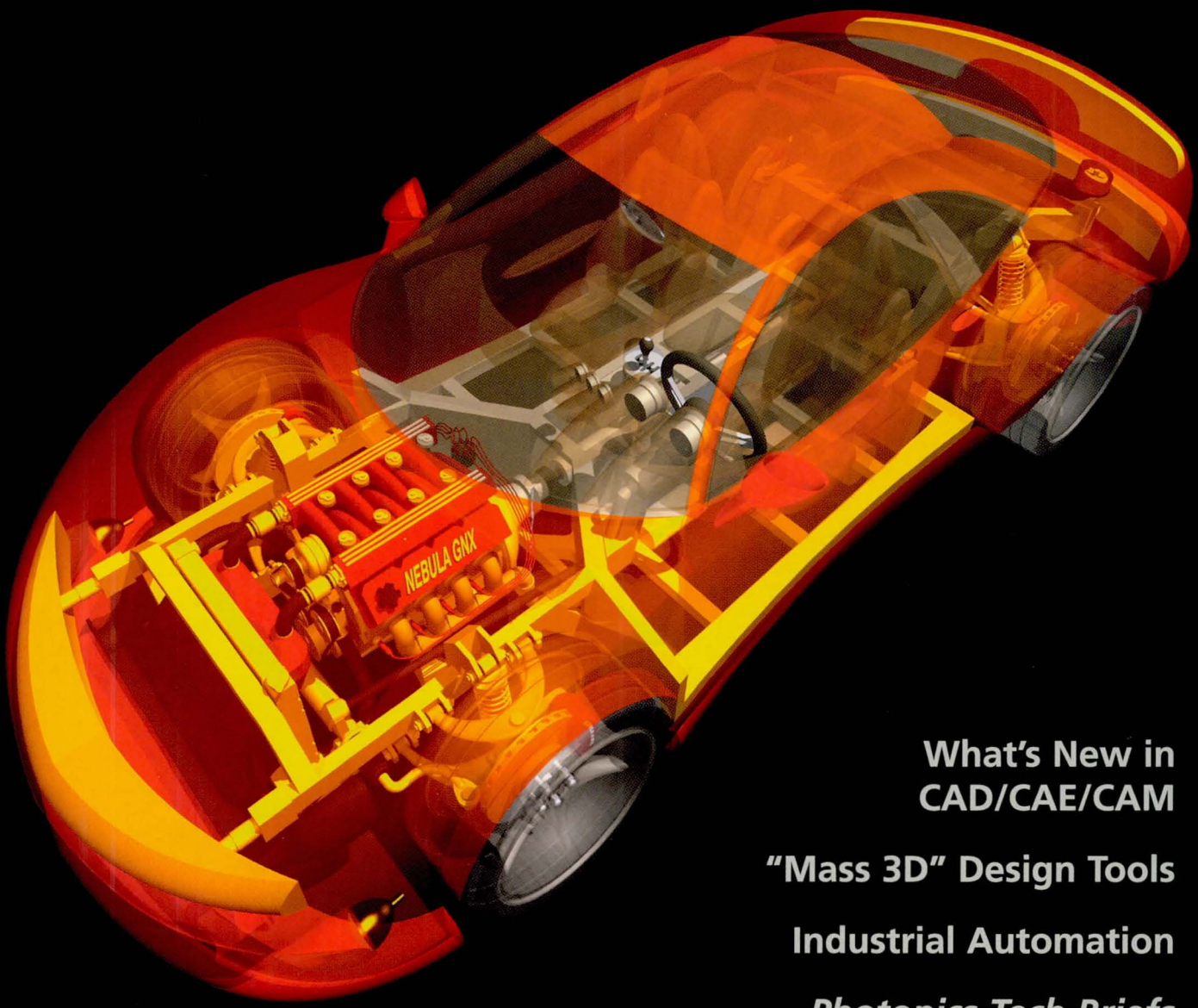
March 2000

Vol. 24 No. 3

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



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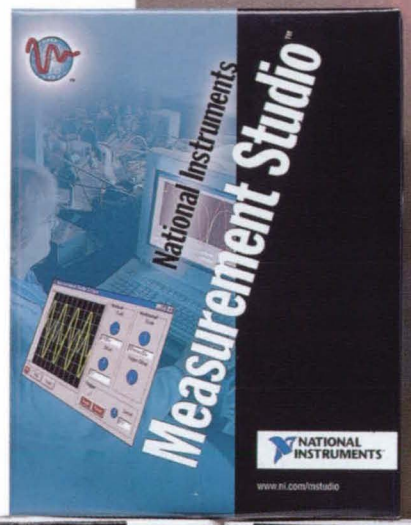

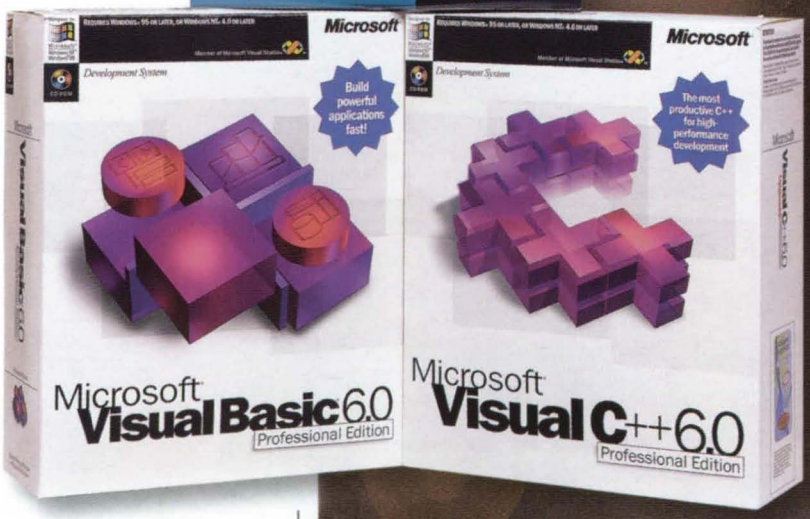

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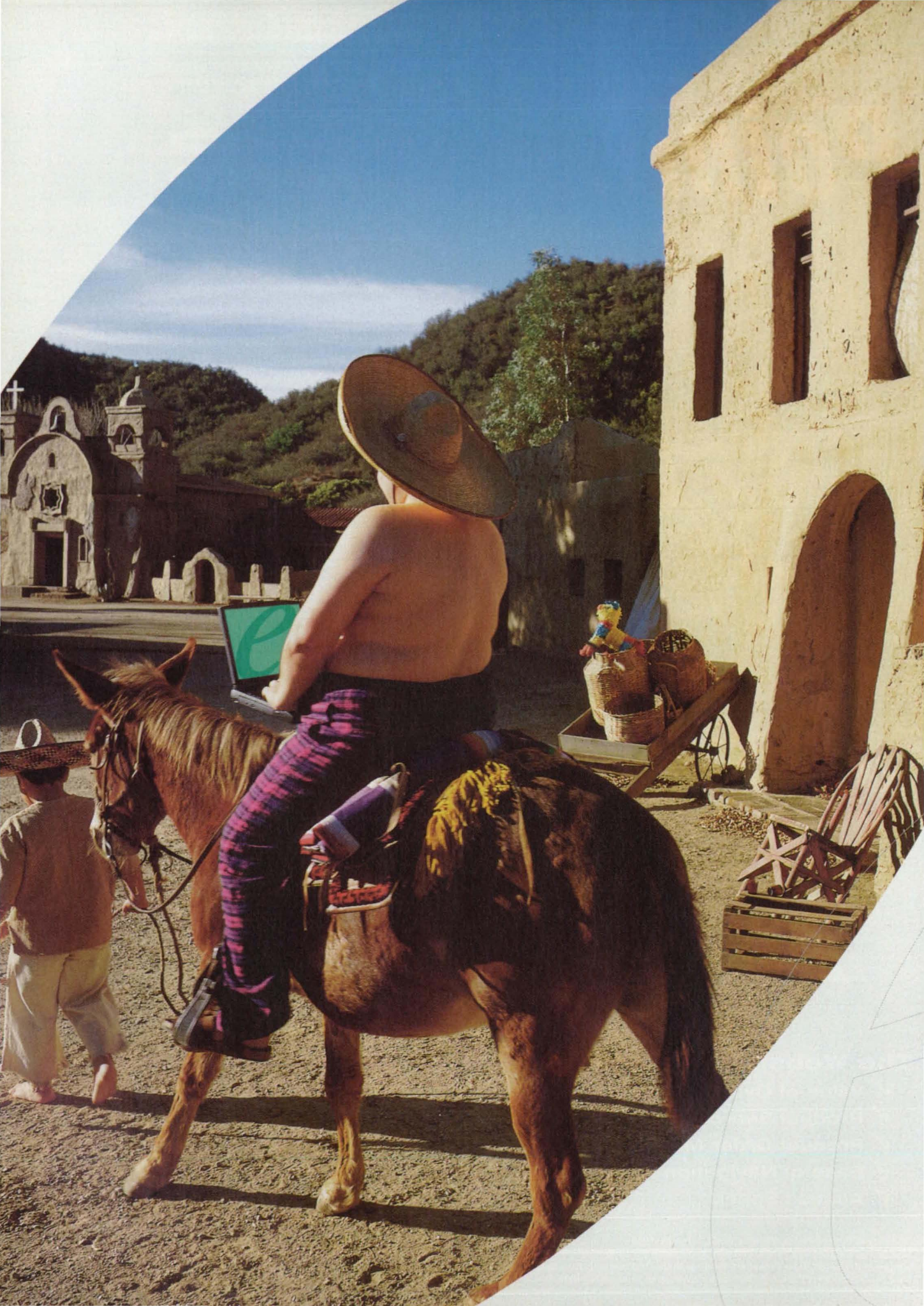

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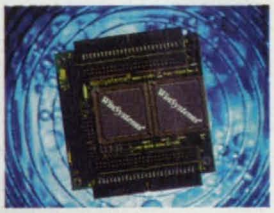

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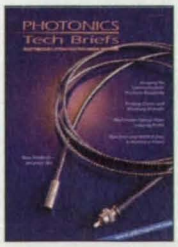
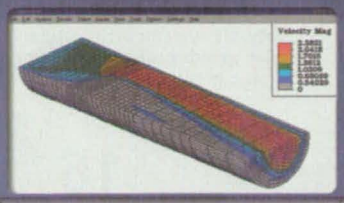


1a - 32a
Photonics Tech Briefs

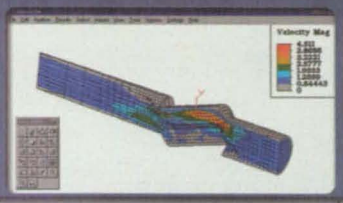
Follows page 16 in selected editions only.

12 Reasons Why Algor Should Be Your FEA Partner

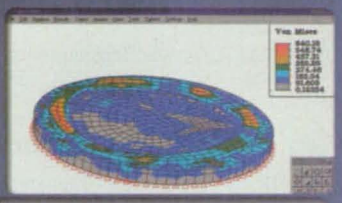
Linear Static Stress - Algor's linear static stress product enables you to capture complex assemblies, such as this valve assembly, from a CAD solid modeler and run a finite element analysis using fast solver technology. Typical loadings are pressure, acceleration, temperature, force and prescribed displacements.



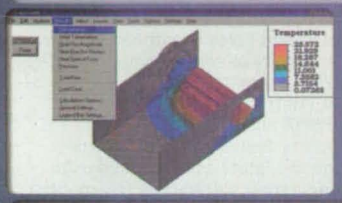
Steady Fluid Flow - Prescribed velocities and pressures provide the loading for this 3-D steady fluid flow analysis of a pipe with a gate valve. Algor's multiple load curves allow for easy data entry for adding loading such as gravity.



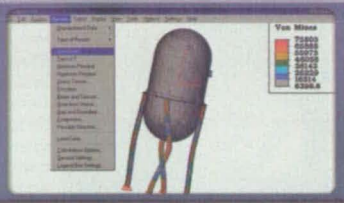
Unsteady Fluid Flow - Unsteady fluid flow of this ball valve system was analyzed using a 3-D CAD solid model. Algor's unique processor solves for velocities and pressures throughout the dynamic event, using a specialized meshing algorithm for high velocity gradients.



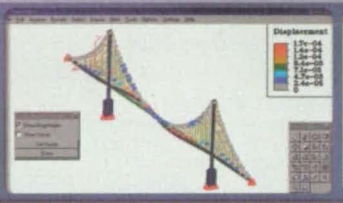
DDAM - Algor's Dynamic Design Analysis Method enables you to analyze the shock response at the mountings of shipboard equipment such as watertight doors, masts, propulsion shafts, rudders, exhaust uptakes and portholes, as shown above.



Transient Heat Transfer - The dynamic effects of a transient heat transfer analysis were needed for the time-dependent temperature loading of this heat sink assembly. Algor's multiple load curves for various loading conditions allow for the simulation of the thermal event.



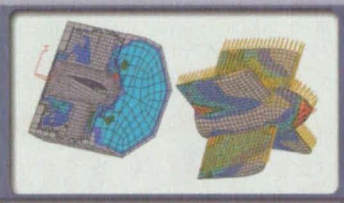
Nonlinear Static Stress - Algor's nonlinear product helps to accurately predict large deformation and large strains caused by static loading. As seen by this water tank, buckling of a structure is one type of failure that can be exposed.



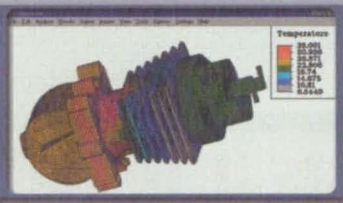
Linear Dynamic Stress- A modal analysis is one of the linear dynamic stress analyses performed on this suspension bridge. Failure can occur when the loading frequency is at the structure's resonant frequency. Algor's linear dynamic analyses accurately predict these frequencies and dynamic effects.

Mechanical Event Simulation (MES) with Nonlinear Material Models - Algor's MES extends full dynamic analysis capabilities to large strain/deformation analyses of nonlinear materials, as shown by this landing gear assembly. Kinematic elements can be used for quicker processing.

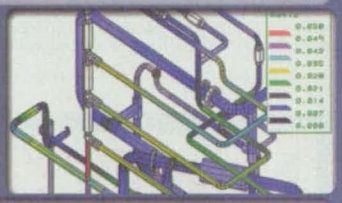
Mechanical Event Simulation (MES) with Linear Material Models - Algor's MES with linear material models allows you to represent a dynamic analysis while solving for kinematics, deflections and stresses of the structure. Analyses using large CAD assemblies, such as this rocker arm assembly model, can be expedited by using kinematic elements.



Multiphysics - Algor's multiphysics products enable you to combine multiple analysis types into one event. Resultant forces from flow around this turbine were calculated and then projected onto the object for a structural analysis. Other multiphysics capabilities include combining heat transfer with fluid flow, heat transfer with static/transient stress and heat transfer with fluid flow and stress.



Steady-State Heat Transfer - Algor's steady-state thermal processor helps predict temperature distribution due to thermal loading. Loading such as convection, radiation, conduction, applied temperatures and surface heat fluxes can be added to an analysis for fast, accurate results. In the case of this engine casing, both conduction and convection were part of the analysis of this 3-D solid model.



Piping Design and Analysis - Algor's piping design and analysis product enables you to calculate the deflections and stresses of this plant piping system and then compare the results with ASME/ANSI code allowables. Loadings can include: dead weight, thermal differences, pressure, wind loads, earthquake loads, time history of forces/displacements, response spectrum, natural frequencies and pitch and roll.

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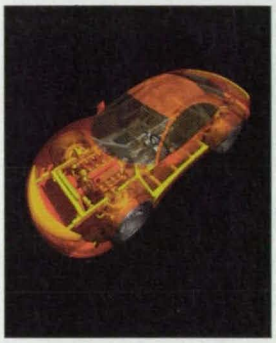

Charles J. Wood of HLM Design, Bethesda, MD, designed the Nebula GNX car in 3D using MicroStation CAD software from Bentley Systems, Exton, PA. Wood's design takes advantage of MicroStation's ability to create complex shapes and surfaces, and to provide realistic renderings. For more information on the Nebula GNX and MicroStation software, visit Bentley Systems at www.bentley.com. See the latest advances in design and engineering software in this month's Special Coverage on CAD/CAE/CAM, beginning on page 32.

(Image courtesy of HLM Design)

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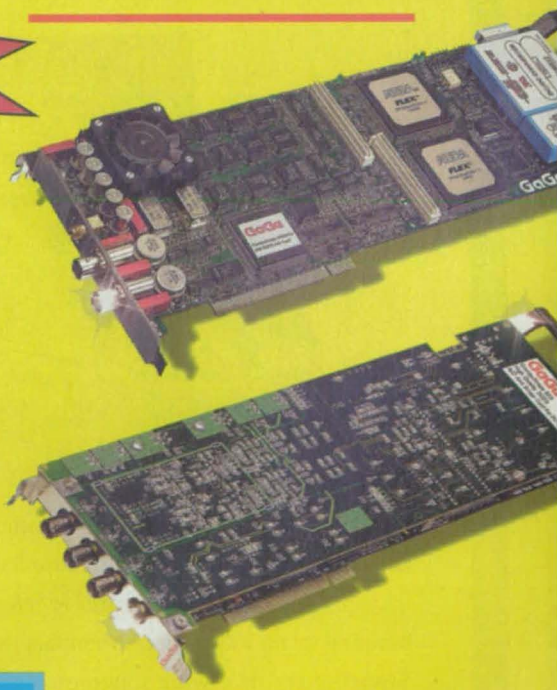

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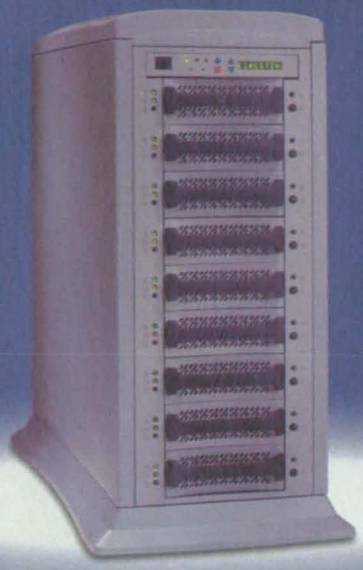

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For More Information Circle No. 570

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

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

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
lee.duke@dfrc.nasa.gov

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

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@ccmail.jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(281) 483-0474
hdavis@gp101.jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Command, Control, and Monitoring Systems; Range Systems, Fluids and Fluid Systems; Materials Evaluation and Process Engineering.
Gale Allen
(407) 867-6226
gale.allen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
(757) 864-6005
s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(256) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
technology@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
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Dr. William Gasko
Center for Technology Commercialization
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J. Ronald Thornton
Southern Technology Applications Center
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Gary Sera
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Lani S. Hummel
Mid-Atlantic Technology Applications Center
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Chris Coburn
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

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

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
Office of Commercial Technology (Code RW)
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Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

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

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
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Joe Boeddeker
Ames Technology Commercialization Center
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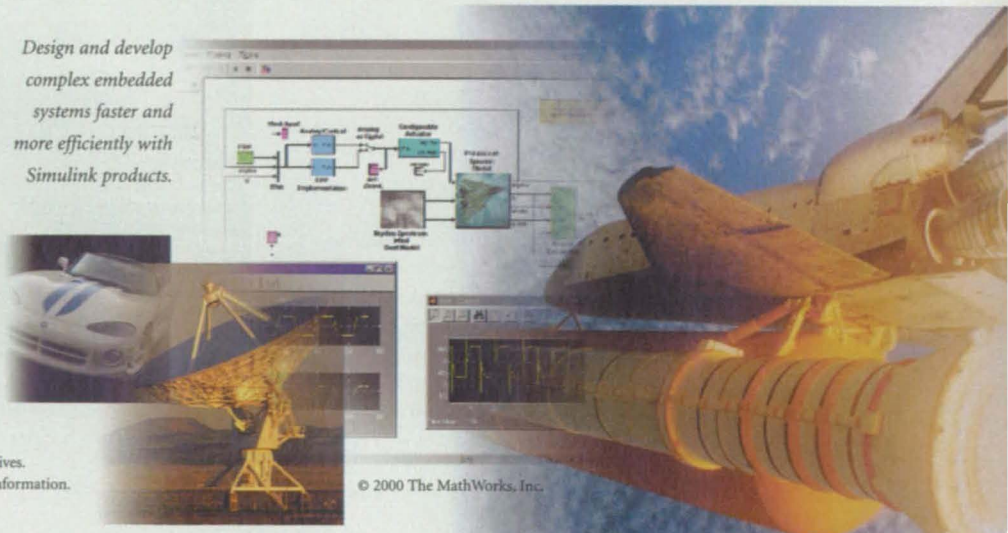

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For More Information Circle No. 557

PRODUCT OF THE MONTH

Intergraph Computer Systems, Huntsville, AL, has introduced the Zx10 ViZual Workstation™ that features new Wahoo Technology™ with Streaming Multiport Architecture™. This architecture is specifically designed to improve system throughput and performance of the 2D/3D graphics pipeline. The workstations also feature 64-bit PCI buses, single or dual Intel Pentium® III 733-MHz processors, up to 8 GB of PC133 ECC SDRAM, and Intense3D Wildcat™ 4110 VIO 3D graphics. Designed for high-performance MCAD and visual simulation applications, the Zx10 workstations are Windows NT-based and provide a 128-bit memory bus running at 133 MHz. The computer's Ultra-tower chassis provides internal support for seven drive bays and seven full-length, full-sized card slots.

