaheim Convention Center and 20,000+ business and government leaders in attendance. Technology 2006 attendees can tour the TeleCon exhibit hall at no charge; conference registrants additionally can attend two joint NASA/TeleCon tracks on telemedicine and distance learning.

Conference At A Glance

Tuesday Oct. 29

8am - 4pm **Registration**

9am - 1pm **Poster Presentation Showcase**

9 am - 10am **Exhibit Hall Breakfast**

10:30am - 12pm **Concurrent Sessions:**
Advanced Manufacturing 1
Agriculture 1
Computers & Communications 1
Education 1
Environmental Technology 1
Materials 1
Medical/Rehab Technology 1
Power & Energy 1

1pm - 4pm **Plenary Session**
Keynote Addresses:
- Daniel Goldin, NASA Administrator
- James Barksdale, Pres. & CEO, Netscape Comm.
- Glen Urban, Dean, MIT Sloan School
- Ace Allen, Dir., Univ. of Kansas Med Cntr
- Jay Sanders, Pres., American Telemed Assoc.

Wednesday Oct. 30

7:30am - 4:30pm **Registration**

8:30am - 10am **Plenary:**
Agricultural Technology
Plenary:
Small Business Growth Opportunities

10:30am - 12pm **Concurrent Sessions:**
Advanced Manufacturing 2
Agriculture 2
Education 2
Materials 2
Medical/Rehab Technology 2
Physics 1
Power & Energy 2
Small Business Workshop 1
Sensors/Instrumentation 1

2pm - 3:30pm **Concurrent Sessions:**
Advanced Manufacturing 3
Computers & Comm. 2
Environmental Tech. 2
Education 3
Physics 2
Small Business Wkshp 2
Telemedicine 1
Sensors/Instrumentation 2

4pm - 5:30pm **Concurrent Sessions:**
Computers & Comm. 3
Environmental Technology 3
Materials 3
Physics 3
Power & Energy 3
Small Business Workshop 3
Telemedicine 2
Telemedicine 3
Sensors/Instrumentation 3

7pm **Awards Dinn**

Thursday Oct. 31

7:30am - 3pm **Registration**

8:30am - 12pm **Short Courses:**
A) Russian Aerospace & Aviation Partnerships
B) Technology Commercialization Strategies/ Finding Niche Markets
C) Protecting Technology From Industrial Espionage
D) Financial Planning For Entrepreneurs & Small Businesses

2pm - 5:30 pm **Short Courses:**
A) Russian Partnerships (cont'd)
E) Introduction To Patents & Licensing
F) Setting Up Your Company's IntraNet
G) Intellectual Property — Defining, Valuing, & Protecting It

2pm - 3:30 pm **Telemedicine Sessions 4 & 5**

4pm - 5:30 pm **Telemedicine Sessions 6 & 7**

Notes: *On Monday evening, Oct. 28, a reception will be held at the Richard Nixon Library. All Thursday short courses require individual registration.*

TECHNOLOGY 2006 REGISTRATION FORM

USE A SEPARATE FORM OR PHOTOCOPY FOR EACH REGISTRANT. BE SURE TO ANSWER ALL QUESTIONS BELOW.
DO NOT USE THIS FORM IF YOU ARE AN EXHIBITOR OR SPEAKER.

Name _____

Title _____

Company _____

Address _____

City/St/Zip _____

Phone No. _____ Fax No. _____

E-Mail Address _____

Guest/Spouse Name _____

1 Which of the following best describes your industry or service? *(check one)*

1 ❒ Electronics
2 ❒ Computers
3 ❒ Communications
4 ❒ Aerospace
5 ❒ Defense
6 ❒ Government
7 ❒ Materials/Chemicals
8 ❒ Industrial Equipment
9 ❒ Manufacturing
10 ❒ Power/Energy
11 ❒ Biomedicine
12 ❒ Transportation/Automotive
13 ❒ Research Lab
14 ❒ University
15 ❒ Agriculture
16 ❒ Environment
17 ❒ Other (specify) _____