For More Information Circle No. 756

Understanding the Global Climate

In a keynote address to weather forecasters early this year, NASA Administrator Daniel S. Goldin outlined NASA's role in studying Earth's climate — specifically, the agency's commitment to scientific research that will help forecasters make more accurate weather predictions. NASA technology has helped predict such events as El Niño and La Niña. For the future, NASA's Earth Sciences projects could result in new satellite technologies and models to help the National Weather Service provide accurate 10- to 14-day forecasts.

"What most people don't know is that our efforts to open the space frontier are largely based on our quest to understand our own planet," said Goldin. "Our development of new technologies and Earth-observing spacecraft complement the vital work of our sister agencies in weather prediction and global climate modeling."

NASA missions such as the Landsat 7 Earth-mapping satellite, the Tropical Rainfall Measuring Mission, and Terra, an Earth observatory, contribute to our understanding of the global climate.

For more information on NASA's Earth Science Enterprise, visit the web site at www.earth.nasa.gov.

Linux Takes Off at JPL

NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, has begun experimenting with the Linux operating system for its performance and cost-savings potential. Computers that run the navigation systems for smaller projects such as the Mars Pathfinder have been expensive due to the high performance required. According to Peter Breckheimer of the Navigation and Flight Mechanics Section of JPL's Systems Division, as PC costs declined and speeds improved, the lab decided to use Linux in certain projects as an alternative to more expensive UNIX platforms.

Breckheimer's group designs, implements, and maintains the Institutional Navigation System Software (INSS) in all flight projects, including Cassini, Galileo, and Deep Space 1. The INSS consists of more than 160 programs written in Fortran 77, C, and Hypertext Markup Language, totaling more than 4.5 million lines of source code.

INSS was designed for portability, and has run on a number of computer systems over the past 40 years, from IBM mainframes, to Digital Equipment Corp. VAX minicomputers, to Hewlett-Packard HP-UX systems. The new Linux operating system was chosen over Microsoft Windows NT because the lab had tens of thousands of lines of UNIX C-shell scripts with no adequate tool to convert them to NT.

NASA's Deep Space 1 project uses navigation code running under Linux.

Visit the JPL web site at www.jpl.nasa.gov.

March 2000

PHOTONICS Tech Briefs

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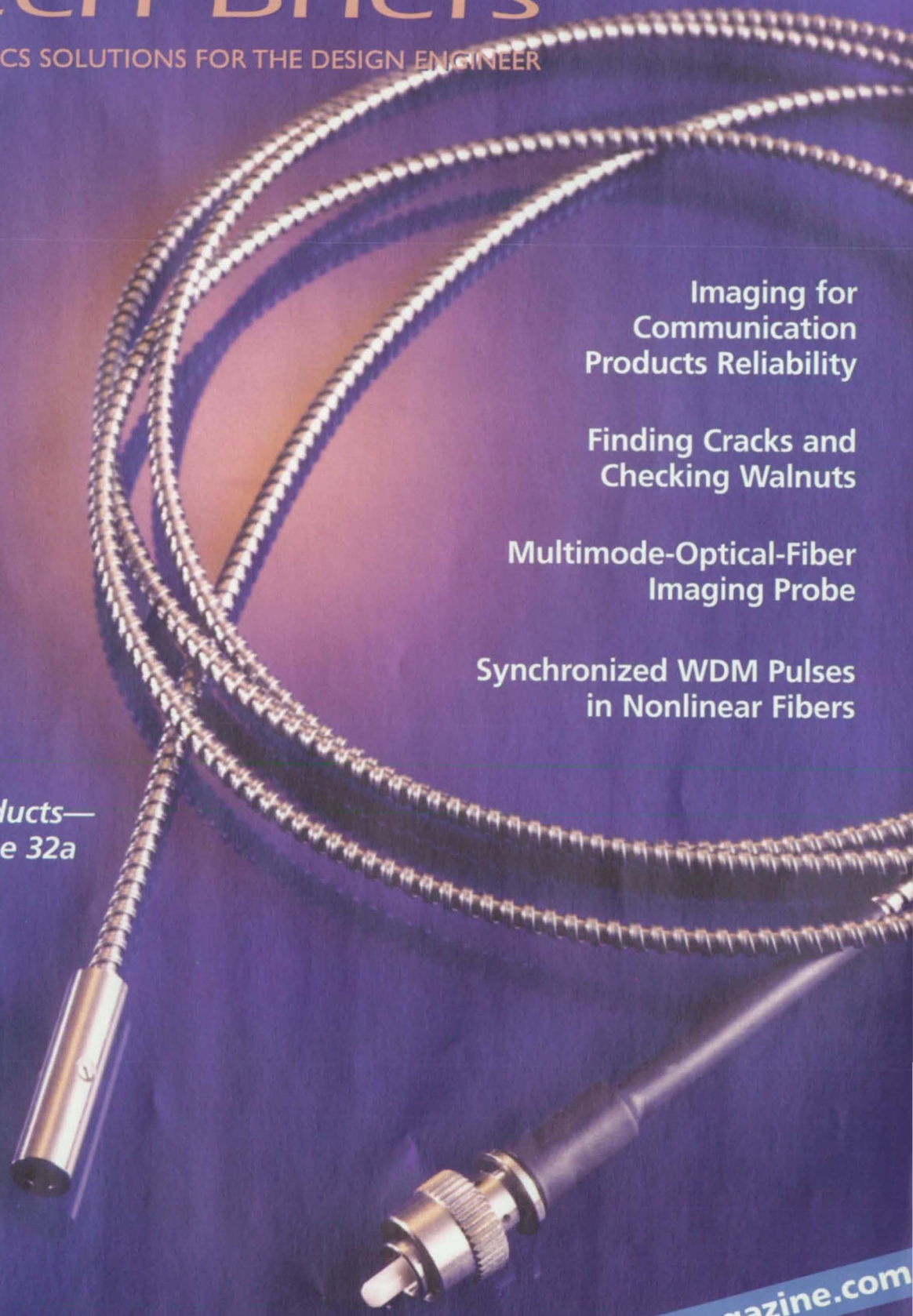

Imaging for Communication Products Reliability

Finding Cracks and Checking Walnuts

Multimode-Optical-Fiber Imaging Probe

Synchronized WDM Pulses in Nonlinear Fibers

New Products— see page 32a

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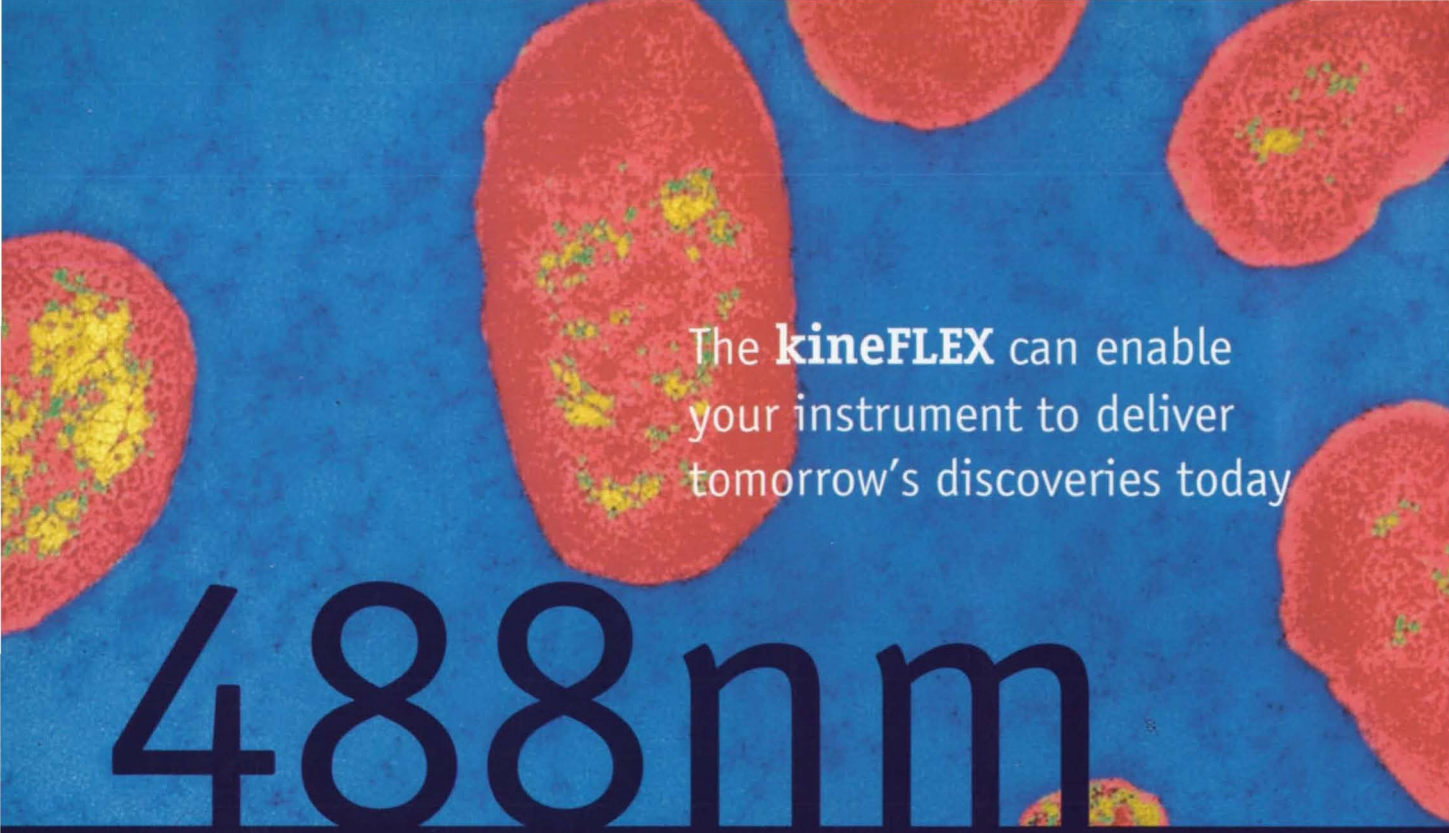

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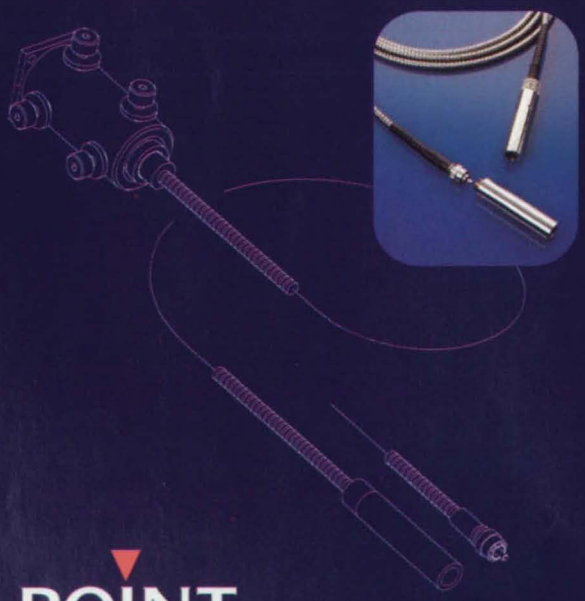

The pace of the human genome project with its goal of discovering 3 billion base pairs of the human genome by 2003, has driven the development of new instruments capable of handling the vast amounts of information analyzed. Technologies to characterize gene expression and DNA Cloning requiring high throughput screening and processes for rapid molecular separation have been developed.

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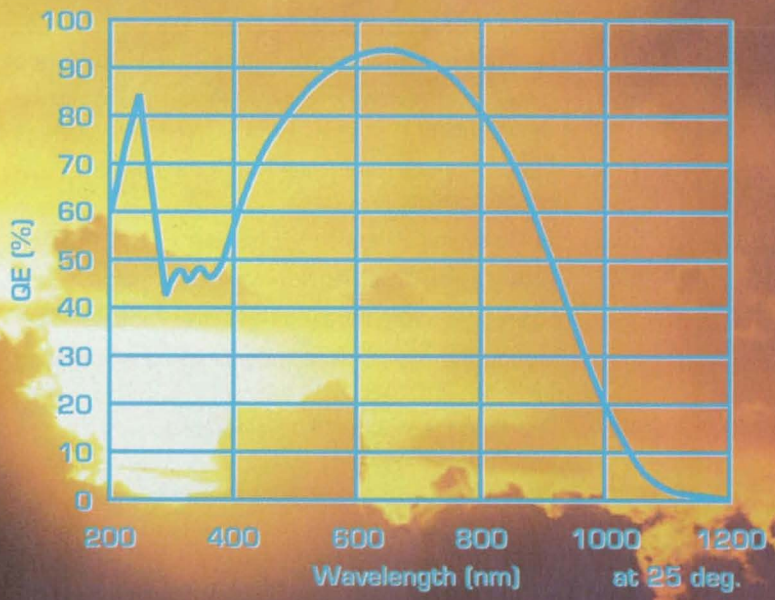

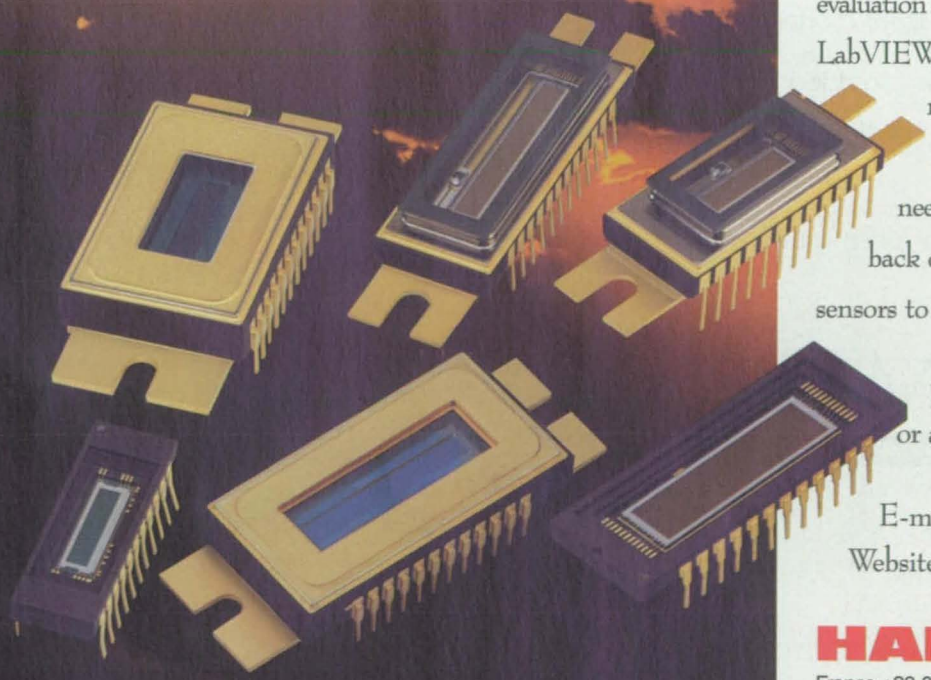

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PHOTONICS Tech Briefs

Supplement to *NASA Tech Briefs'* March 2000 Issue
Published by Associated Business Publications

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On the Cover: Point Source's picoFLEX miniature single-mode fiber delivery system, the assembly of which is constructed from a ruggedized small-bore stainless steel jacket. *Photo courtesy Point Source.*

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For More Information Circle No. 458

Photonics Tech Briefs 1999 Readers' Choice Product of the Year

Readers' votes for *Photonics Tech Briefs'* Third Annual Product of the Year Awards have been tallied, and the winners are:

Gold Winner

and Product of the Year Winner

Lambda Physik (Ft. Lauderdale, FL) ScanMate™ OG, a complete spectroscopy system for critical work in the UV, visible, and near-IR, continuously tunable from 320-1036 nm

Silver Winner

Synrad (Mukilteo, WA) FH Series CO_2 laser marking system with a galvanometer-based scanning head, marking software, focusing lenses, mounting assemblies, and power meters

Bronze Winner

Meller Optics (Providence, RI) high-precision optical domes for protecting sensors and detectors from water, chemicals, particles, debris, and corrosive materials

Other finalists include Siemens Microelectronics (Cupertino, CA) stackable high-power laser diode bars, TUIOptics GmbH (Munich, Germany) blue external cavity diode laser, and Spectra-Physics (Mountain View, CA) Mai Tai™ tunable Ti:sapphire femtosecond laser source

Winners were chosen by reader vote on *Photonics Tech Briefs'* web site from among the six Products of the Month nominated by the editors during 1999. The awards were presented to the winning companies at a reception cosponsored by *Photonics Tech Briefs* and SPIE at Photonics West 2000 in San Jose in January.

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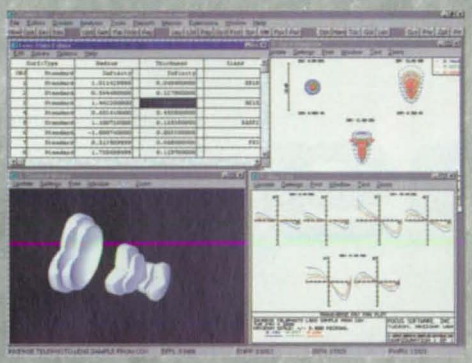

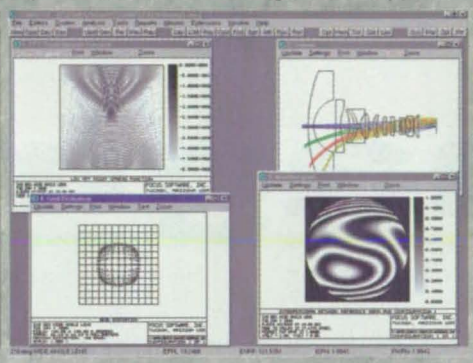

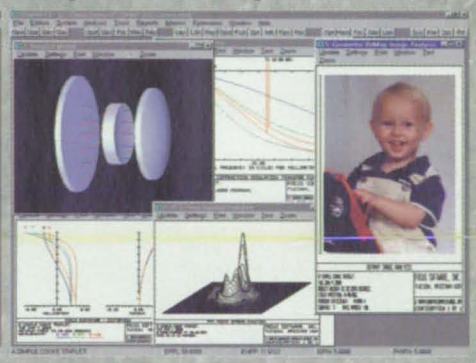

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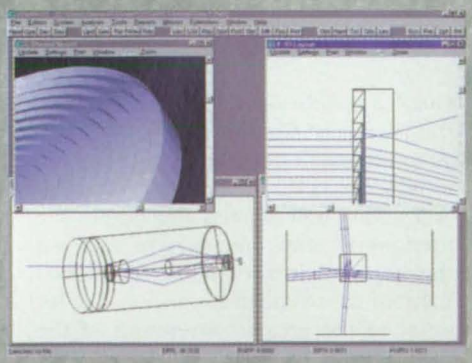

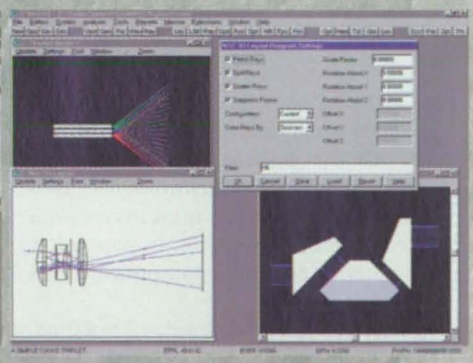

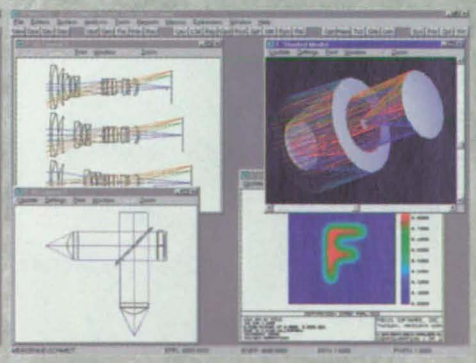

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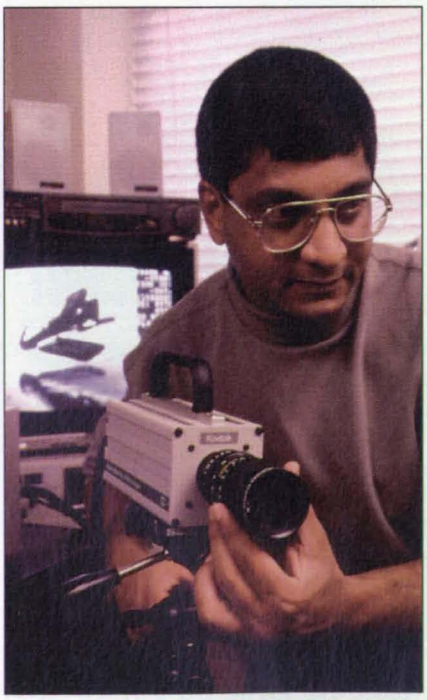
For More Information Circle No. 495

Hitting the Deck with High-Speed Imaging

Motion analysis contributes to the quest for impact-tolerant products.



Suresh Goyal, a mechanical engineer in the Wireless Packaging Research Department of Bell Labs, positions the HS motion analyzer Model 4540 to capture high-speed digital imagery.

High-speed motion analysis has emerged as an important tool for product reliability engineers. At Lucent Technologies' Bell Labs, for example, it is used in research on packaging of reliable, impact-tolerant components for communications products.

Reliability is a critical measure of quality in high-tech communications products, and Lucent supplies components to manufacturers of portable electronic devices for which impact tolerance — surviving accidental drops and impacts — is not only a valuable attribute but a major selling point.

Portable electronic devices offer mobility. But with mobility comes risk. Cellular phones, notebook computers, personal digital assistants and pagers drop to the floor or are bumped against unyielding objects every day. Yet users expect them to continue operating.

That's where the work of such researchers as Suresh Goyal comes in. Goyal, a member of the technical staff in the Wireless Components and Packaging Research department at Bell Labs in Murray Hill, NJ, analyzes products and studies how impacts affect them. He then works with designers to improve the impact tolerance of products. Bell Labs, whose scientists are responsible for many of the greatest inventions of the past century, from the transistor to the laser and cellular telephony, is the research and development arm of Lucent Technologies.

Impact-Induced Loads

During impact testing, the force on a portable device such as a cellular phone may range from hundreds to thousands of g's (1 g is the acceleration of an object because of gravity) over the course of several milliseconds. As a result, the product's housing may become deformed or come apart, and such fragile components as ceramic substrates or liquid crystal displays may fracture.

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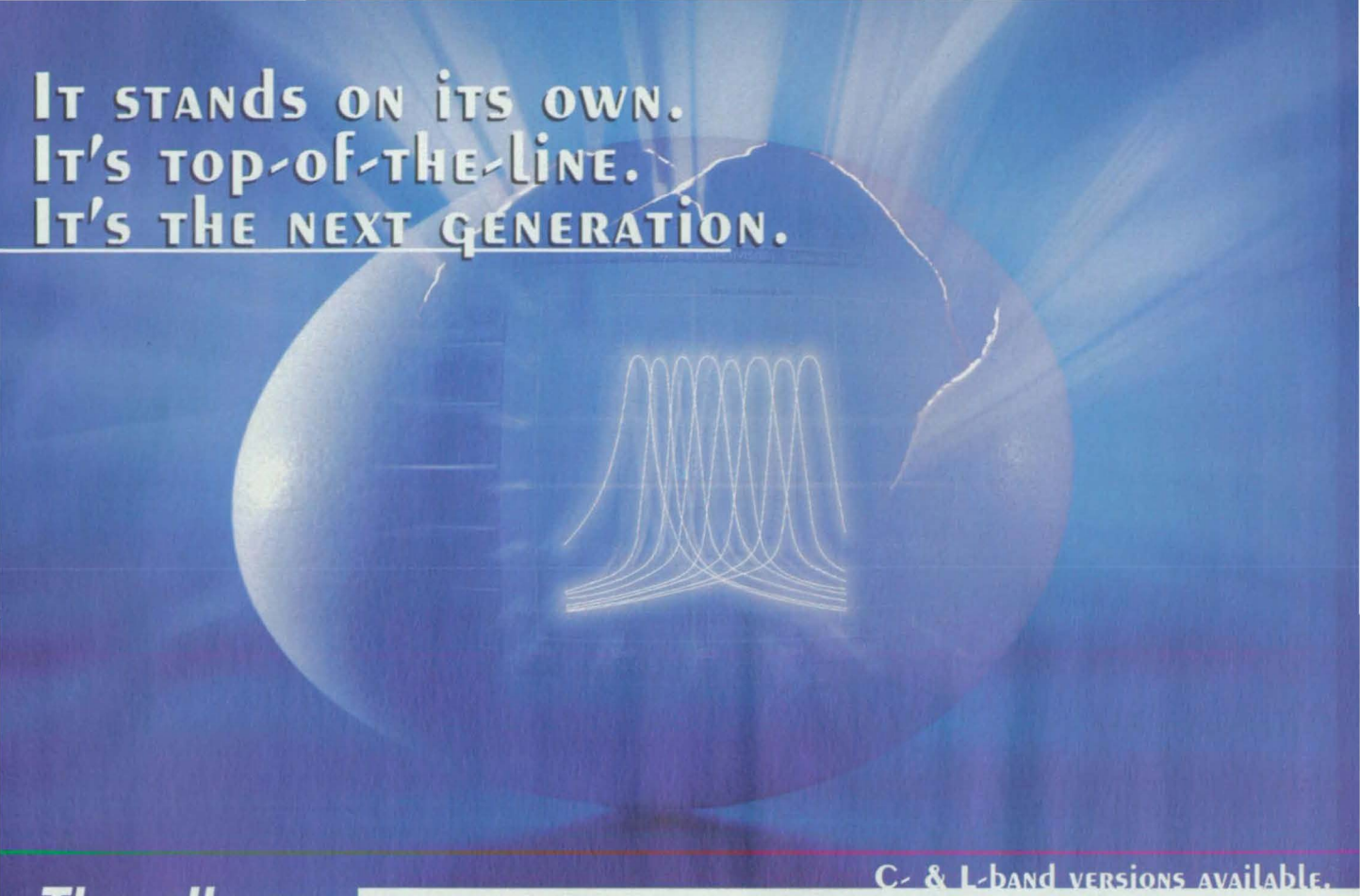

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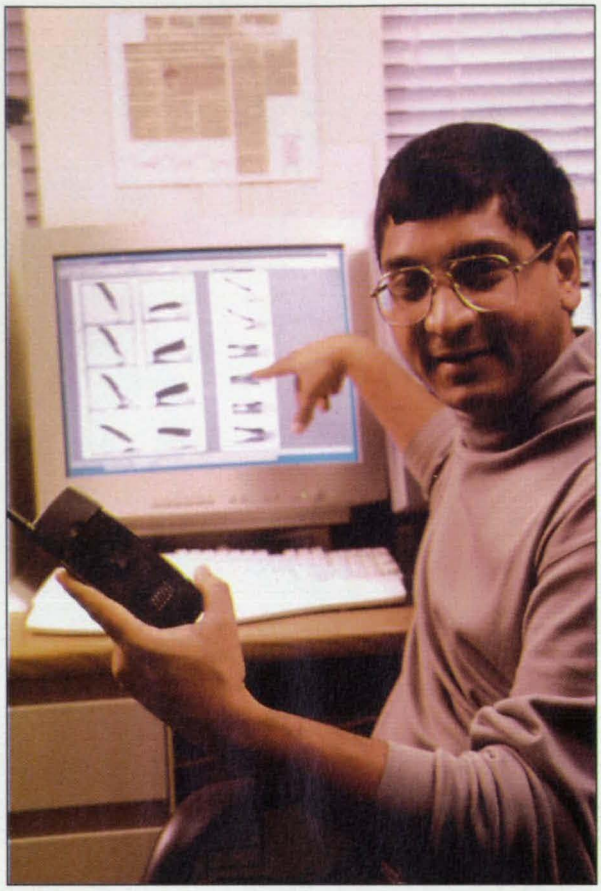

High-speed digital photography allows Lucent product and packaging engineers to immediately see weaknesses in product design that lead to product flexing and deformation, according to Goyal.

"A dropped portable electronic device is most likely to strike the floor at an angle," Goyal said. "First one corner touches down, then the object rotates, and other corners bounce and clatter. The result is that the ends of the product strike at much higher velocities and receive much more powerful impacts than the initial drop would lead you to expect."

The most common approach to protecting portable electronic equipment against such impact forces comes in the form of plastic housings with extra-thick walls, numerous screws, snaps, and hooks to hold the casing together, and extra space between components. But in communications, the market demands small, lightweight products. So designers must find other ways to protect the delicate internal electronics.

The Role of High-Speed Imaging

To observe and record the complex sequence of events in impact testing, Goyal employs a high-speed camera—preferably one that can record from 1000 to 10,000 frames per second. "The higher the frame rate, the better. The higher the time resolution, the greater the information we have to work with," he explains.

At present Goyal is using the high-speed motion analyzer Model 4540 from Roper Scientific MASD (formerly Eastman Kodak Company's Motion Analysis Systems Division). The imager captures up to 4500 full-frame gray-scale images per second at 256 × 256 pixels and up to 40,500 partial frames at lesser resolutions. Typically, he uses the analyzer at 4500 to 18,000 frames per second.

The high-speed motion analyzer captures an event digitally in dynamic RAM. The sequence of images can then be saved to a hard disk or written to CD, like any computer data, or recorded on analog videotape. A direct digital interface from the analyzer's CPU to a desktop computer makes it simple to store the images for later review and quantitative analysis using a computer.

Using the high-speed digital motion analyzer to document and study impact testing lets Goyal frame the shot, record, and view the image series in minutes. If he wants to see different views of the impact event, he can stage the experiment again until he succeeds in getting the scenes he wants.

The high-speed motion analyzer he uses, configured with 1536 megabytes of DRAM, can capture and store 24,576 frames (5.46 seconds of recording at 4500 frames per second). Out of that total, only a few hundred capture the impact event. The lab's previous digital-motion analyzer could capture only 0.66 seconds of data. The extended period of capture now makes it much more likely that the event will be sufficiently recorded in a single attempt, since it isn't necessary to synchronize the event and trigger the motion analyzer so precisely.

Once the images are captured, Goyal can review them on a video monitor at a variety of playback speeds, from real-time replay to freeze frame. A few milliseconds can be stretched out to minutes.

Selected frames can be analyzed in detail. Goyal can choose a subset of the event—a half dozen frames that capture the most important moments — and share them over e-mail with designers in the next building or thousands of miles away.

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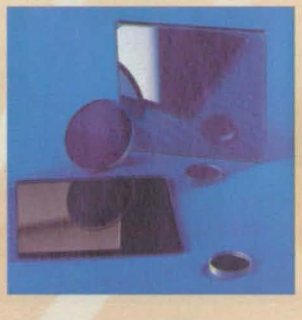

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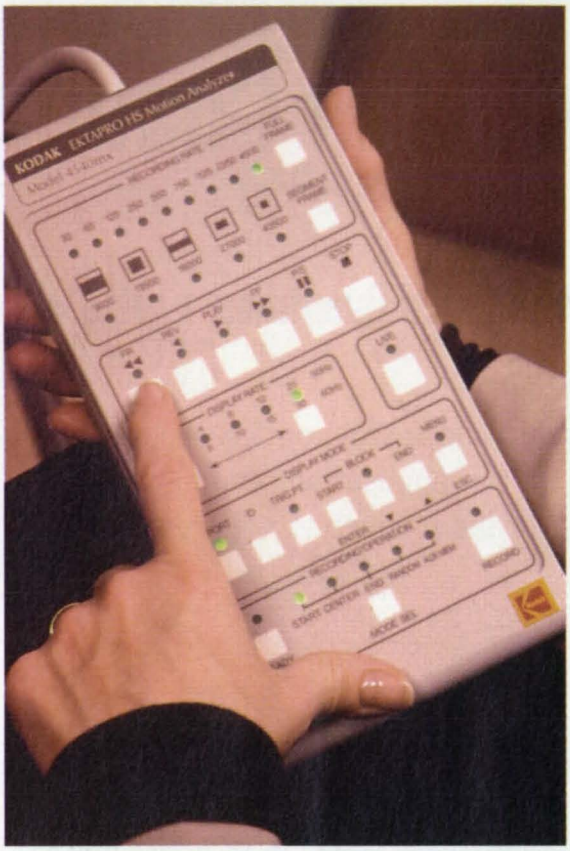

This handheld controller provides easy-to-use touch-pad control over the operation of the Model 4540 motion analyzer.

Making Sense of the Images

What do the images show? The body of a device with a clamshell case flexes when it strikes a surface. It deforms and buckles, and the top and bottom halves of the case separate momentarily. These are effects that can be seen and understood only by viewing the high-speed images. A second after a device is dropped, it may appear completely normal and unaffected. Only the digital images reveal the violence it has endured.

"The high-speed images are used to validate analytical results and to design modifications," Goyal said. The final product design is tested before commercial release.

The value of this work can be measured in the increased reliability of products. Greater impact tolerance means fewer warranty claims, which translates directly to the bottom line, and a reputation for reliability in the marketplace.

The value of testing makes even more sense as the value of the product increases. Devices with special capabilities and proprietary interfaces may sell for hundreds or thousands of dollars, but they are likely to come with an iron-clad warranty. Whatever happens to them, the customer can take them back for replacement. For products like that, impact tolerance is critical.

The value of impact testing is clearly more important than ever before. Impact test data can be used to optimize designs almost from the start of the design process.

"Equally important, it confirms the public perception of products as sturdy, reliable, and of the highest quality," Goyal said. "It's difficult to put a price on that."

For more information, contact Wendy Telford at Roper Scientific MASD, 11633 Sorrento Valley Rd., San Diego, CA 92121; (858) 535-2909; e-mail: wendytel.aol.com; www.masdroperscientific.com.

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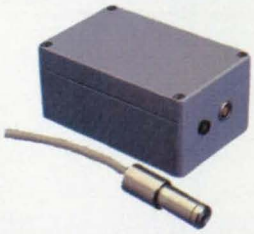

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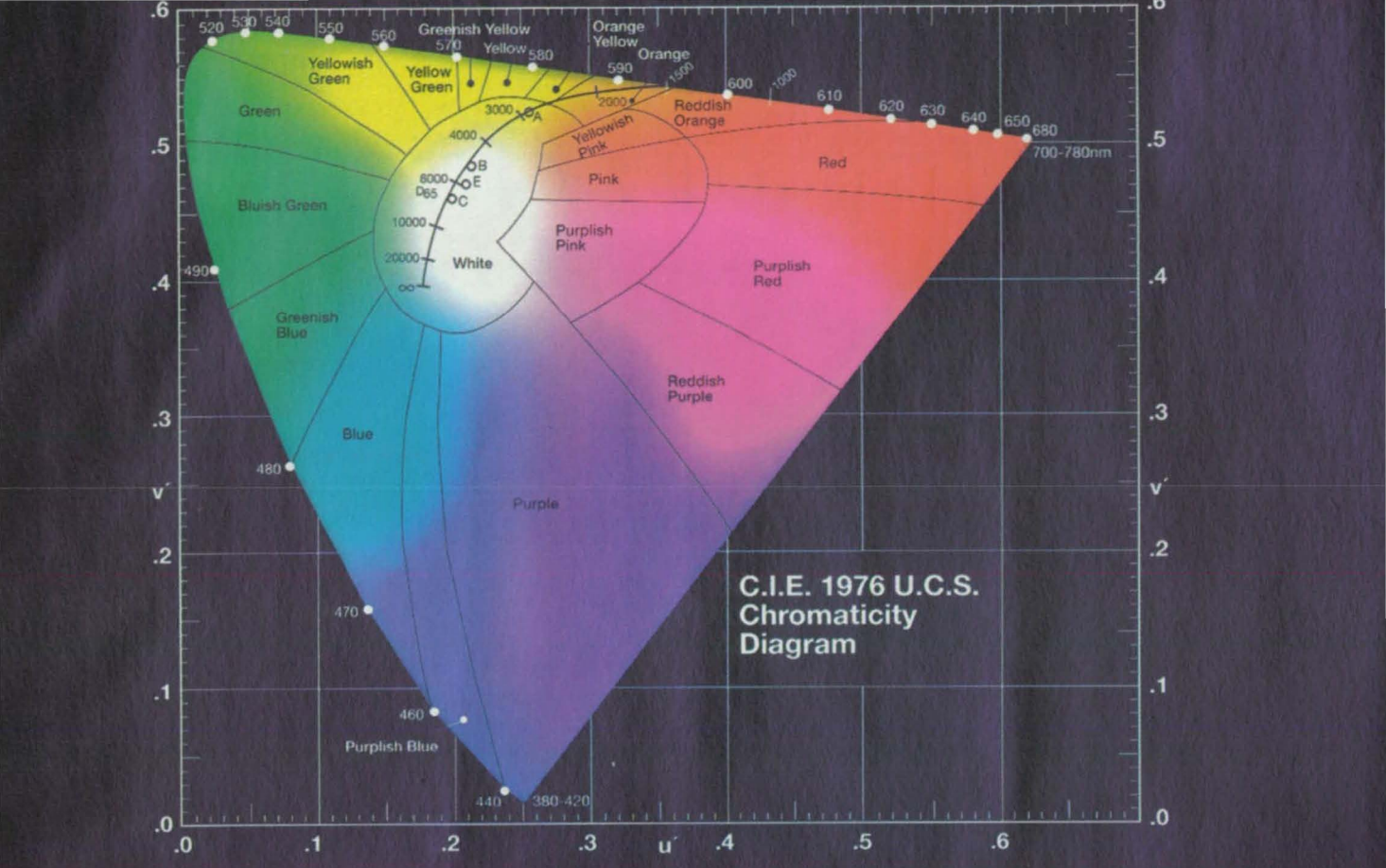

Diagram courtesy of Photo Research, Inc., "The Light Measurement People."

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For More Information Circle No. 484

Finding Cracks and Checking Out Walnuts

A novel nondestructive testing technique combines infrared imaging technology and ultrasonics.

One of the biggest problems facing manufacturers of safety-critical parts is the existence of hard-to-find defects that can cause catastrophic failure of materials under stress. An automotive steering knuckle is an example of a component that can cause serious injury or death if undetected cracks lead to mechanical failure, as when a car is cornering at high speed. Unfortunately, conventional techniques for finding cracks in parts all have major drawbacks. For example, dye penetrant inspection relies on fluorescent dye that penetrates into cracks in a surface. When the surface is wiped off, small amounts of dye left in the cracks will fluoresce. The dye is toxic, however, and the process takes time. X-ray imaging can reveal cracks, although the technique is expensive and hazardous, and will not effectively detect some crack types such as compression cracks. A compression crack can form during manufacturing when a part cracks at high temperature and the crack closes up as the part cools, rendering the crack nearly invisible.

ThermoSoniX (thermal imaging and sonic excitation) is a novel nondestructive testing technique that uses high-frequency sonic excitation, together with infrared (IR) detection, to image surface and subsurface defects.* This imaging technique uses a short (50-200 ms) pulse of high-frequency sound, typically 20-40 kHz, that is applied at some convenient point on the surface of the object under inspection to produce localized frictional heating at the defect. An IR camera images the heating of the surface resulting from the effects of friction or other irreversible internal surface interactions in the vicinity of cracks or disbonds. These effects result from the fact that the two surfaces of internal defects do not move in unison when sound propagates in the object. Thus, for instance, the facing surfaces of a closed crack will appear as a planar heat source.

A crack in a ductile iron part is shown in Figure 1, just before ultrasonic stimulation (left). If the crack intersects the surface, the heat source first appears as a line in the IR image, as shown in Figure 1 at center. The line subsequently blurs and broadens into a diffusely heated

*Patent pending, Wayne State University, Detroit, MI.

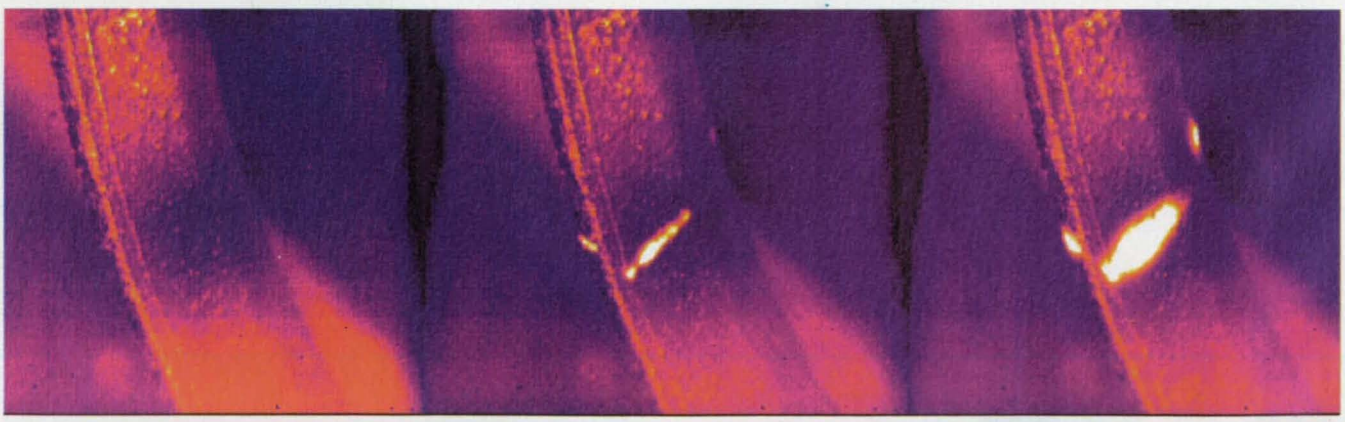

Figure 1. Crack detection in a ductile iron cast part.