2 Which of these products do you recommend, specify, or authorize the purchase of? *(check all that apply)*

18 ❒ Electronic Components & Systems
19 ❒ Software
20 ❒ Computers/Peripherals
21 ❒ CAD/CAE/CAM/CASE
22 ❒ Lasers/Optics
23 ❒ Materials
24 ❒ Mechanical Components
25 ❒ Positioning Equip./Motion Control
26 ❒ Test/Measurement Instruments
27 ❒ Sensors/Transducers
28 ❒ Data Acquisition
29 ❒ Video/Imaging Equipment
30 ❒ Industrial Controls/Systems
31 ❒ Communications Equipment
32 ❒ Laboratory Equipment

3 Your role in purchasing is:

33 ❒ Decision maker
34 ❒ Specify
35 ❒ Recommend

4 Your principal job function is: *(check one)*

36 ❒ General & Corporate Management
37 ❒ Design & Development Engineering
38 ❒ Engineering Services - Tests/Quality
39 ❒ Basic Research
40 ❒ Manufacturing/Production
41 ❒ Purchasing/Procurement
42 ❒ Other (specify) _____

Please write in the code that appears on your mailing label _____

If you require assistance to fully participate, call Wendy Corvi at 1-800-944-NASA.

PLEASE REGISTER ME FOR THE FOLLOWING:

(check all that apply)

	by 10/11	after 10/11	
❒ **Conference Registration**	$375	$450	$_____

Includes sessions & refreshment breaks on Tues., Oct. 29 & Wed., Oct. 30; 1 ticket to the opening reception on Mon., Oct. 28; exhibit hall opening breakfast on Tues., Oct. 29; 1 ticket to the Awards Dinner on Wed., Oct. 30 & entrance to the exhibits Oct. 29-31.

Thursday's Short Courses are not included.

❒ **1-Day Conference Registration**	$160	$185	$_____

check day: ❒ **10/29** **or** ❒ **10/30**

Includes sessions & refreshment breaks on the applicable day only, exhibit hall opening breakfast on Tues., Oct. 29 & entrance to the exhibits Oct. 29-31.

OPTIONAL SHORT COURSES ON THURSDAY, 31 OCTOBER

(Morning short courses include continental breakfast.)

	by 10/11	after 10/11	
Morning			
_____ (A) Russian Partnerships (full day, inc. refreshments, lunch)	$350	$400	$_____
_____ (B) Commercialization & Niche Markets	$100	$125	_____
_____ (C) Industrial Espionage	$100	$125	_____
_____ (D) Financial Planning	$100	$125	_____
Afternoon			
_____ (E) Patents & Licensing	$100	$125	_____
_____ (F) IntraNet	$100	$125	_____
_____ (G) Intellectual Property	$100	$125	_____

❒ **Awards Dinner:** _____**tickets @**	$55	$65	_____
❒ **Exhibits Only**	FREE	FREE	$0

Includes the exhibit hall opening breakfast on Tues., Oct. 29 & entrance to exhibits Oct. 29-31.

❒ ***Guest/Spouse Registration**	$95	$110	$_____

Includes the exhibit hall opening breakfast on Tues., Oct. 29; entrance to exhibits Oct. 29-31; a ticket to the opening reception on Mon., Oct. 28 & a ticket to the Awards Dinner on Wed., Oct. 30.

*** Guests must be over the age of 18.**

TOTAL AMOUNT ENCLOSED $ _____

❒ **Check/MO enclosed**
(payable to Technology Utilization Foundation)

❒ Charge my: ❒ MasterCard ❒ VISA ❒ Am Ex

Card No. _____

Cardholder Name _____

Signature _____ Exp. Date _____

Registrations & Awards Dinner reservations are transferable. Cancellations must be received in writing by October 11 for a refund. Refunds will not be granted for no shows.

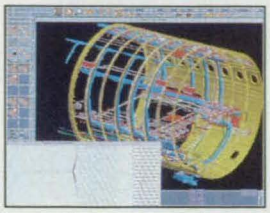
A $50 processing fee applies for all refunds.

RETURN WITH PAYMENT TO:

Technology 2006, c/o Convention Data Services, Inc., P.O. Box 1328, Hyannis, MA 02601
For fastest registration fax to: (508) 778-7718
For hotel and travel information, call (212) 490-3999.