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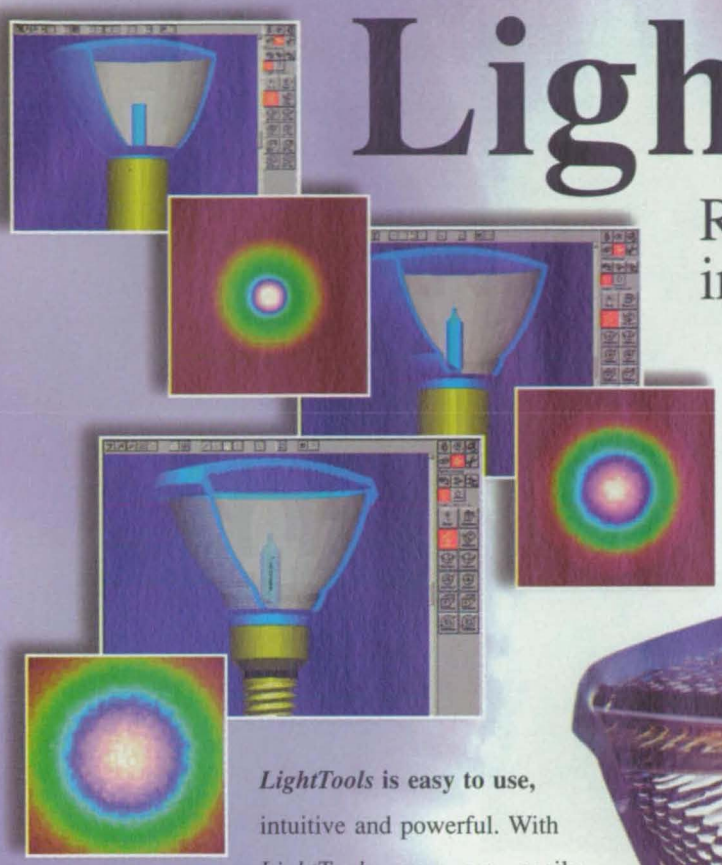

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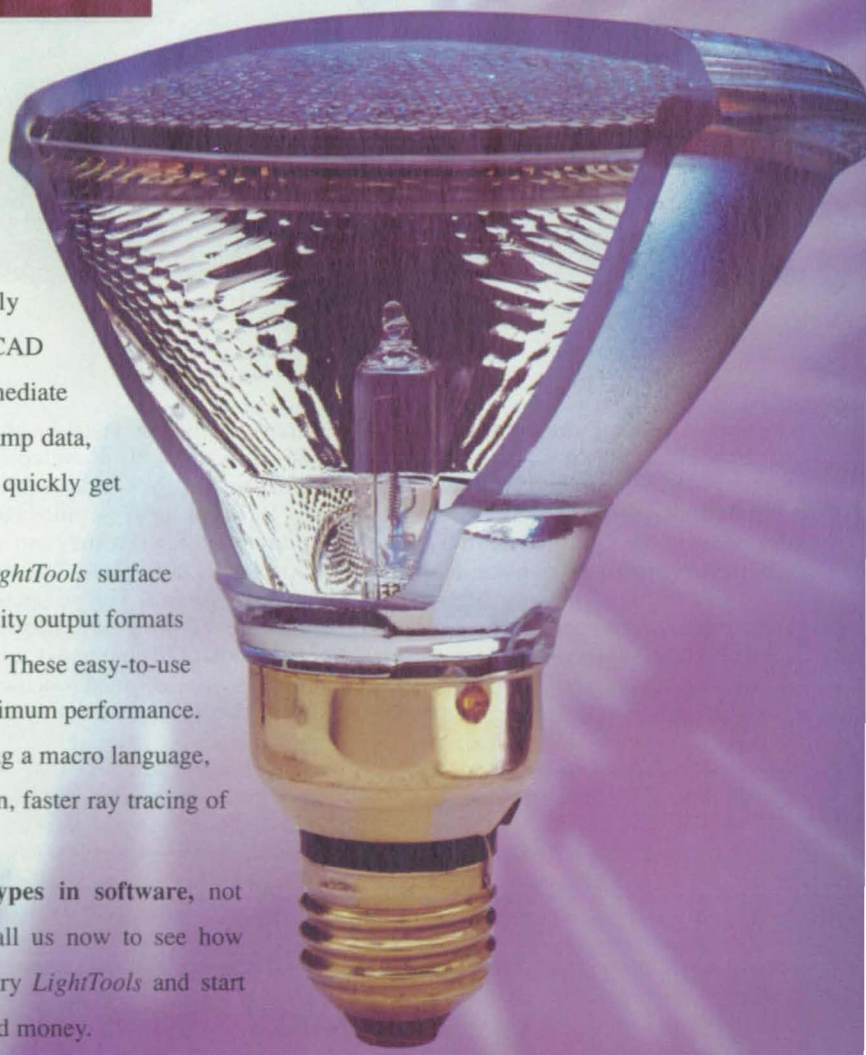

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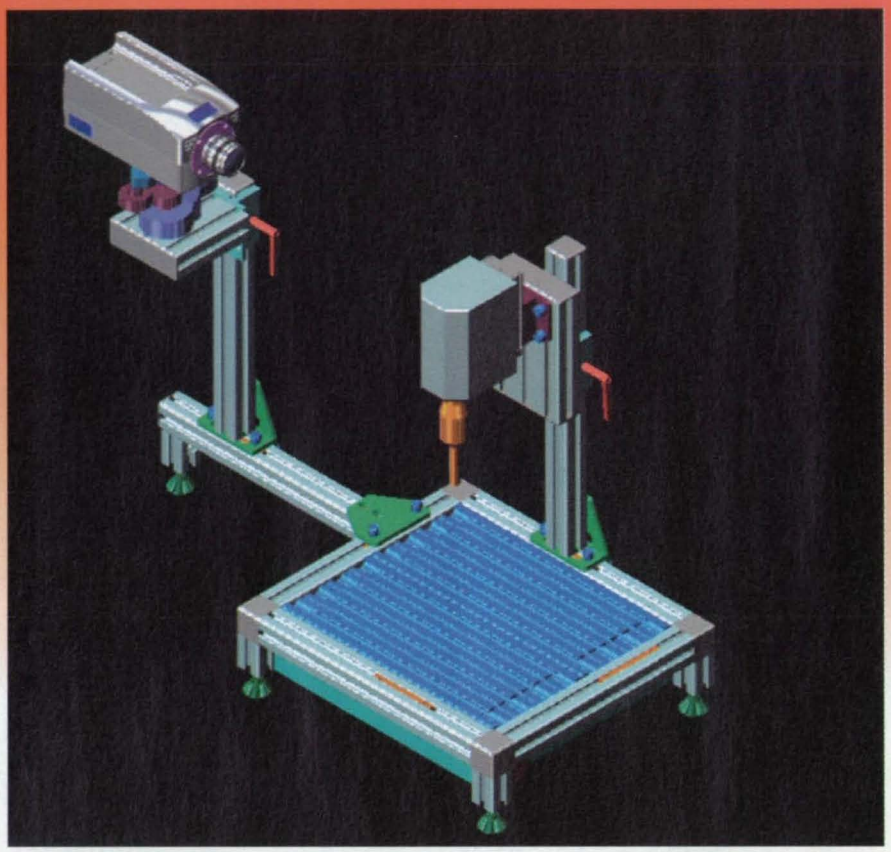

Figure 2. ThermoSoniX test station.

region surrounding the original line, as shown in Figure 1 at right. When the sound pulse is turned off, the resulting temperature pattern decays according to the usual process of thermal diffusion. This entire process takes place in a fraction of a second, enabling high-speed automated defect inspection.

Note that these images have not been enhanced for contrast. The superb temperature sensitivity of the indium antimonide IR camera makes a fraction of a degree temperature rise stand out in sharp contrast to the surrounding material. Similar images have been obtained with damaged samples of ceramic, carbon, hard plastics, and even walnuts and pistachios. In fact, any hard material with a high emissivity in the mid- or long-wave IR bands can be evaluated.

Indigo Systems Corp. has developed a ThermoSoniX test station based on technology developed at Wayne State University and licensed by Indigo Systems. The test station, shown in Figure 2, is primarily intended for hand inspection of low-volume, high-cost parts such as aircraft turbine blades. It is also intended for research and development of fully automated ThermoSoniX inspection systems. The test station consists of the following subsystems:

- A pneumatically actuated ultrasonic energy source coupled to a hard metal probe that makes contact with the part under test;
- A mechanical structure that holds the actuator, ultrasonic probe, camera, and a platform for the part under test;
- An Indigo Systems Merlin mid-infrared camera that images the part under test in the 3- to 5-micron waveband and transmits 12-bit digital image data to a digital framegrabber;
- A computer hosting the data acquisition and control system. The test station is run by a LabVIEW virtual instrument (VI) that controls the pneumatic actuator, the ultrasonic source, a digital framegrabber, and the Merlin camera.

For many practical applications, this new imaging technique has significant advantages over traditional nondestructive inspection methods. It is fast, wide-area, and sensitive to cracks with any geometrical orientation. ThermoSoniX is not restricted to particular classes of materials, nor does it have the radiation or chemical hazards associated with x-ray imaging or dye penetrants, respectively.

This article was written by Dr. Austin Richards, applications engineer at Indigo Systems Corp., and Prof. Xiaoyan Han of the department of electrical and computer engineering, Wayne State University, Detroit, MI. For further information, contact Indigo Systems at 5385 Hollister Ave., Suite 103, Santa Barbara, CA 93111; (805) 964-9797; fax: (805) 964-7708; e-mail: richards@indigosystems.com; www.indigosystems.com.

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For More Information Circle No. 497

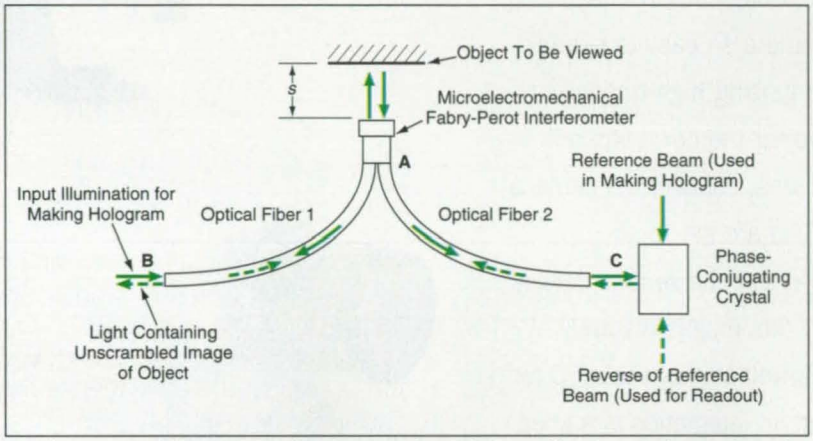
Development of Multimode-Optical-Fiber Imaging Probe

A very thin probe could be used to view a tightly confined object.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental electro-optical system would enable remote real-time viewing of a scene through a multimode optical fiber, as though the fiber were a conventional image-transmitting optic like a lens or prism. The system is intended to be a prototype of fiber-optic imaging probes that could be made very thin and could be particularly useful as minimally invasive probes in medical diagnosis.

A previous version of the system was described in "Multimode Optical Fiber as Imaging Probe" (NPO-19671), *NASA Tech Briefs*, Vol. 22, No. 2 (February 1998), page 21a. Both versions were conceived to address the following issue: It would be desirable to use an optical fiber as an imaging probe or imaging optic. Ordinarily, it would not be possible to do this because image information would become distorted (scrambled) during propagation along the fiber. The developmental system would make it possible by exploiting phase conjugation to reverse the scrambling.



A **Hologram Would Be Generated in the Crystal** at C during calibration. During readout, the object at A would be viewed at B by exploiting phase conjugation at C to reverse the scrambling that occurs during propagation along the optical fibers. The microelectromechanical Fabry-Perot interferometer would make it unnecessary to replace the object with a mirror during calibration.

The system (see figure) would include two multimode optical fibers, which would be terminated side by side at one end (location A) facing an object that one seeks to view. In the previous version, the tips of the fibers would face the object directly across a gap of width *s*. In the present version, a microelectromechanical Fabry-Perot interferometer (for use as described below) would be interposed between the tips of the fibers and the gap *s*. To ensure the coupling of sufficient phase information into and out of the fibers, the gap must very narrow; specifically, $s << D^2/\lambda$, where D is the aperture diameter of a fiber and λ is the wavelength of the light.

A source of light (in this case, a laser) at location C would illuminate the object via fiber 2. An observer at location B would attempt to view the illuminated object through fiber 1. The problem is to predistort the illumination (prescramble the amplitudes and phases of the fiber-optic waveguide modes of the illuminating electromagnetic field) in such a way as to compensate for the scrambling that occurs during transmission of the image along fiber 1 from A to B, so that the image of the object would arrive unscrambled at B.

The solution would involve the generation and use of a hologram in a phase-conjugating crystal (in this case, a photorefractive crystal) at location C during a calibration phase of operation. First, a flat mirror would be placed facing the tips of the optical fibers at location A, where the object would later be placed for viewing. A source of light would be placed at B, where the observer would later be stationed. Light from this source would travel through fiber 1 to A, where it would be reflected into fiber 2. Upon emerging from fiber 2 at C, the light would enter the crystal. At the same time, the crystal would be illuminated with a reference (plane-wave) beam of light. Interference between the reference beam and the light emerging from fiber 2 would produce the desired hologram via the photorefractive effect. The hologram would encode the information about scrambling in both fibers 1 and 2.

Once the hologram had been generated, one could exploit the phase-conjugation principle to reverse the propagation of the optical signal and thus reverse scrambling during a readout phase of operation. The crystal would be illuminated with the phase conjugate of the reference beam (in essence, a beam of the same wavelength propagating along precisely the reverse of the path of the reference beam); this would cause reverse-propagation with unscrambling of light from C back to A, then back to B. If the mirror were replaced by the object to be viewed, then the reverse-propagating light would illuminate the object and the image of the object would spatially modulate the reverse-propagating beam, such that an undistorted image of the object would appear, upon completion of reverse propagation and unscrambling, at B.

One obstacle to implementation is that exposure of the crystal to the reverse reference beam during the readout phase of operation would gradually erase the hologram. Thus, the photorefractive crystal material should be one that has a long characteristic erasure time, and one must complete the readout well within that time. The prime candidate photorefractive material is $BaTiO_3$, in which erasure lags by 1 to 20 seconds.

Another obstacle to implementation is the need to place the flat mirror and then the object of interest at location A. In a real-time-viewing application, it would be necessary to switch repeatedly between the flat mirror and the object of interest in order to alternate the calibration phase with the readout phase. The microelectromechanical Fabry-Perot interferometer would make it possible to leave the object of interest in place and would make it unnecessary to use a separate mirror. Instead, the interferometer could be switched electrically between (1) a state of total reflection, in which the interferometer itself would serve as the mirror for calibration; and (2) a state of total transmission, in which light would be coupled between the fibers and the object of interest during readout. An additional advantage of this concept is that microelectromechanical Fabry-Perot interferometers could be fabricated at low cost.

This work was done by Deborah Jackson of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Physical Sciences category. NPO-20429*

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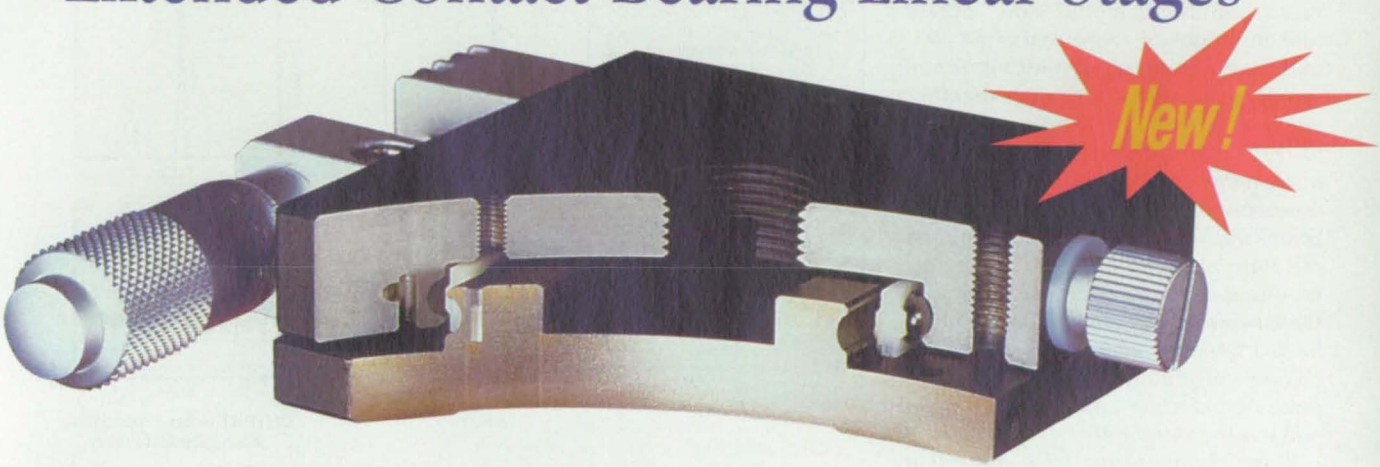

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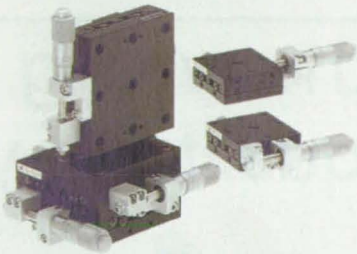

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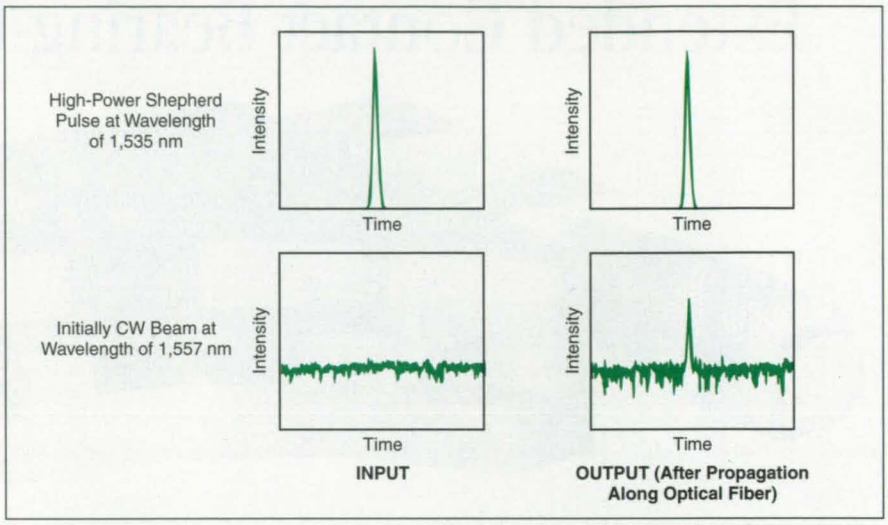
Generating Synchronized WDM Pulses in a Nonlinear Optical Fiber

Cross phase modulation can be exploited to generate WDM synchronized pulses at reduced cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

Pulse shepherding (defined below) can be exploited to impress synchronized amplitude-modulation pulses, with durations of the order of picoseconds, onto beams of light with different wavelengths that propagate together along a single-mode nonlinear optical fiber. This is significant because synchronized picosecond pulses on wavelength-division-multiplexing (WDM) light beams will be essential for the operation of future ultrafast bit-parallel data-communication systems. In comparison with the customary use of an array of mode-locked lasers to generate synchronized picosecond pulses on WDM beams, the pulse-shepherding approach is simpler and more economical.

Pulse shepherding is a nonlinear signal-propagation phenomenon attributable to cross phase modulation, which is an interaction between co-propagating light beams that arises from a nonlinearity in the response of the fiber-optic material. In particular, the cross phase modulation arises from the intensity dependence of the index of refraction.



These **Oscilloscope Traces** were obtained in experiments in which shepherd pulses of 60-ps duration and peak power somewhat greater than 200 mW were launched into a 20-km-long single-mode, dispersion-shifted optical fiber along with 33-mW CW laser beams.

Pulse shepherding is so named because it involves the use of one pulse (denoted the shepherd pulse) to "herd" together a number of other pulses that propagate along with it. In the present application, the shepherd pulse is also

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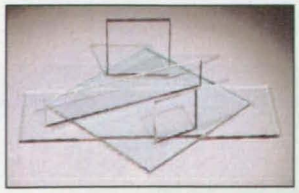

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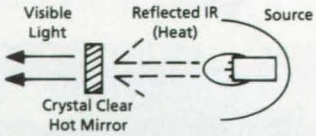

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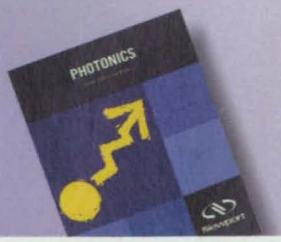

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used to generate the other copropagating pulses. The shepherd pulse — in this case, a high-power picosecond pulse — is launched into a single-mode optical fiber, along with a number of low-power continuous-wave (CW) beams. The high-power shepherd pulse and the copropagating low-power beams all have different wavelengths.

At the input end of the optical fiber, the low-power beams are unmodulated. However, as the beams propagate along the fiber, the cross phase modulation causes the low-power beams to become increasingly amplitude-modulated by pulses that travel along with the shepherd pulse. For each low-power beam, the amplitude modulation is either a brightening pulse or a darkening pulse, according to whether the coefficient of group-velocity dispersion of the optical fiber at the beam wavelength is negative or positive, respectively (see figure). The magnitude of the modulation of each beam at the output end of the fiber depends on the magnitude of the dispersion coefficient, the length of the fiber, the coefficient of the nonlinearity that affects the index of refraction, the coefficient of absorption in the fiber at the given wavelength, "walk-off" among the various pulses, and other factors.

This work was done by Larry Bergman, Cavour Yeh, John Michael Morookian, and Steve Monacos of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
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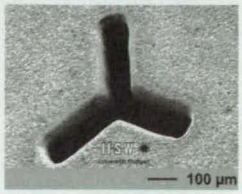

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Cancellation of Laser Noise in an Unequal-Arm Interferometer

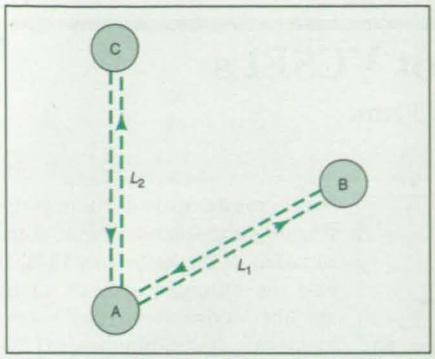
Exact cancellation is achieved by double differencing and cross time shifting.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of processing phase measurements in an unequal-arm laser Michelson interferometer makes it possible to detect phase effects much smaller than the laser phase noise. In the original application for which the method has been proposed, the interferometer, used to detect gravitational waves, would be based on three spacecraft flying in an approximately equilateral triangular formation with arm lengths of the order of 5×10^6 km. In principle, the method could also be utilized in other applications in which one seeks to measure relative lengths interferometrically with high precision and the interferometer arm lengths cannot be made equal.

In an interferometer of the type to which the method applies, a laser at corner A of the triangular formation transmits a beam of nominal frequency ν_0 along leg 1 (of length $L1$) to corner B and along leg 2 (of length $L2$) to corner C. Lasers at B and C use the phase of the light arriving from A for coherent transmission of light back to A. For each leg, the phase or frequency change in the light returning to A is measured. This measurement includes contributions of laser phase noise, phase noise from secondary sources, and the phase effect of interest. Typically, the phase effect of interest is associated with a Doppler effect caused by changing arm length and/or a gravitational wave that crosses the interferometer.

The laser is the main source of phase



In this **Unequal-Arm Interferometer**, laser light is sent from A to both B and C, from whence it is transponded back to A.

noise. Conventionally, one desires equal arm lengths because in that case, the laser-phase-noise components of the measurements for the two arms are equal, making it possible to cancel the effect of laser phase noise by subtraction. The resulting relative-phase information can be much more precise than the raw laser phase noise would otherwise allow. If the arm lengths are not equal, then simple subtraction does not result in cancellation of the laser phase noise and, as a consequence, the desired measurement can be severely degraded.

In the present method, one records the interference of the outgoing and incoming light for each of the two arms as a function of time. One also takes account of the fact that for each arm i ($i = 1$ or 2), the laser phase noise in the light returning at time t equals the phase noise in the light that was transmitted at time $t - 2L_i/c$, where c is the speed of light. Let the time series of phase-difference measurements for the ith arm be denoted by z_i. One can synthesize a double-difference time series $Z(t)$ in which the data for each arm are time-shifted by the round-trip propagation time in the other arm:

$$Z(t) = [z_1(t - 2L_2/c) - z_1(t)] - [z_2(t - 2L_1/c) - z_2(t)].$$

By inserting the explicit time dependences for the two arms in this equation, one can readily show that the laser-phase-noise terms cancel exactly, even when $L_1 \neq L_2$; the only terms that remain are those for the phase effect of interest plus noise from secondary sources.

Of course, the success of this approach depends on the approximate knowledge of L_1 and L_2. Provided that L_1 and L_2 are known with sufficient accuracy, the precision of the phase measurement is limited only by the phase noise from secondary sources, which can be reduced as much as 100 to 200 dB below the laser phase noise.

This work was done by Massimo Tinto and John Armstrong of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20611*

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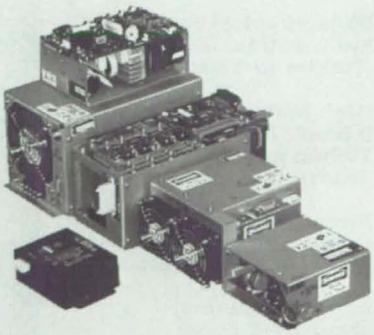

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For More Information Circle No. 464

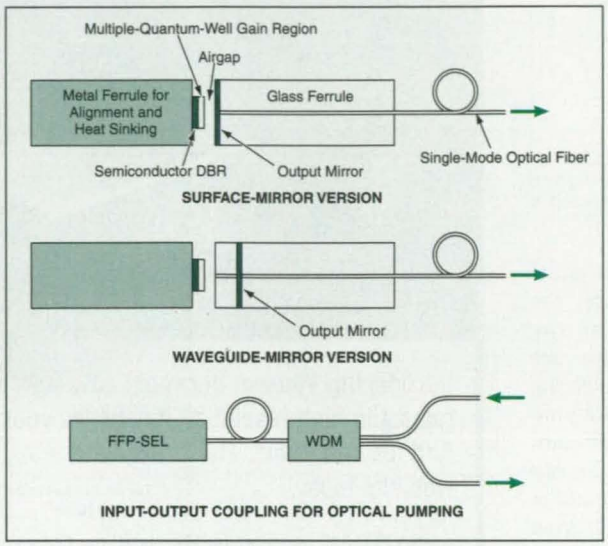
Tunable, Single-Frequency, Fiber Fabry-Perot VCSELs

Operation has been demonstrated at wavelengths of 850 and 1,300 nm.

Goddard Space Flight Center, Greenbelt, Maryland

The figure depicts several aspects of a unique type of vertical-cavity surface-emitting lasers (VCSELs) that incorporate fiber Fabry-Perot (FFP) optical cavities. These lasers have been designed to be compact, compatible with optical fibers, capable of single-frequency operation, and tunable. Lasers of this type that operate in frequency bands centered at wavelengths of about 850 and about 1,300 nm have been demonstrated.

In a laser of this type, a partial VCSEL and an FFP are incorporated with other optical components in a hybrid structure. The partial VCSEL is of a half-cavity design that features (1) a semiconductor distributed Bragg reflector (DBR) as the mirror on the surface opposite the emitting surface and (2) a multiple-quantum-well (MQW) gain region with an uncoated emitting surface. An airgap separates the emitting surface of the MQW from the end facet of a single-mode optical fiber that is held in a glass ferrule. The output mirror is a dielectric one that can be either deposited on the end facet of the fiber or else embedded within an optical-waveguide assembly that comprises two collinear single-mode-optical-fiber/glass-ferrule subassemblies. The combination of the half-cavity VCSEL and the output mirror on or in the fiber constitutes a fiber Fabry-Perot surface-emitting laser (FFP-SEL). Wavelength tuning is achieved by using a piezoelectric transducer to change the length of the airgap.



A **Surface-Emitting Laser in a Fiber Fabry-Perot Cavity** can operate in a single mode and can be tuned in wavelength by adjusting the airgap.

An 850-nm laser of this type is electrically pumped. A 1,300-nm laser of this type is optically pumped at a wavelength of 980 nm; in this case, the single-mode optical fiber is connected to a 980-nm/1,300-nm wavelength-division multiplexer (WDM) to enable both continuous pumping at 980 nm and output coupling at 1,300 nm.

Both the 850- and the 1,300-nm lasers have been shown to be capable of single-longitudinal-mode, single-transverse-mode, and single-polarization-state operation. Tests have shown that the 850-nm lasers are continuously tunable over a wavelength range ≈10 nm wide, and that their output power levels range up to about 1 mW. The 1,300-nm lasers in which the output mirrors are on the ends of the single-mode optical fibers have been shown to be capable of continuous tuning over a wavelength range ≈40 nm wide, with output power levels up to tens of microwatts. The 1,300-nm lasers in which the mirrors are incorporated into the single-mode-optical-fiber waveguides have been shown to be capable of tuning over a wavelength range slightly less than 10 nm wide, with output power levels up to about 400 μW; the optical-waveguide mirrors clearly exhibit the advantage of mode-field confinement. By use of a FFP scanning interferometer with a resolution of about 42 MHz, the spectral line width of a 1,300-nm laser with an optical-waveguide mirror was determined to be <260 MHz.

This work was done by Kevin Hsu and Calvin M. Miller of Micron Optics, Inc., for **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronics Components category.*

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-14249.

For More Information Circle No. 465

Alloy Casting Produces New Mirror Technology

The results are achieved with no heat treating.

Advanced Optical Systems, Inc.

Under a Phase 1 Small Business Technology Transfer (STTR) award of $99,000 with Goddard Space Flight Center, Advanced Optical Systems Inc. (AOS) has produced a 13.5-kg/m² 6-in.-diameter mirror flat to 1 wave peak to valley (0.2 wave RMS) with no heat treatment. Many known techniques, such as heat treating, thermal cycling, and finite element analysis can further improve the mirror's merit characteristics. The surface microroughness achieved was 30-40 angstroms RMS.

AOS's 13.5-kg/m2 6-in. mirror.

Open-back cast substrate for the mirror.

AOS teamed with Oak Ridge National Laboratories (ORNL) for the STTR, taking advantage of past relationships and residual mirror technologies in place from the MODIL program. AOS and ORNL plan a Phase II follow-on to build a 0.6-meter primary and a complete telescope using the Phase I technology. The goal is areal density <6 kg/m² in Phase II along with further improvements in material properties.

The new technology has yet to prove its merit among the beryllium and silicon-carbide mirror technologies. AOS's innovation is the casting of an aluminum-silicon alloy to near-net shapes and plating them with electroless nickel (<0.7 coefficient of thermal expansion mismatch) to produce the high-performance optical surface at low cost. The Al-Si alloy is vanasil. Material properties are low coefficient of thermal expansion, very high microyield, and low deformation.

For more information contact Thomas M. Cantey, lead scientist at **Advanced Optical Systems Inc.**, *2702 Triana Boulevard S.W., Suite A, Huntsville, AL 35805; (256) 536-5960; fax: (256) 536-5966; e-mail: cantey@aos-inc.com; www.aos-inc.com.*

Filterless Si-Based Ultraviolet-Selective Photodetectors

These detectors are relatively inexpensive, compact, and readily integrable with silicon-based circuitry.

Stennis Space Center, Mississippi

Monolithic semiconductor photodiodes that discriminate against infrared and visible light and that can be tailored to detect ultraviolet light in selected wavelength bands have been invented. These devices could serve as ultraviolet sensors in such instruments as hydrogen- and hydrocarbon-flame detectors, dosimeters for monitoring exposure to ultraviolet in industrial processes, and instruments for measuring ultraviolet in sunlight to monitor the ozone content of the upper atmosphere.

These photodetectors are made from silicon or combinations of silicon and silicon carbide, and therefore can readily be monolithically integrated with silicon-based electronic readout circuitry. They are relatively compact and inexpensive alternatives to previously developed ultraviolet detectors that (1) must be equipped with expensive, bulky

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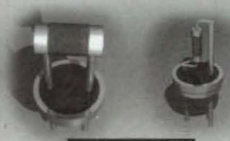

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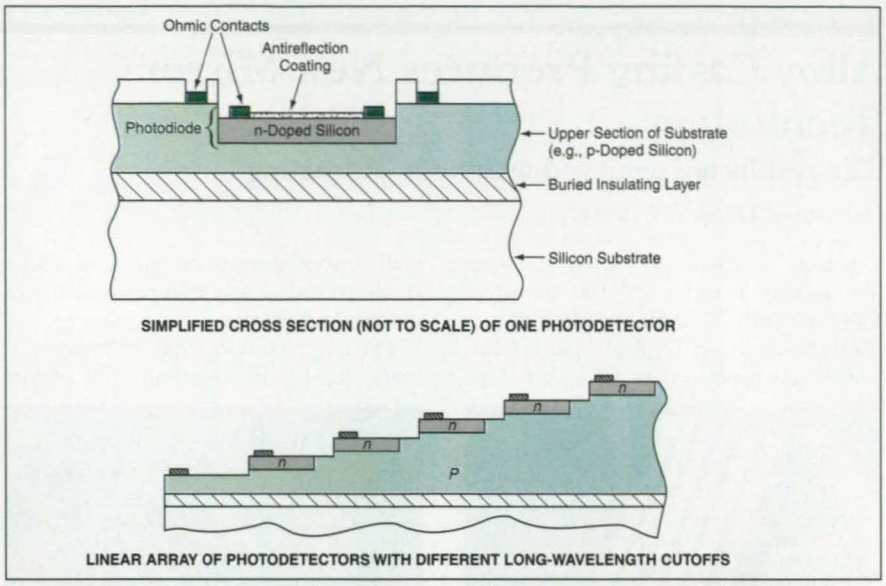

The **Layer Thicknesses and Materials** are the primary determinants of the spectral responses of photodiodes of this basic photodiodes configuration. A monolithic array of such photodiodes can serve as a multiple-wavelength-channel detector for a spectrometer.

monochromators or optical interference filters to obtain the desired wavelength selectivity, or (2) incorporate GaN- or GaP-based photodiodes, which are expensive to fabricate and cannot be monolithically integrated with silicon-based readout circuitry.

The upper part of the figure shows a simplified cross section of a representative device according to the invention. The device is fabricated on a silicon-on-insulator (SOI) or a SiC-on-SOI (SiC/SOI) substrate. A buried insulating layer made of silicon dioxide divides the substrate into a relatively thin active Si or SiC upper section and a relatively thick passive lower section made of silicon. The depth at which the insulating layer is buried determines the thickness of the active upper section and thus, as described below, affects the wavelength selectivity of the device.

A photodiode is fabricated in and on the upper section of the substrate. If, for example, the upper section of the substrate is made of p-doped silicon, then the photodiode includes a layer of n-doped silicon formed in the upper section. One of the ohmic contacts for the photodiode, in the form of a ring, is deposited on the n-doped silicon layer. The other ohmic contact — a wider ring that surrounds the first-mentioned ring — is formed on top of the p-doped upper section. Optionally, an antireflection coating is applied to the top surface of the photodiode in the area enclosed by the contact ring.

In operation, the absorption of incident photons in the photodiode gives rise to paired electrons and holes, which become separated at the p/n junction. Thus, photocurrent is generated across the junction. The photocurrent can be measured by use of external circuitry connected to the ohmic contacts. The long-wavelength cutoff (the maximum wavelength for photons to excite photocurrent) and the quantum efficiency of the device as a function of wavelength depend on the thickness (or the thicknesses of the sublayers) of the upper section of the substrate and on band gap(s) of the photodiode material(s) (Si and/or SiC). A monolithic array of such devices, with different upper-section thicknesses and thus different spectral responses, can be fabricated for use in a spectrometer.

Those photons that pass through the photodiode without being absorbed strike the insulating layer. Preferably, the device should be designed so that (1) photons with wavelengths greater than some cutoff wavelength (which may or may not be the same as the cutoff wavelength for excitation of photocurrent) pass through the insulating layer and are dissipated within the lower section of the substrate, while (2) photons with wavelengths shorter than the cutoff wavelength are reflected by the insulator back through the diode to provide another opportunity for absorption, thereby increasing the quantum efficiency and electrical output of the device.

This work was done by Nader M. Kalkhoran and Fereydoon Namavar of Spire Corp. for **Stennis Space Center**.

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 Nader Kalkhoran, Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (781) 275-6000.

Refer to SSC-00072, volume and number of this NASA Tech Briefs *issue, and the page number.*

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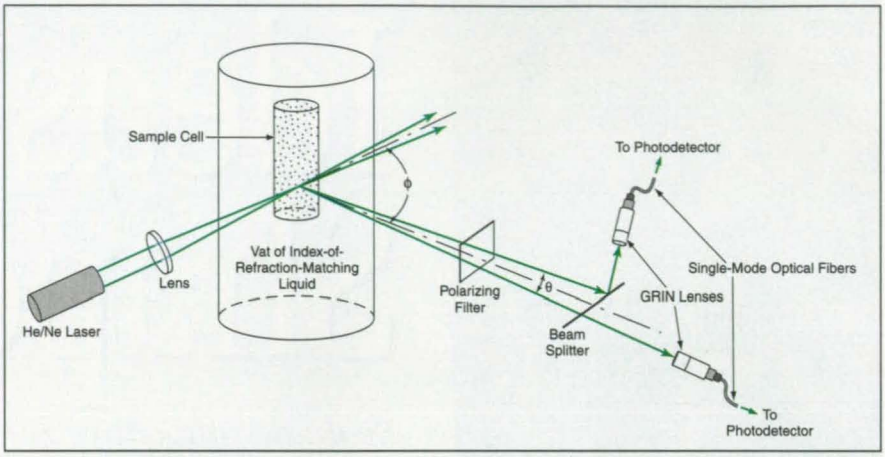
Improved Cross-Correlation Dynamic-Light-Scattering Method

Contributions from multiple scattering are suppressed to increase signal-to-noise ratios.

John H. Glenn Research Center, Cleveland, Ohio

A dynamic-light-scattering (DLS) method that reduces undesired contributions from multiply scattered photons has been invented. The method involves, among other things, cross-correlation processing of the outputs of two photodetectors aimed along intersecting, nearly parallel lines of sight. This present method can be characterized as an improved version of the method described in "Multiple Scattering Suppression in Laser Light Scattering" (LEW-16517), *NASA Tech Briefs*, Vol. 23, No. 11 (November 1999), page 14a.

The various DLS methods constitute various implementations of the concept of extracting information on the sizes and motions of light-scattering particles from the spatial and temporal dependence of the loss of coherence of scattered laser light. Typically, the particles of interest are suspended in liquids and are in Brownian motion, so that scattering of laser light from the particles gives rise to a temporally varying speckle pattern.



Scattered Laser Light enters two adjacent optical fibers attached to photodetectors. Cross-correlations of the outputs of the photodetectors are obtained for several different values of θ. The resulting data can be used to select a value of θ for best discrimination against multiply scattered photons.

The underlying physical principle makes it necessary to measure only singly scattered photons in order to be able to determine particle sizes and motions. However, the speckle pattern is a result of both multiple and single scattering, and photodetectors are unable to distinguish between singly and multiply scattered photons. Thus, there is a need to design a light-scattering apparatus and to process the photodetector outputs in such a way as to

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suppress the contribution of multiply scattered photons arriving at the photodetectors. The present method satisfies this need.

A typical apparatus used in the present method, shown in simplified form in the figure, is similar to the apparatus described in the noted prior *NASA Tech Briefs* article. A laser beam is aimed horizontally through a vertically oriented cylindrical sample cell containing the particles of interest suspended in a liquid. Optionally, the cell can be placed in a vat of another liquid, the index of refraction of which approximates that of the liquid in the cell. The laser beam is focused to a waist at the middle of the cell or at any other desired depth within the cell.

Two optical fibers with gradient-index-of-refraction (GRIN) lenses at their input ends are positioned with their input ends close to each other and aimed toward the beam waist (the nominal scattering volume) to receive light scattered from the beam axis to a chosen angle, ϕ, in the horizontal plane. The value of ϕ can be chosen conveniently to be 90°, but a different value can just as well be chosen to suit a specific application. The tip of one fiber is placed a short distance above and the receiving tip of the other fiber a short distance below the light-scattering (nominally horizontal) plane, thereby forming a small angle, θ, between the lines of sight from the two input fiber tips to the center of the nominal scattering volume. The positions of the fiber tips can be adjusted, by use of a micrometer-driven mechanism, to adjust the angle θ. The output ends of the fibers deliver the collected light to photodetectors.

Preferably, a polarizing filter is placed between the sample and the input fiber tips. The filter is oriented for polarization that is either parallel or perpendicular to the plane of polarization of the incident laser beam. Although scattered light of both polarizations includes contributions from multiple scattering, only the parallel-polarized light contains a contribution from single scattering. Thus, the polarizing filter can be used to increase the signal-to-noise ratio by serving as an additional means for discriminating between single and multiple scattering.

The outputs of the photodetectors are cross-correlated in such a way as to make it possible to discriminate against the multiple-scattering contribution to the speckle pattern. The cross-correlation processing is formulated to exploit the fact that single-scattering speckle arises from inside of the incident laser beam and is correlated over an angular range wider than that of multiple-scattering speckle, which can originate from anywhere within the sample. Measurements are made at several values of θ; at each such angular setting, the outputs of the photodetectors are cross-correlated over a suitably long interval of time to obtain a single numerical value for that detector angle. From the resulting ensemble of cross-correlations at various angles, one can construct a profile that can be used to determine the angular ranges over which multiple and single scattering predominate and one can estimate an optimum (or nearly optimum) value of θ to minimize the multiple-scattering contribution in subsequent measurements.