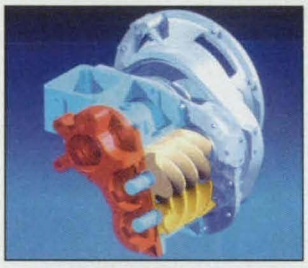
New on Disk

Product of the Month



Computervision, Bedford, MA, offers Electronic Product Definition **software tool suite** that enables the specification, concept, design, analysis, drafting, manufacturing, and support of a complete product to occur simultaneously, and allows the product to be shared electronically. A digital model is created, displayed on screen, and made available anywhere in an enterprise for developing, testing, and managing the product through its life cycle. Each participant interacts with the model without interfering with what others are doing. Included in the suite are CADDS® 5 design automation software, Concurrent Assembly Mock-Up (CAMU), Optegra™ enterprise data management software, and PELORUS™-based design automation software.

For More Information Write In No. 730



Version 5.5 of Bravo **mechanical assembly design software** from Applicon, Ann Arbor, MI, features a new Desktop Modeler and Detailer for design and drafting applications on Intel/NT PCs, and the ability to import parts and assemblies from ACIS-based packages. An enhanced user interface reduces the number of steps needed to design parts and assemblies.

For More Information Write In No. 735

Fluid Dynamics International, Evanston, IL, has released FIDAP Version 7.6 **finite element-based simulation software,** which features enhanced upwinding schemes, relaxation schemes, and solution algorithms. An extrapolation scheme accelerates the convergence of nonlinear iterations. The program allows users to perform all aspects of fluid flow analysis, including model building, mesh generation, data input, solution, and post-processing.

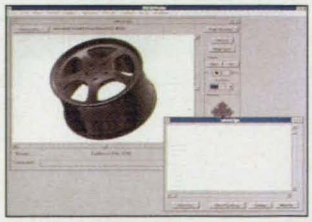
For More Information Write In No. 734

FCAD, Novato, CA, has introduced FelixCAD **3D CAD software** for Windows NT and 95. Users can simultaneously view and edit up to four drawings, with four views of each, for a total of 16 separate 2D or 3D views. It provides seamless reading and writing of DWG and DXF files and features up to 10 palettes and toolboxes and context-sensitive online help.

For More Information Write In No. 732

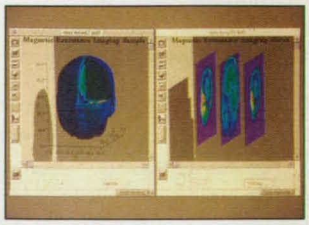
3D Builder **CAD modeling software** from 3D Construction, Elizabethton, TN, is a Windows-based program that builds 3D models of real-world data from photographs. The program provides a constraint-based CAD modeler and photogrammetry solver. It enables users to work with one, two, or numerous photos, photo CDs, or digital camera images. The program combines photo information, extracts it, and merges it into a single 3D model for export to AutoCAD, Studio 3D, or most rendering packages. It is priced at $595.

For More Information Write In No. 731



IGES/Works® for Windows NT **data exchange software** is available from International TechneGroup, Milford, OH. The program reads Initial Graphics Exchange Specification (IGES) files from any source, allowing users to view, analyze, edit, and transfer data to any other CAD/CAM/CAE system. The software is priced at $7500.

For More Information Write In No. 733



Fortner Research LLC, Sterling, VA, has released upgrades for DataPlot, Transform, and Slicer **visualization software tools** for Windows and Macintosh, allowing scientists and engineers to visualize and analyze large amounts of data. Upgrades include new Hierarchical Data Format libraries in the Windows versions of all three products. The DataPlot or Transform for Windows or Macintosh, or the Slicer for Windows cost $39 each; any two are $69; and all three are $99.

For More Information Write In No. 736

New Literature

Beswick Engineering, Greenland, NH, offers a 44-page catalog of miniature **fluid power products**, including fittings, valves, quick disconnects, cylinders, air pressure regulators, tubing, and flow controls. All products feature a leakproof O-ring face seal design.

For More Information Write In No. 740

Cambio International, Laconia, NH, has released a catalog of Warth **electromagnetic shielding products** and thermally conductive insulators. The 84-page catalog includes high-voltage insulators, transistor spring clips and insulating bushes, strips and gaskets, and conductive elastomers and adhesives.

For More Information Write In No. 741

A 240-page catalog of **controls and gauges** is available from Dwyer Instruments, Michigan City, IN. Featured are pressure gauges, switchers, transmitters, flowmeters, indicators, valves, actuators, positioners, and level control systems.

For More Information Write In No. 743

Comair Rotron, San Ysidro, CA, has released a 16-page brochure on **AC and brushless DC motors** for medical and laboratory equipment, computer peripherals, fans, blowers, and pumps. The guide provides dimensions and specifications for size, torque, and speed.

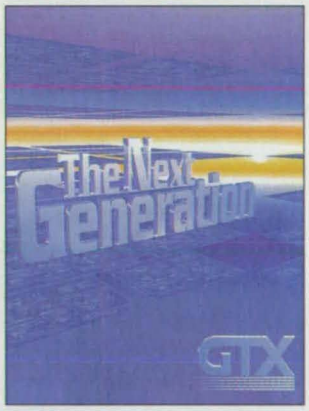
For More Information Write In No. 744

Roller screws are described in a 44-page catalog from SKF Specialty Products, Bethlehem, PA. Included are design hints, assembly procedures, special nuts, actuators, ordering information, applications, definitions, and unit specifications.

For More Information Write In No. 745

FieldWorks, Eden Prairie, MN, offers a brochure describing the 5000 Series and 7000 Series Field WorkStation™ **rugged portable computers.** The workstations incorporate ISA, PCI, and/or PCMCIA expansion slots to provide testing, acquisition, communication, and video capture in the field.

For More Information Write In No. 746



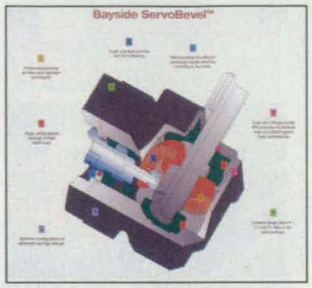
The GTXRaster CAD® **raster editing and conversion software** is described in a four-page brochure from GTX Corp., Phoenix, AZ. The software is used with AutoCAD® to modify designs in workflow, whether in raster or vector.

For More Information Write In No. 742

TestEquity, Thousand Oaks, CA, has released a 48-page catalog of new and used **electronic test equipment,** including meters, analyzers, RF measurement equipment, oscilloscopes, pulse generators, counters, plotters, recorders, power supplies, calibrators, and data acquisition systems. New scopes, bench instruments, DMMs, and optical test equipment also are included.

For More Information Write In No. 747

New on the Market

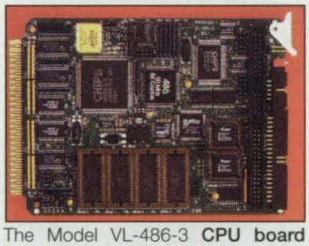


Bayside Controls, Port Washington, NY, has introduced ServoBevel™ right-angle **gearheads** for use in servo applications such as machine tooling and packaging. Features include backlash of 10 arc minutes, with a 5-minute, low backlash option; hardened gears for quiet operation; frame sizes from 115 to 220 mm square; output torque from 1000 to 7000 inch-pounds; and standard motor output faces for bolt-on capability with servomotors.

For More Information Write In No. 715

FLIR Systems, Portland, OR, has introduced the Prism DS **thermal imaging camera,** which incorporates 78,080 infrared detector elements in its focal plane array to detect thermal problems. The radiometric digital camera has 320 x 244 resolution and collects thermal data for all points on the infrared image. A 25mm lens is standard. Images can be stored digitally onto removable PC cards, which can hold over 200 images per card.

For More Information Write In No. 719

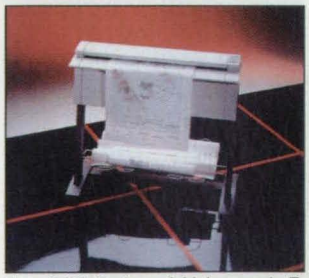


The Model VL-486-3 **CPU board** from VersaLogic Corp., Eugene, OR, is a 50 MHz, STD 32-based board that features a low-power, 3.3-volt 486 SXLC chip. It is DOS and Windows compatible and comes standard with an RS-232/485 configurable COM port, one LPT port, onboard floppy, and IDE interfaces. The board can hold up to 8 MB of RAM and up to 1 MB of Flash memory.