This work was done by Bruce J. Ackerson of Oklahoma State University for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135.
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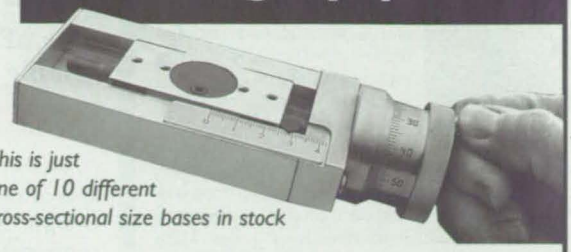

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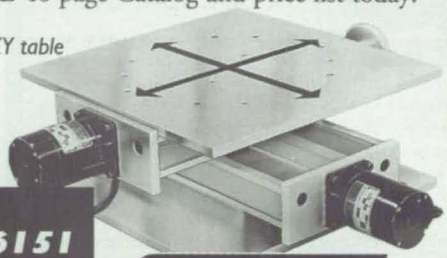

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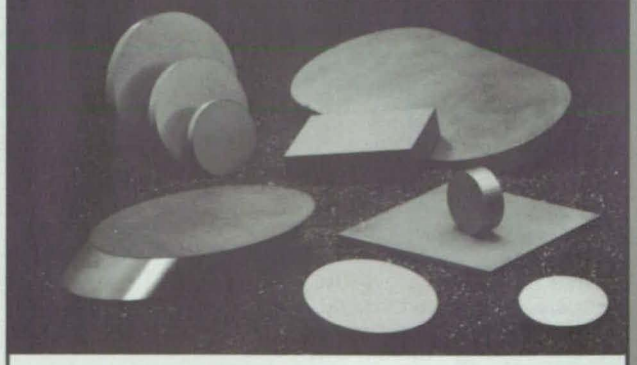

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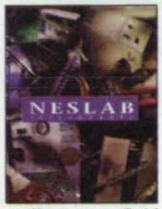

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For More Information Circle No. 489

Reducing the Volume of a Holographic Data-Storage System

Use of some optical components for dual functions would enable some shortening.

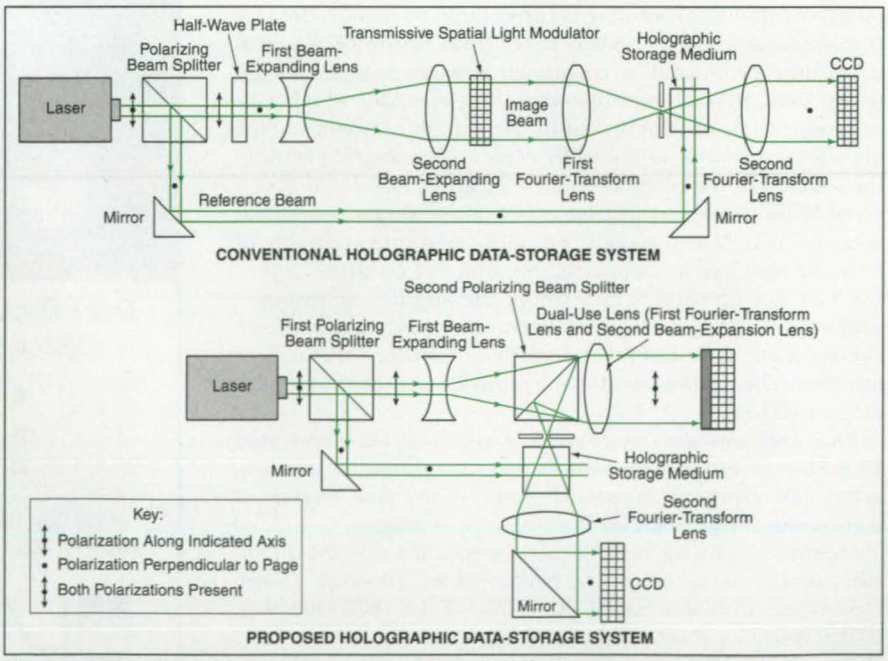
NASA's Jet Propulsion Laboratory, Pasadena, California

The size of a holographic data-storage system could be reduced by a proposed design modification that calls for replacement and repositioning of some optical components and the use of some of the components to perform dual functions. The modification would enable a substantial decrease in length with a small increase in width, yielding an overall decrease in volume.

The upper part of the figure schematically depicts a typical three-dimensional holographic data-storage system. A laser and a polarizing beam splitter are used to generate reference and image light beams, which are coherent with each other. These beams are made to interfere with each other in a holographic storage medium (e.g., doped $LiNbO_3$). In the simplest case, the reference and image beams enter the storage medium perpendicularly to each other. The reference beam is not modulated on its way to the storage medium. However, the image beam is expanded, then the desired image is impressed on the beam during passage through a transmissive spatial light modulator. The image beam is then directed through a first Fourier-transform lens into the storage medium. During retrieval of a stored image, the image beam is blocked, and a second Fourier-transform lens projects the image onto a charged-coupled-device (CCD) camera.

The lower part of the figure illustrates this system as modified according to the proposal. Among other changes, one of the lenses would be eliminated and the second beam-expanding lens would also serve as the first Fourier-transform lens. During recording, the image beam would be modulated with the desired image and reflected back through this lens by a reflective spatial light modulator (instead of by a transmissive one as before). A second polarizing beam splitter would be placed between the two beam-expanding lenses; with the chosen combination of polarizations, this beam splitter would pass the expanding (rightward-propagating) beam but would reflect the modulated (leftward-propagating) image beam downward into the holographic storage medium. As before, the reference and image beams would enter the holographic storage medium at right angles to each other during recording. As before, a second Fourier-transform lens would be used during retrieval of a stored image. In this case, a conjugate image would be formed and would be reflected rightward onto a CCD.

This work was done by Kevin Heim of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20347*



The **Proposed Holographic Data-Storage System** would differ from the conventional system in the replacement and repositioning of some optical components and the use of some of the components to perform dual functions.

Fabricating Small Apertures in Silicon-on-Insulator Wafers

Apertures with features as small as 0.5 μm can be formed repeatably.

Goddard Space Flight Center, Greenbelt, Maryland

Precise small apertures for a variety of optical applications can be formed in silicon-on-insulator (SOI) wafers by use of a photolithographic process developed specifically for the purpose. In comparison with the formation of apertures in standard silicon wafers by previously developed processes (including photolithographic ones), the present combination of SOI wafers and processing yields apertures of more precise, repeatable dimensions.

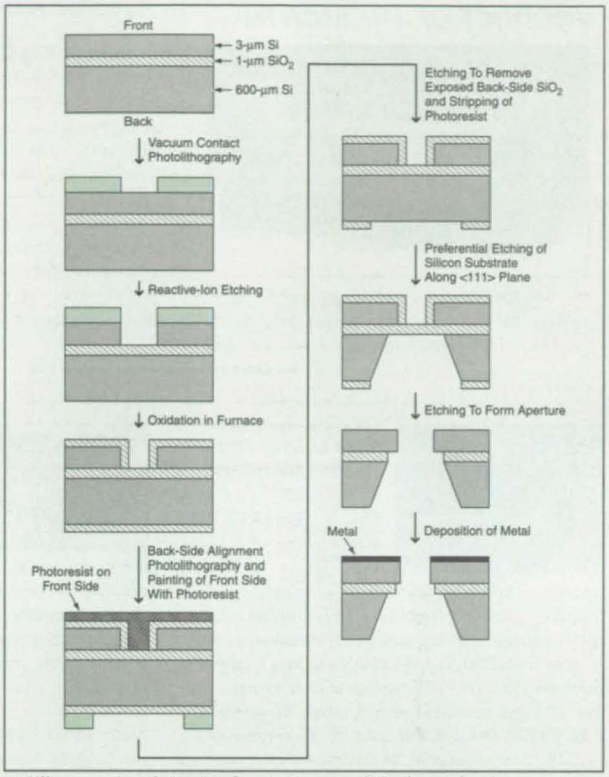
The figure illustrates a cross section of a SOI wafer at the major steps of the process. The starting material is an SOI wafer that consists of a 1-μm layer of SiO_2 sandwiched between a 3-μm layer of Si and a 600-μm-thick Si substrate. Vacuum contact photolithography is used to define apertures as small as 1 μm in photoresist on the front (3-μm Si) side. With the photoresist serving as a mask, reactive-ion etching (RIE) is used to form a hole completely through the 3-μm Si layer; by suitable choice of RIE operating parameters such as the types of gases, operating pressure, and power, the hole can be formed with nearly vertical sidewalls.

Next, the wafer is heated in a furnace and exposed to an oxygen atmosphere to grow a layer of silicon dioxide (see figure). Then by use of back-side alignment photolithography (in which features on the back side are aligned with the features on the front side), the required back-side aperture pattern is formed in photoresist. In addition, the front side of the wafer is painted with photoresist to protect the front-side SiO_2 during the oxide-etching step described next. The portion of the back-side SiO_2 not masked by photoresist is etched by use of a buffered hydrofluoric acid solution. Then the photoresist is stripped off.

An anisotropic silicon etch such as 20-percent KOH or tetramethyl ammonium hydroxide (TMAH) is used to etch the silicon substrate preferentially along the <111> crystal plane. Then the front-side SiO_2, the back-side SiO_2, and the exposed portion of the buried middle SiO_2 layer are etched away by use of a buffered hydrofluoric acid solution to create the desired apertures. If necessary for the application, aluminum or another suitable metal can be deposited on the front side to make the region surrounding the apertures opaque.

In a variation of the process, anisotropic chemical etching (instead of RIE) is used to form an inverted pyramidal (instead of the vertical-sided) hole in the 3-μm-thick Si layer. This variation is useful for making arrays of highly precise square or rectangular holes.

This work was done by Sridhar Manthripragada, Doug Leviton, David Brent Mott, and Christine Allen of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*
GSC-13871



A **Silicon-on-Insulator Wafer Is Processed** to form precise apertures with smallest dimensions in the micron or submicron range.

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Monolithic X-Ray Digital Camera

PerkinElmer Optoelectronics, Santa Clara, CA, describes its RID 1024-400 monolithic x-ray digital camera as the first such camera to offer a monolithic active-detector area equal in size to conventional x-ray film. The company says that the 41-x-41-cm detector, coupled with its mega-pixel spatial resolution and 65,000 gray-scale detectivity, produces images impossible to achieve using x-ray film. PerkinElmer says that with a complete image available for viewing in less than half a second, the user can determine if the captured image is the desired one, and if not take any number of others without having to once again pose the subject. The electronic capture is Internet-compatible, and compatible with all image analysis software and all PCs.

For More Information Circle No. 740

Handheld Infrared Laser Beam Finder

Pathfinder Laser Products, Lafayette, CO, calls its CoolCard™ the only handheld infrared laser beam finding and spatial mode imaging product available on the market for lasers beyond 1.7 µm in wavelength. It uses thermoelectrically temperature-stabilized liquid crystal technology to resolve IR laser beams across a span of 0.8-10 µm and beyond. Pathfinder says the device can resolve beams of as little as 3 mW/cm² power density, with 4 line-pair/mm resolution under optimal ambient conditions. It can be used with a broad range of new and established laser sources, such as Ho:YAG, Tm,Ho:YLF, broadly tunable IR OPOs and CO_2 lasers.

For More Information Circle No. 741

Scan Lenses and Beam Expanders

Rodenstock Precision Optics, Rockford, IL, offers a line of F-Theta scan lenses and fixed and adjustable beam expanders in wavelengths for frequency-doubled, tripled, and quadrupled Nd:YAG specifications. F-Theta lenses are available in wavelengths from 255 to 1064 nm, including frequency-doubled (532 nm) and tripled (355 nm) YAG. The line of fixed beam expanders range in wavelength from 255 to 1064 nm, with magnification ratios of 1.5 to 20×. The adjustable beam expanders range in wavelength from 266 to 1064 nm, and have magnification ratios of 1 to 8 ×.

For More Information Circle No. 742

Laser Ultrasonic Receiver

Lasson Technologies, Culver City, CA, says its EMF-500 laser ultrasonic receiver is the core of an inspection system capable of performing process control measurements in hostile environments. The receiver measures surfaces vibrating with nanometer amplitudes at megahertz frequencies. Lasson says the instrument can process highly speckled beams from rough surfaces while rejecting low-frequency noise signals. Applications include the measurement of temperature and thickness, as well as flaw detection in parts at high temperature or translating at high speeds.

For More Information Circle No. 743

Laser Marking System

The new LE series Class I solid-state desktop marking system from Laser Marking Technologies, Lafayette, CO, uses the company's own diode-pumped solid-state laser. According to the company, this technology enables better beam quality, eliminates the need for external cooling systems, and expands the intervals between maintenance by increasing operation time to as much as 10,000 hours plus. With the same wavelength as the Nd:YAG laser, the LE-100SD uses the Nd:$YV0_4$ medium, resulting in higher peak power per wattage, the company claims.

For More Information Circle No. 744

1625-nm Optical Loss Test Capability

EXFO Electro-Optical Engineering, Quebec City, Canada, has added testing for L-band (1570-1610) transmission to the capabilities of its FOT-920 MaxTester. The automated return loss test set can now be configured to measure optical and return loss at 1625 nm. The company says that instead of limiting DWDM transmission to the 1550-nm window, service providers are beginning to use the L-band window to increase the number of channels on existing physical layers. EXFO's exclusive FasTesT technology enables dual-wavelength (1550/1625 nm or 1310/1550 nm) bidirectional loss testing in less than 30 s at the touch of a single button.

For More Information Circle No. 745

Versatile Laser Power Meter

Ophir Optronics, Danvers, MA, announces the release of the ORION/TH laser power meter, which the company says was designed to meet the growing need for an easy-to-use low-cost meter that permits quick measurement of laser power. The ORION/TH supports more than 50 different thermal heads in the microwatt to 20-kW range. The unit's "smart" connector heads automatically configure and calibrate the meter when plugged in. Preferred startup configuration can be set by the user and stored in the heads' "smart" plugs.

For More Information Circle No. 746

Telecentric Video Lens

The new J54-798 telecentric video lens from Edmund Industrial Optics, Barrington, NJ, has a constant magnification of 0.5 × with a telecentricity of 0.03 degree. The working distance is 125-150 mm, which Edmund says means images are dimensionally accurate over a 25-mm range of focal points. Depth of field is ±3 mm at f/12. The lens is designed to be used with camera systems that feature 1/2-in. to 2/3-in. CCDs. It comes in a standard C-mount configuration.

For More Information Circle No. 747

Fiber Channel Cables

C&M Corporation, Wauregan, CT, is offering its QuadClear™ fiber channel cables for data communications applications. The cables are designed to enable the interconnection of storage and other peripheral devices to processors in workstations and mainframes, particularly in tight bend and motion environments. The company says its patented Megaflex™ PVC jacket protects against cut-throughs, is oil-resistant, and provides a high resistance to flex stress cracking. C&M says that the cables' low loss, low jitter, and sharp rise time result in an excellent bit error rate.

For More Information Circle No. 748

Objective Lens for UV Viewing

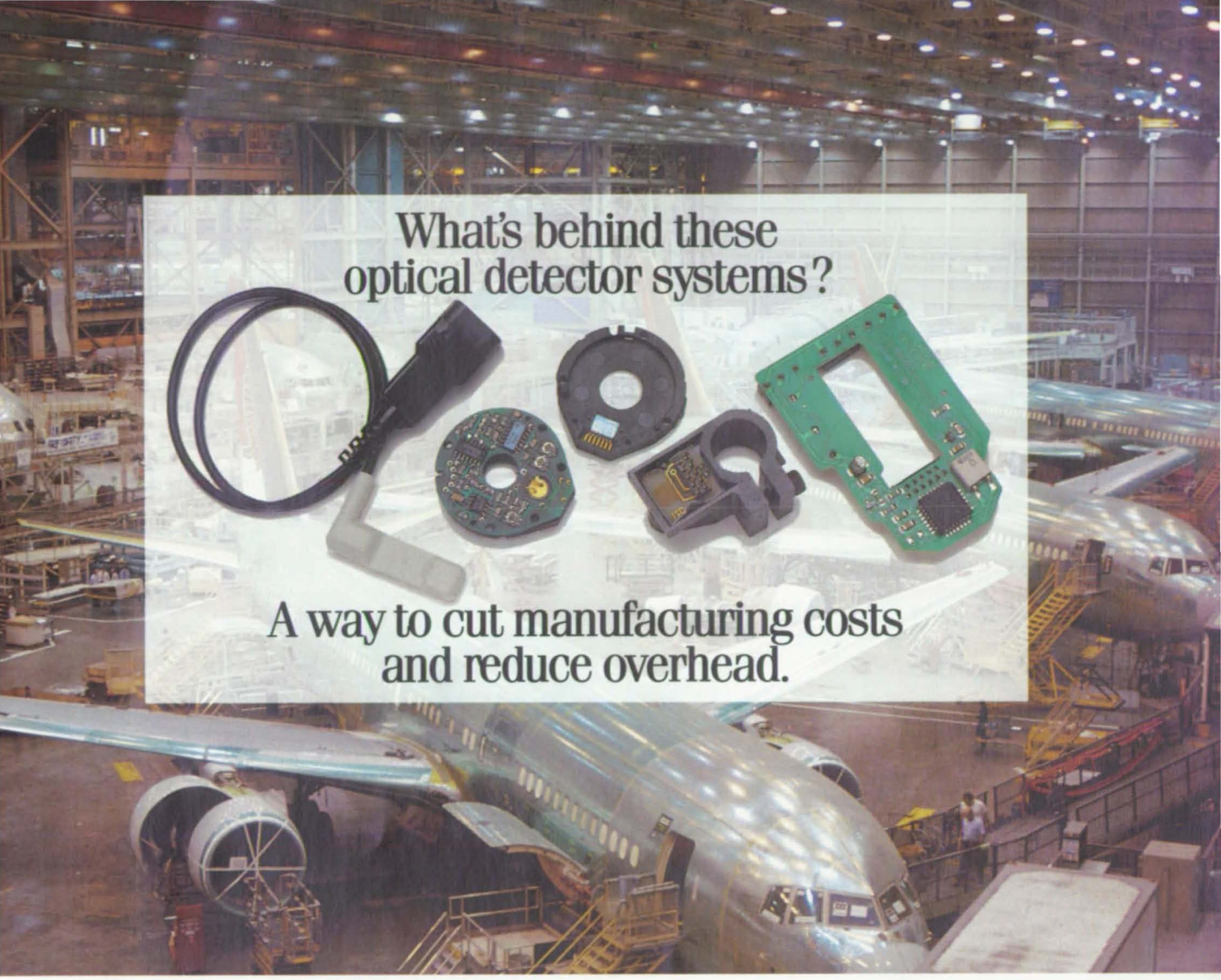
Electrophysics, Fairfield, NJ, introduces the quartz LQ78F3.8 objective lens designed to view radiation of wavelengths of less than 250 nm. The lens has a fixed focal length of 78 mm, an aperture range of f/3.8-f/22, and an angle of view of 6.64° diagonal. It is available with C- and T-mount adapters as well as many single-lens-reflex camera mounts. All surfaces are antireflection coated.

For More Information Circle No. 749

Grazing-Incidence Plano-Interferometer

Graham Optical Systems, Chatsworth, CA, says that its Lazer Grazer Fizeau interferometer is the first modestly priced instrument for the measurement of matte or semi-matte finished surfaces. The instrument is configured to show one interference fringe per wavelength. Its HeNe laser source operates at 632.8 nm, and it has a λ/20 fused silica reference flat. The Lazer Grazer is available with high-speed data reduction using Windows™-based static fringe or phase analysis. Graham says that the instrument makes possible the measurement of difficult unpolished parts of ceramic, graphite, silicon, tungsten carbide, and silicon carbide.