For More Information Write In No. 716

The STB/STC family of tension-control **clutches and brakes** is available from Horton Industrial Products, Minneapolis, MN. Three different-sized piston sets in the products can be actuated singly, or in any combination, for a large number of torque-to-air pressure ranges. The units are offered in two sizes: the 600 and the 940.

For More Information Write In No. 720



The 4700 Series of high-speed, E-size **document scanners** is offered by Océ-Engineering Systems, Chicago, IL. The 4720 and 4730 models scan documents into digital archiving systems and convert paper drawings into CAD formats with raster overlay programs or raster-to-vector packages. The units' digital signal processor automatically adjusts inconsistencies. The systems can scan typical E-size drawings at 400 dots per inch in 15 seconds.

For More Information Write In No. 722

Loctite Corp., Rocky Hill, CT, has published the 1996-97 Worldwide Design Handbook, an **adhesives reference manual** that covers adhesive, sealant, coating, and dispensing technologies. The 464-page manual includes engineering data, illustrations, compatibility tables, industry definitions, and information on adhesive engineering, industrial application, gasketing, bonding, and products for electronic assemblies.

For More Information Write In No. 721

A line of **remote access ports** is available from Contact Electronics, Fairfield, NJ. The ports are designed to provide two-way data communication from the outside of a control panel. Access ports include D' subminiature and coaxial connectors, single/duplex 120V receptacles, circuit breakers, circular din jacks, and other panel-mounted components.

For More Information Write In No. 718

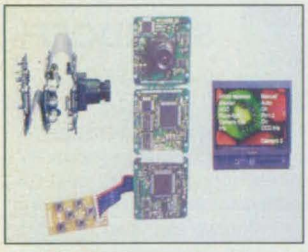
New on the Market

Polymer Design Corp., Rockland, MA, offers Liquid Resin Casting™ for producing **parts and device prototypes** for the semiconductor industry. Materials such as epoxies, polyurethanes, and silicones are used in steel, aluminum, epoxy, RTV silicone, and polyurethane molds. Custom colors, casting logos, and EMI/RFI shielding are available for most parts.

For More Information Write In No. 723

Battery-powered **data loggers** with one to 32 inputs are offered by Science/Electronics, Dayton, OH. The loggers are programmed by computer or on-board pushbuttons, and are compatible with laptops and PCs via an RS-232 interface. The microprocessor-based units feature on-board, non-volatile memory to 2 Mb readings; PCMCIA SCRAM cards also can be used. Single-channel units allow analog and digital/event logging at rates from 0.5 ms to 24 hours.

For More Information Write In No. 726



The MB-1050C programmable color **CCD camera** from Polaris Industries, Atlanta, GA, features an on-screen menu that provides user access to definable settings such as white balance, shutter, camera title, and iris. The camera can be mounted and installed in various configurations due to its multi-board design. A C-mount lens option allows the user to select from a range of standard and special-purpose optics.

For More Information Write In No. 724

Greco Systems, El Cajon, CA, has announced the RCS 5100 **rugged computer system** for data collection and relay in environments with high EMI emissions or high heat environments. The rack-mount unit has hot-swappable fans, comes with two 5.25" and one 3.5" drive bays, and can accommodate a CD-ROM. It features a positive air flow and exhaust system, is Pentium-upgradeable, and has a 315 watt power supply.

For More Information Write In No. 727

Purdy Electronics Corp., Sunnyvale, CA, has introduced the AND1391ST **intelligent graphics display** module that features a resolution of 128 x 128 pixels and fine dot pitch of 0.43mm x 0.43mm. The display has a built-in LCD controller, which includes a character generator ROM and RAM and can be used for text and/or graphics.

For More Information Write In No. 725

Yokogawa Corporation of America, Newnan, GA, has introduced the DL1520 two-channel **digital oscilloscope,** which features 150 MHz bandwidth, 100 MS/s sampling on two channels, and 200 MS/s on one channel. The standard 3.5" floppy drive stores data, setups, and bit map files and a built-in printer provides hard copy of the screen data. A GPIB or RS-232C interface is standard. A zooming feature allows simultaneous viewing of the entire waveform image and a magnified portion.