For More Information Circle No. 750



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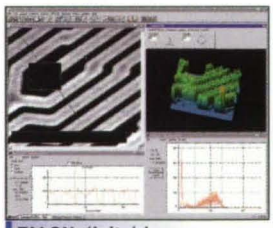

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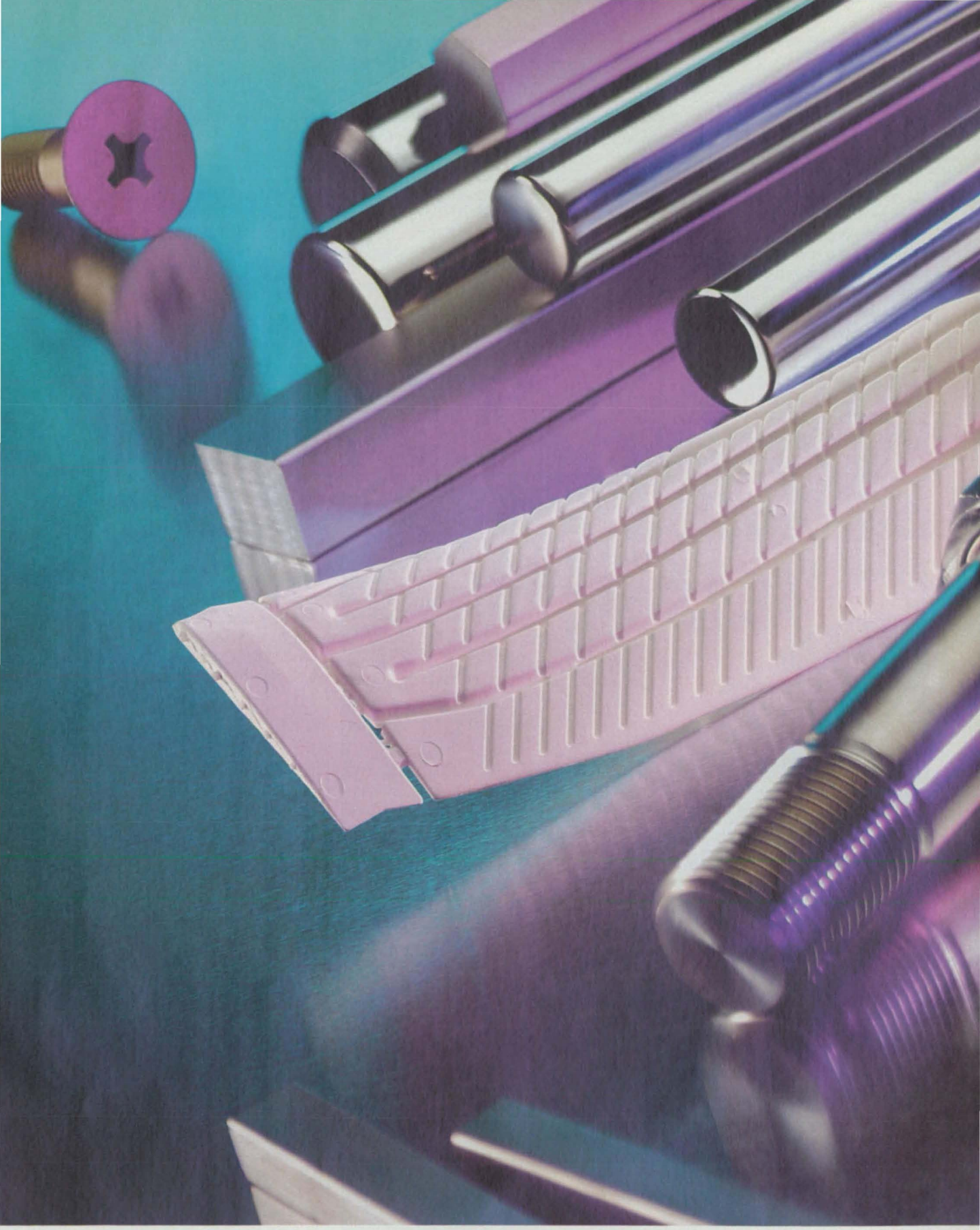

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Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I was hoping to find a computer program to investigate the electrostatics of a bed of needles at a high DC voltage that are near a grounded surface. This is for a device that removes water vapor from air. Clearly, the closer the needles are to each other, the better. Theory suggests that as the needles become closer together, the distance to the grounded surface can be reduced. Experimentally determining this would be an infinite task — there must be a computer program to do this. Thank you.

Dr. Stuart A. Hoenig
Professor of Electrical Engineering
University of Arizona
hoenig@ece.arizona.edu

A previous Reader Forum letter from Mark Kane requested information on obtaining Tungsten sheet for an enameling kiln. The product is available from Alfa Aesar of Ward Hill, MA. They offer foil from 0.0002 to 0.080" thick in squares typically measuring 25 x 50 mm. They can be reached at 800-343-0660 or at www.alfa.com

Joe Thoma
Sr. Quality Systems Engineer
Johnson Matthey
West Chester, PA
thomajt@jmusa.com

The December 1999 issue of NASA Tech Briefs *featured an article on NASA's Langley Research Center's work in artificial vision technology to develop a way for diabetes patients to "see" blood flow (UpFront, p. 14). The web site listed no longer exists, and I was unable to find any additional information on the project from the Langley web site. Thanks for your help.*

Robert Crane
robert.crane@afrl.af.mil

*(**Editor's Note:** Robert, you can contact Langley Research Center's Office of Public Affairs (OPA) for more information. They can be reached at 757-864-6121, or via e-mail at opa@larc.nasa.gov.)*

On behalf of the many, but too often silent readers of NASA Tech Briefs, *I would like to express my gratitude and appreciation for the stimulus that you provide in our high-tech world. As the new millennium begins, I reflect on all of the wondrous technologies and products NASA has spawned, and their contributions to a better, albeit more complex, world. I look forward to your continued communication and inspiration in the new millennium.*

Charles F. Comstock
comcharl@pwfl.com

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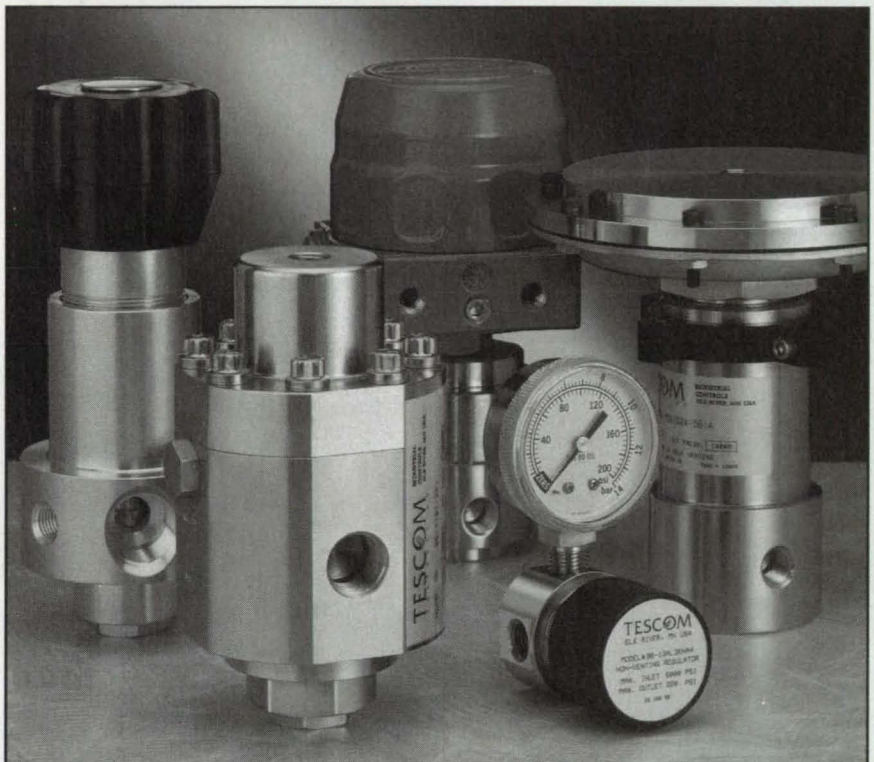

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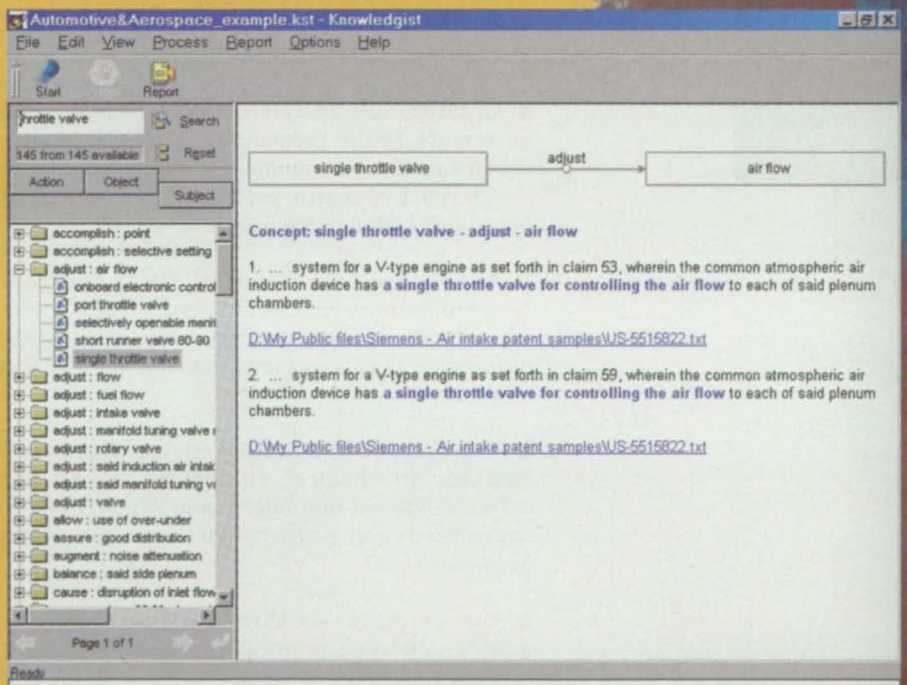

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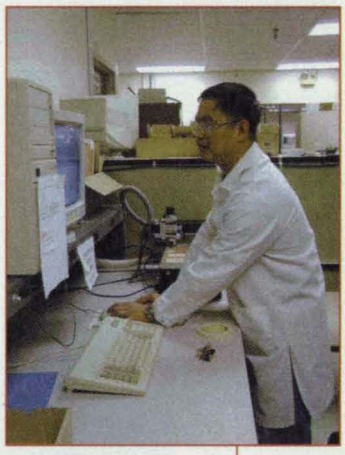

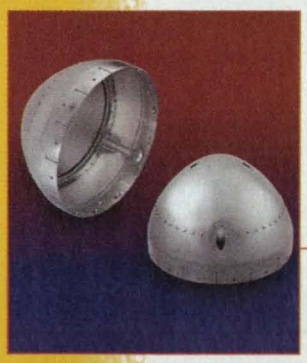

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This month's RPD Online includes:

- **Optimization Software Helps Design Low-Noise Rotorcraft Flight Procedures** — NASA's Langley Research Center used commercial optimization software to design quiet approach procedures for an experimental tiltrotor aircraft in a few weeks.

- **Prototyping System Solves Major Semiconductor Test Problems** — A circuit board plotter system fabricated hundreds of text fixtures, yielding big dividends in turnaround time, lower test costs, and improved accuracy of test results.

- **Polyurethane RIM System Enables Complex Design Features in Medical Equipment** — An advanced polyurethane reaction injection molding (RIM) technology enabled cutting-edge design in an automated medical diagnostic system.

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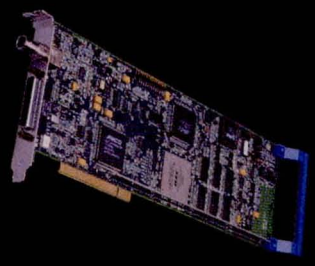

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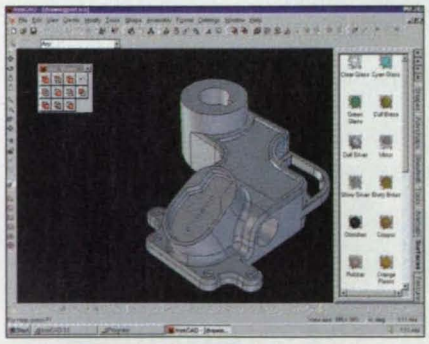
IronCAD 3.1

Steven S. Ross

It just feels right. Here's a CAD product that is, well, easy to draw with. IronCAD is a new kid on the block when it comes to high-end mechanical design software. Visionary Design Systems (Santa Clara, CA), IronCAD's developer, has been around since 1990, and has been producing modeling tools. But IronCAD itself was introduced in 1998. This allowed VDS to start with a clean slate. But VDS also realized it would be entering a crowded, mature market — a market in which many users already have made serious choices about their CAD software.

The solution: IronCAD has superb file translation capabilities. Aside from the "standard" ways to import and export design intelligence — good translation filters for IGES, STEP and so forth — VDS also equipped IronCAD with an unusual core. Almost all high-end CAD packages for mechanical design are based on one of two solid modeling engines: ACIS or Parasolid.

IronCAD's solution? It uses both. When you install IronCAD, you get to choose which one to use as a default. But, you can switch back and forth at any time. Because VDS promotes IronCAD's interoperability, I spent quite a bit of time testing that feature. You can indeed build assemblies that use parts modeled in both ACIS and Parasolid at the same time. And I found it quite easy to bring parts modeled with, say, SolidWorks (with a Parasolid core) and Inventor (which uses ACIS) into IronCAD.



A general view of the IronCAD workspace. Note the catalog tabs on the right, and the toolbar for changing views in the upper left corner.

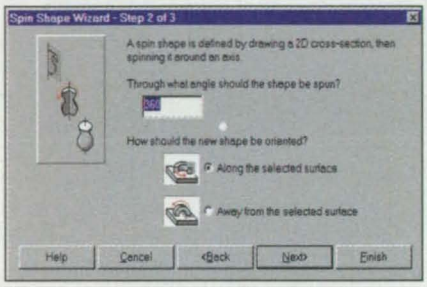
Users should understand that such imports and exports usually are not seamless, because various file formats differ. For instance, if you have modeled a complex component in a standard CAD package and exported it to IGES, the IGES kernel defines surfaces, not solids. IronCAD (and many other packages, for that matter) will turn IGES surfaces into the solids that the surfaces define, as long as the surfaces truly enclose a solid with no gaps. If there is a gap in your drafting, you don't get a solid from an IGES file.

Likewise, many CAD packages add surface textures in various ways to solids. Some add a true texture embedded in the part. Others add a color that mimics a texture. Still others apply a "decal," and some use more than one method. Translating into IronCAD tends to use one method to the exclusion of others. Sometimes no color or texture can be translated. Again, this tends to be a limitation of the file formats, not IronCAD.

IronCAD has a good suite of tools for modeling sheet metal, but is not as good at handling large assemblies. Almost all the geometry translates beautifully. But design sense — notes in the model about why a designer chose to build the part a certain way — is lost unless it is added as text, as part of the drawing itself, or is translated through STEP (STEP translation usually takes awhile, even on a fast machine). Even something as simple as the fact that a bend is modeled to ANSI or DIN constraints is not easy to keep with the part. The result is a part that's shaped perfectly under a given set of rules, but designers further along the chain might not know exactly what those rules are. This situation really is a shame, since IronCAD has great ways to capture design sense. You should not think of routinely using IronCAD, as amazing as it is, for translations without carefully setting rules among the shop's design professionals.

I also discovered that IronCAD outputs beautifully to many graphic formats — great for doing documentation (on paper or on disk) and for creating Web illustrations and animations. Output to AVI video was a breeze. The rendering options are quite precise — you can set lights and cameras easily on-screen. There are enough options for JPEG, GIF, PNG, VRML, and even TIFF and EPS to make the documentation folks very happy.

All that said, what about the drawing tools? There's a great mix of parts catalogs and tools for creating new geometry from scratch. You can add shapes and components to catalogs (lots of standard "Intellishape" items are provided) and drag them out to the drawing, embed drawing "handles" for tweaking the design into the model, and lock specific dimensions. You also can embed parametric intelligence, and relate shapes to one another for "smart" snapping.



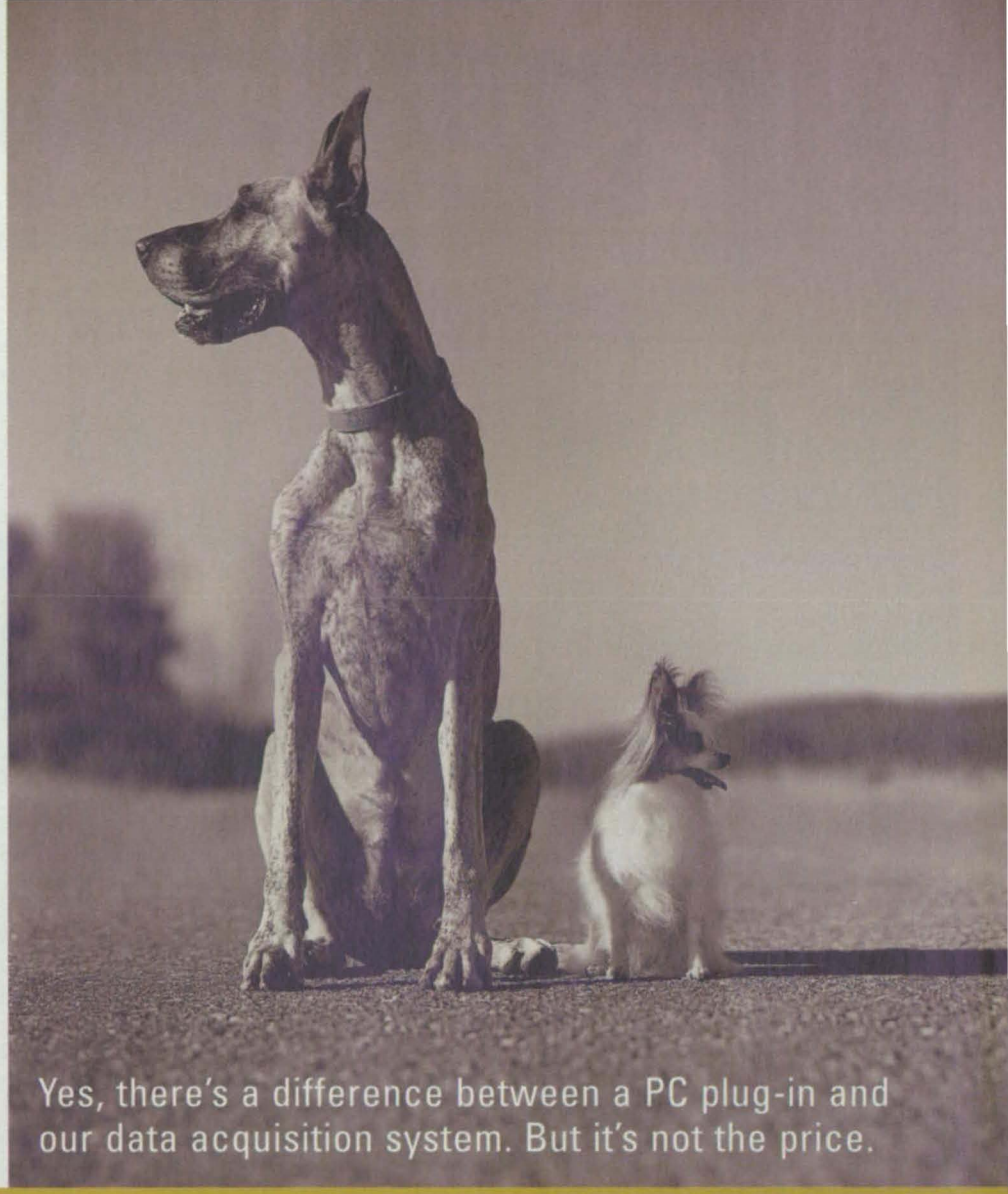
There are some nice wizards to help those new to 3D modeling. This one enables you to get a 3D shape by spinning a 2D image template.

I like the "TriBall" cursor that lets you rotate as well as move (translate) a part. It is reminiscent of old versions of DataCAD, although VDS says it has patented the idea.

System requirements are fairly modest. I got acceptable performance with a 15-part assembly under Windows NT 4.0 with 80 MB of RAM and OpenGL graphics fully enabled, on a 200-MHz Pentium Pro. I got about the same performance with Windows 98 on a 366-MHz machine with 128 MB of RAM.

IronCAD is priced at $4,995. Annual maintenance, which includes updates and on-line and phone support, is $1,295. An on-line demo is available on the VDS website at www.ironcad.com.

Steven S. Ross teaches journalism at Columbia University in New York City. He has authored three commercial software packages, including a units conversion program and an engineering calculations program.



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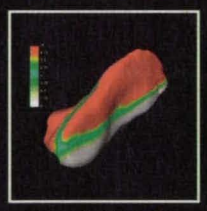

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Michael B. Mann, Deputy Associate Administrator for Aero-Space Technology

Michael B. Mann is Deputy Associate Administrator for the Office of Aero-Space Technology. He provides executive leadership, as the second in command to General Spence M. Armstrong, for a $1.3 billion program covering four research and development centers working on long-term, high-risk, high-payoff technologies for aviation and space transportation.

***NASA Tech Briefs:* What are the primary functions of NASA's Aero-Space Enterprise?**

Deputy Associate Administrator Mann: One hundred percent of the activities we do are technology development. We don't take any products to final delivery — we simply develop technologies. And we work in two fundamental areas: aeronautics and space transportation. A number of the technologies are common between the two.

NTB: What do you see as the most critical aerospace technologies to be developed over the next 10 years?

Mann: I think we have a tremendous opportunity in the area of information technology, both in adapting the technologies that are being developed for other industries as well as creating technologies unique to aerospace applications. Intelligent systems is a major push — to have more computational capability available inside the the cockpit of an airplane, so that there's more autonomy. The vehicle can operate more by itself, without human intervention.

We just had a project in which we put a neural network in an F-15 fighter that simulated major failures. The airplane was able to adjust all the control properties to simulate, for example, that the wing fell off, so that you could continue to operate the airplane. That's all information-technology oriented. It's the kind of thing the pilot wouldn't notice until there's a problem. In the past, they wouldn't have been able to control it. Now, with these capabilities — essentially learning systems —they'll have the ability to continue flying the airplane.

NTB: In the future, might we see similar types of technology that could correct a failure in time to prevent the loss of an unmanned spacecraft?

Mann: Absolutely. In the Deep Space 1 that just flew, there were IT experiments from Ames Research Center that controlled the spacecraft autonomously. They performed a number of the functions that were previously controlled by humans. That's a very exciting area that has significant potential. And it's not necessarily to replace humans — it's to either augment their capabilities or to handle situations where humans wouldn't be able to adapt as quickly.

NTB: What are some of the Enterprise's recent developments in aviation technology?

Mann: A lot of these developments show up in X-planes. We have the X-34, which will fly next year. And we have the X-43, which is a hypersonic test vehicle. We have a number of revolutionary concepts we are working on — such as blended-wing bodies — which are just radically different kinds of airplanes. The blended-wing body would be a 300- to 800-seat airplane that would not look at all like today's airplanes. It would look much more like the Stealth bomber — it's a "flying wing" essentially. What that does is change the whole economics of air transportation. It's the major new thrust that we're working on with Boeing to really make a quantum leap in terms of cost, emissions, and noise.