For More Information Write In No. 717

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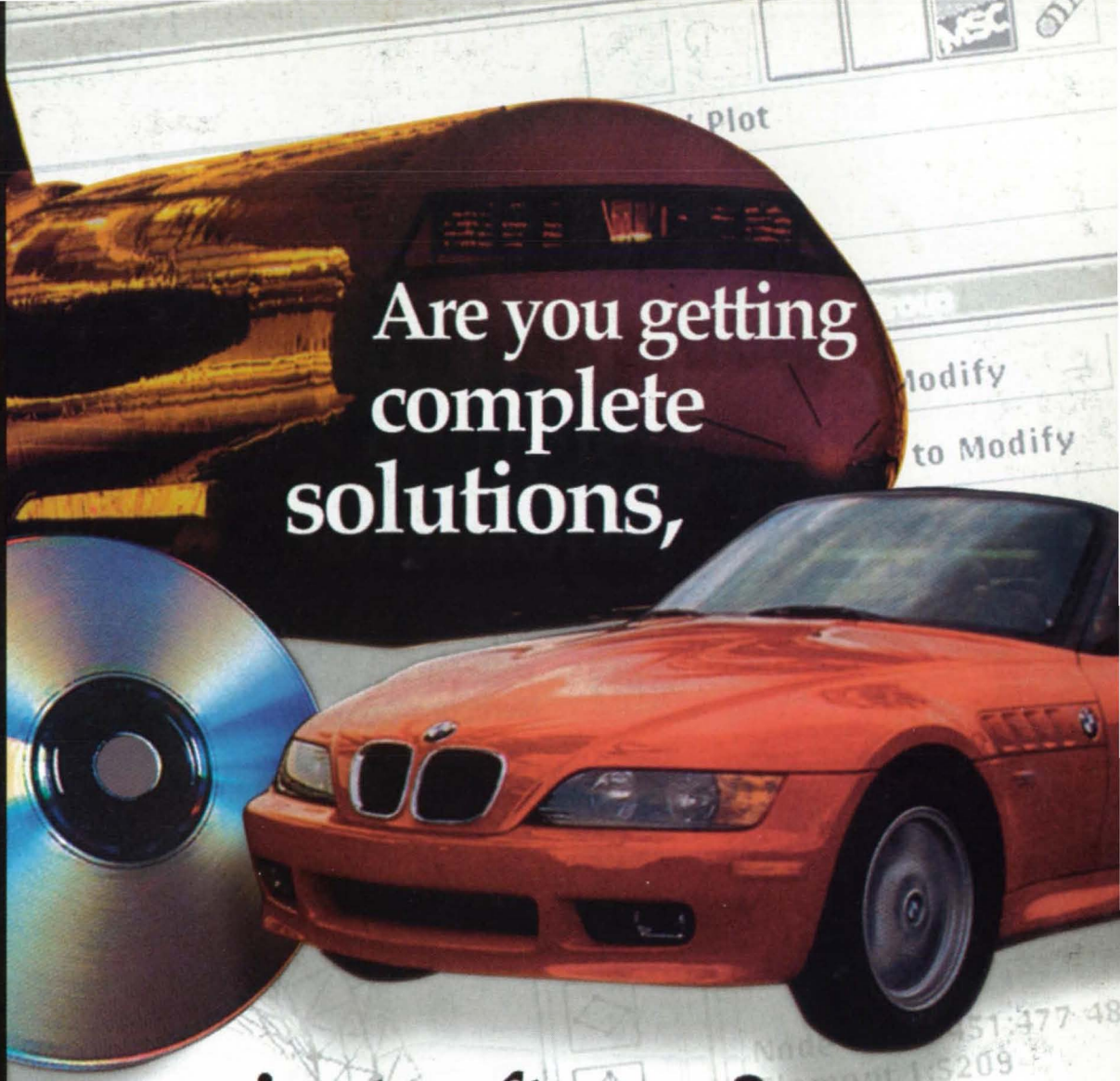

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