NTB: What do you consider to be today's greatest single challenge to the Aero-Space Enterprise?

Mann: The fundamental problem that we continually face is balancing the things that have very near-term return with making sure that we have enough "leap-frog" or revolutionary technology work being supported. We have to continue to make sure that we're doing enough long-term work while we're providing those near-term benefits.

A full transcript of this interview is available online at www.nasatech.com. Contact Mr. Mann at mmann@hq.nasa.gov.

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For More Information Circle No. 560

FEA Software Used in Design of NASA Plant Growth System for Space Station

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Orbiting laboratories like the International Space Station (ISS) can provide unique environments for developing new medicines, industrial materials, and communications technology, and may serve as stepping stones for colonization, which will require humans to be self-sustaining in space. NASA currently is conducting research for on-orbit plant growth that could eventually facilitate longer missions on the ISS or permanent space inhabitancy.

Orbital Technologies Corp. (ORBITEC) of Madison, WI, is providing NASA with the tools needed to grow plants in space, and the finite element analysis (FEA) information to make sure the tools can be transported safely. Astronauts will use the firm's Biomass Production System (BPS) to conduct biotechnology plant research and metabolic experiments on photosynthesis, respiration, and transpiration on the mid-deck of the Space Shuttle, and in rack facilities on the ISS.

In order to qualify the BPS for space flight, ORBITEC used linear static and dynamic stress analysis software from ALGOR to prove that the unit can withstand extreme dynamic loading during liftoff and landing. According to ORBITEC's lead design engineer, Jeffery Iverson, the company studied plant growth systems flown on previous shuttle missions and consulted with NASA engineers to develop the BPS.

The BPS can contain up to four removable chambers, like the one shown here, which can be accessed to capture the results of microgravity studies by freezing plants on-orbit.

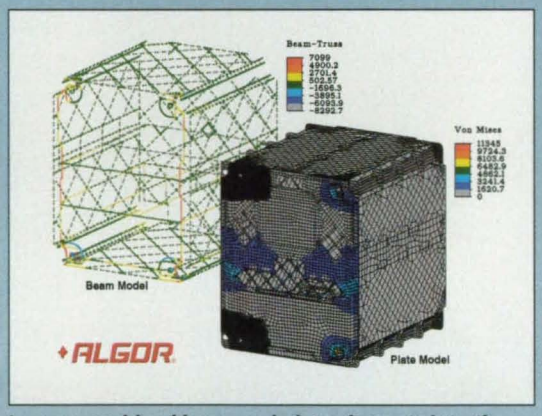
The design features a double-locker enclosure, which more effectively optimizes the available volume over previous payloads. The new unit's enclosure slides open so that astronauts have access to the inner chambers through all phases of the operation. The box-shaped BPS features independent controls for temperature, humidity, lighting, and carbon dioxide levels; an active nutrient delivery system; and sealed chambers for gas exchange measurements.

The project began with Phase I and Phase II contracts from NASA's Kennedy Space Center in Florida through the Small Business Innovation Research (SBIR) program. Today, the project is being funded as a Phase III contract through NASA's Ames Research Center in California.

Meeting Design Requirements

Iverson's FEA studies focused on four fully constrained attachment points at the corners of the BPS since these areas would experience the greatest loads during liftoff and landing. The location of the BPS in the shuttle was a major design concern because it is bolted directly to an internal shuttle wall above the astronauts, making structural analysis a critical requirement. Another concern was the four latches on the front panel that secure the sliding portion of the enclosure.

The BPS enclosure design began with a solid model using AutoCAD 13 (from Autodesk, San Rafael, CA). The model was converted into more than 200 surfaces so that surface edges would align at planned interaction points with beam elements, which were to be added to the FEA model in ALGOR. The model was transferred in IGES format to Superdraw III, ALGOR's single user interface for FEA, where a surface mesh was created using hand-meshing techniques. Iverson first produced a coarse surface mesh and ran preliminary analyses to verify the geometry. Then he produced a finer overall mesh and refined the surface mesh around the attachment points and latches using ALGOR's Merlin Meshing Technology.



Iverson combined beam and plate elements into the FEA model to simulate the structural rigidity of the enclosure. Here, the linear static stress analysis results for the beam structure and plate enclosure are shown separately.

Once the model was completed, Iverson copied the geometry into a new file and selected lines and nodes that represent the ribs and structural elements of the internal payload. The 125-pound weight of the payload and enclosure, as well as varying launch and landing gravitational loadings, were applied in 20 different load cases.

The resulting design met NASA's requirements. Using the software's built-in visualization capabilities, Iverson viewed the stress results and used them to determine the calculated limit stress value. "The loading placed on the BPS is equivalent to 10-15 g. Loads of this magnitude would be virtually impossible to simulate. The benefit of using FEA is to evaluate theoretical loads on an object without physical prototyping," explained Iverson.

The BPS unit will be subjected to a 24-day science test this summer, followed by a long-duration mission verification test that will simulate the actual mission. The BPS currently is scheduled for ISS Utilization Flight (UF-1) in the spring of 2001. Scientists will use Super Dwarf Wheat and a mustard-like plant for the experiments.

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(See page 46.)

High-Power Laser Illuminator

This laser illuminator, originally developed for tracking small satellites from the space shuttle, can be adapted to other moving or stationary platforms for tracking other moving or stationary objects.
(See page 48.)

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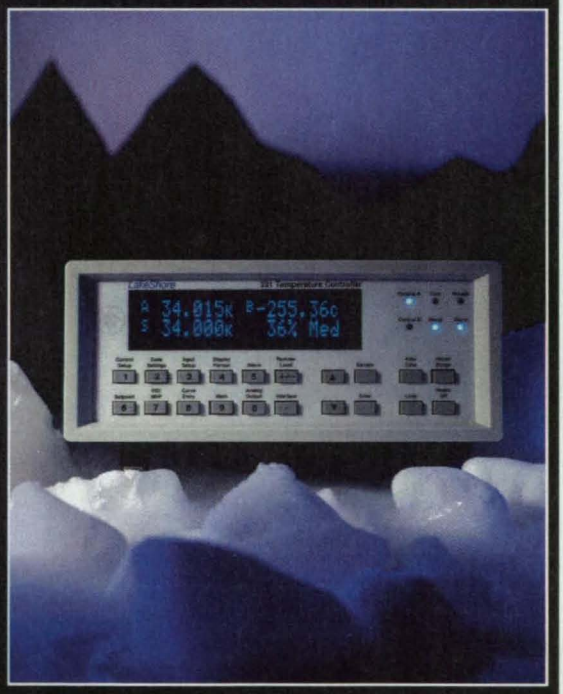

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(See page 56.)

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This one-time-opening valve is regarded as a more reliable, less expensive alternative to a similar pyrovalve. The valve would have no pyrotechnic material, eliminating the risk of premature detonation. Potential applications are in fire-suppression systems, emergency power units for aircraft, and emergency cooling systems.
(See page 58.)

Efficient Ionizer for an Array of Mass Spectrometers

Electron- and ion-beam optics are designed to maximize generation and extraction of ions. This ionizer is designed to deliver ions to the entrance apertures of nine miniature quadrupole mass spectrometers in an array.
(See page 66.)

Apparatus and Technique for Measuring Distance Between Axles

An optoelectronic apparatus and technique were developed for measuring distances of tens of feet with an accuracy of a fraction of an inch. Developed originally for the space shuttle orbiter, this system can be adapted to measuring distances between wall frames inaccessible to tape measuring, to establish fence lines, or to lay out football grids.
(See page 76.)

Miniature, Low-Power, Digital, Wireless Electronic Camera

A laboratory-bench-top version of this camera has been demonstrated. The camera is intended to serve as a low-power, long-battery-life unit in such applications as surveillance of military or civilian facilities, home security, and remote monitoring of babies.
(See page 77.)

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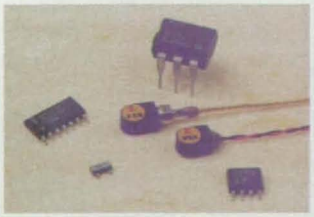

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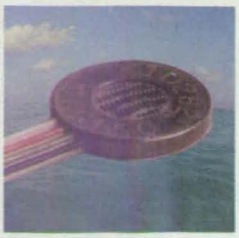

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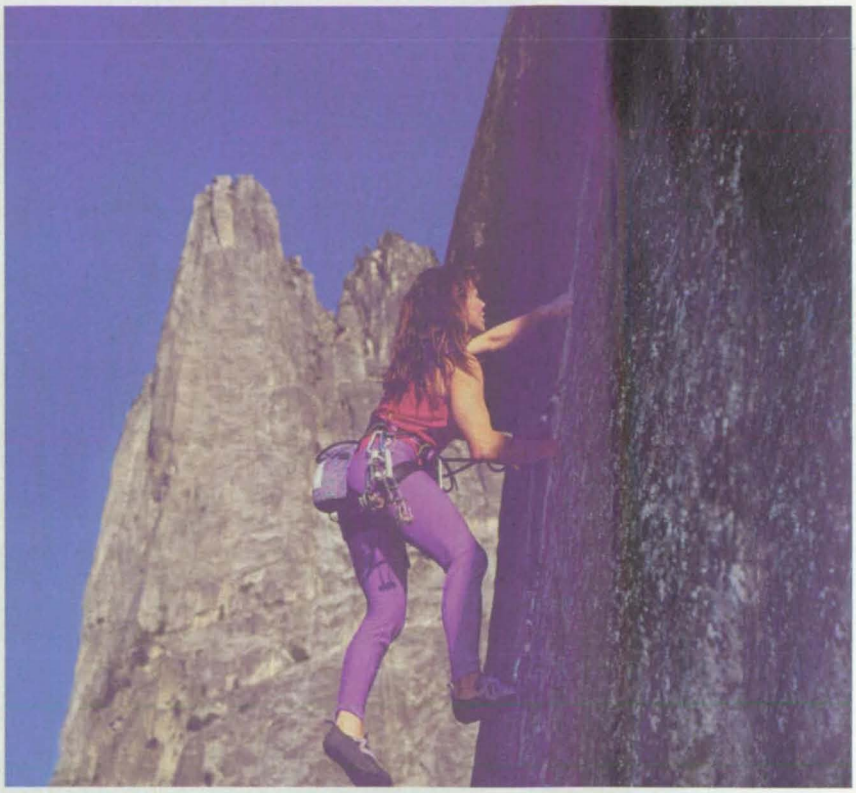

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For More Information Circle No. 555

Mass 3D: From Design, to Manufacturing, to Supply Chain

In today's fiercely competitive global marketplace, sleek, stylized designs have become an imperative, not an option, for most manufacturers. No longer a matter of making tradeoffs between form and function, optimizing both is now critical for nearly any product. It's as true for high-gloss consumer goods (e.g., recreational kayaks, boutique home accessories, exterior auto parts, and running shoes), as it is for other traditionally less glamorous products (e.g., automotive engine parts, the "guts" of PCs, and factory equipment). At the same time, shrinking design cycles and narrow market windows have become the rule.

Like never before, today's market conditions dictate massive proliferation of highly functional, very powerful "mass 3D" design tools, not just on every engineer's desktop, but across the extended enterprise — design, manufacturing, and the supply chain. Beyond using the technology for new product development, 3D users must be able to communicate their ideas to a vast array of people and organizations involved in the process: management, manufacturing, documentation, purchasing, distribution, sales, marketing, vendors, subcontractors, and partners. When everyone across an organization has access to integrated, easy to use, affordable mass 3D design tools, amazing things can happen.

Consider this analogy. To enhance internal and external communications and to allow employees to instantly obtain information, manufacturers are deploying productivity tools such as e-mail and Internet access throughout entire organizations. In this day and age, most of us would consider it preposterous to grant only 10 people in a 100-person organization access to these powerful information tools. The same is true for mass 3D. When only a chosen few can take advantage of desktop 3D functionality, they are severely limited in their ability to communicate design innovations to the extended enterprise. Conversely, when it becomes possible to leverage 3D technology across extended organizations, companies can realize significant benefits, including reduced time to market, streamlined communications among global team members, and better communication of design intent from design through engineering and manufacturing.

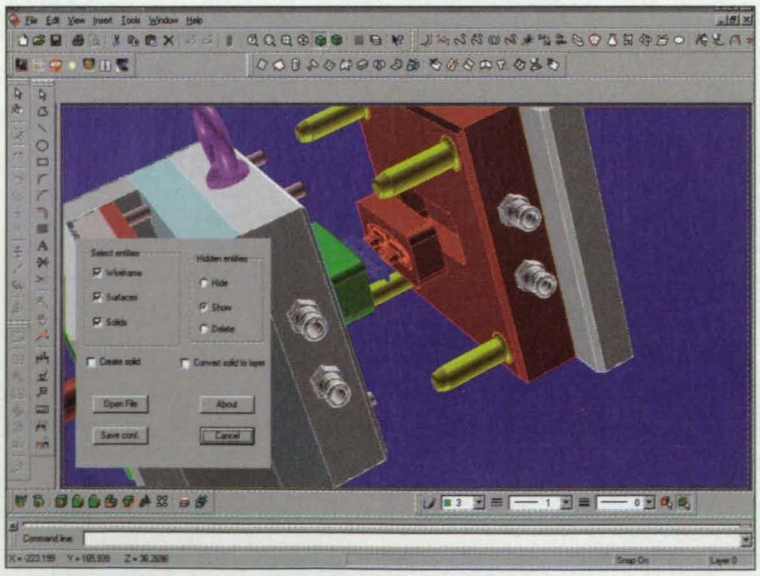
Barriers to Mass 3D

Mass implementation of 3D has been and continues to be very difficult for many manufacturers due to cost, training, compatibility, and limited functionality. In most cases, mid-range systems, although more affordable and easy to use than high-end systems, typically lack the power to complete all the jobs that are required in most design environments. Many companies realize that leveraging full-function solid and surface modeling 3D design tools throughout an extended corporation could help communicate design concepts in a much more efficient and economical manner than traditional means.

While it is easy for most companies to understand the benefits of deploying more 3D CAD tools throughout their company, it is quite a challenge to select the right software tools to meet the disparate needs of users across an organization. They must determine which will be more effective: a few general-purpose tools, or many specialized tools. To reduce costs and simplify administration and training, some companies attempt to standardize on a single system. Others yield to strong pressures to use a variety of systems.

In today's extended enterprises, companies must work more closely, and concurrently, with suppliers, customers, vendors, and other partners. Each of these typically has a different CAD system. Even within single companies, with the number of mergers and acquisitions happening today, it is very common to have a number of design departments working together on different CAD systems. Many companies end up with four or more different CAD systems, and they select which one to use depending on the partner for the project. Although pragmatic, this approach is expensive and, ultimately, not scalable to the entire organization.

At the same time, there is tremendous pressure for companies to increase the productivity of individual tasks. A common solution for this is to use a specialized CAD tool for each task. CAD vendors amplify this situation by specializing only in certain areas in order to remain competitive. Even today, there are systems



think3's "mass 3D" software, thinkdesign, enables designers to easily import geometry from other systems (such as CATIA, pictured here) into their design environment without losing data integrity, structure, or ancillary nomenclature. Data can then be exported in compatible file formats to downstream manufacturing tools.

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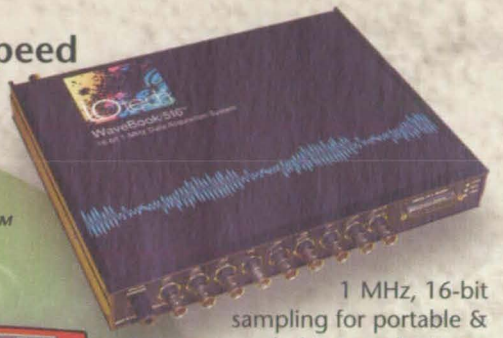

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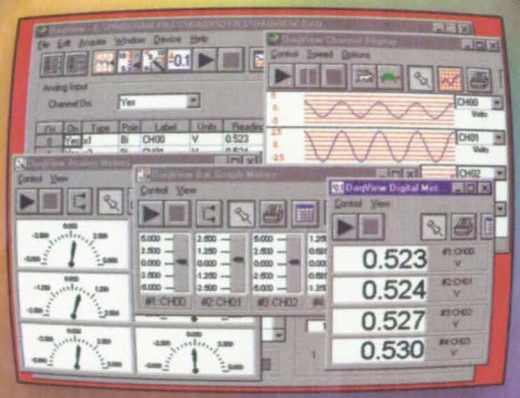

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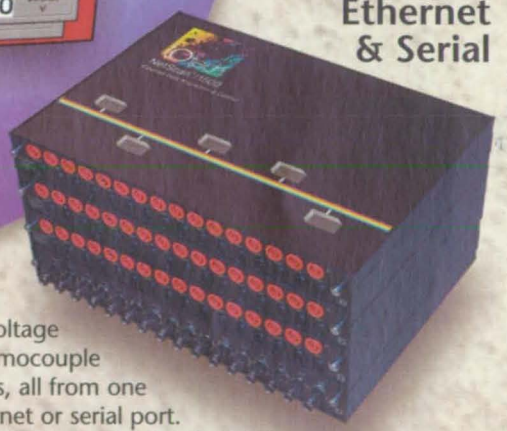

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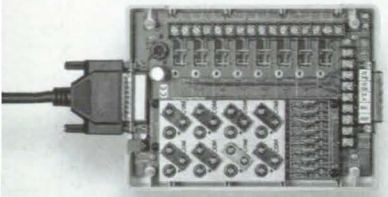

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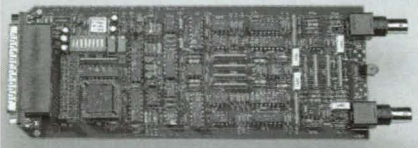

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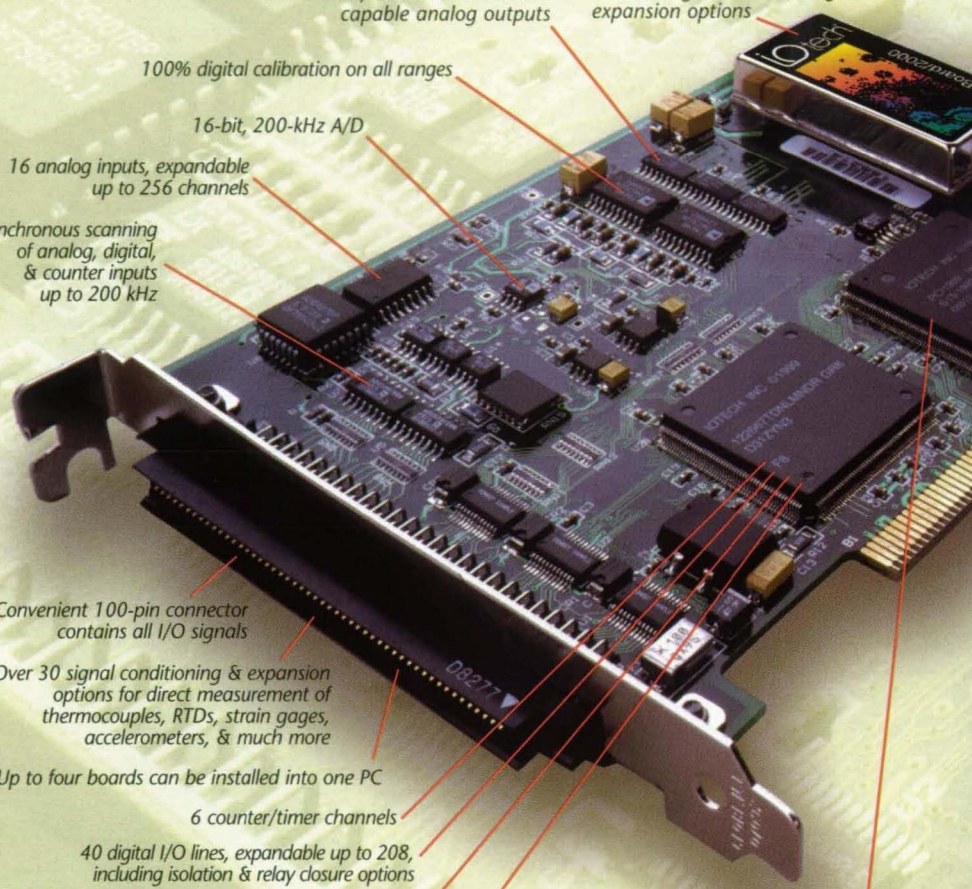

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CIRCLE 403

that are primarily 2D and are still selling well. To reach more users in the enterprise, some vendors specialize in viewing and collaboration tools using simplified 3D geometry models. Unfortunately, it is very easy to lose the productivity gains of a single task when data needs to be constantly moved between systems.

These two pressures often are greatest for companies in the middle of the supply chain. Take a mold designer, for instance. Their customers probably are using high-end surface or solids modeling systems. Their downstream vendors typically only have 2D systems or surface-based NC software. The design of a mold includes the very complex surface modeling task of creating the core and cavity geometry, while the major components of the mold base can be designed in 3D solids or in 2D. There are always a tremendous number of 2D drawings and other documentation required. The choice of a single CAD system for this environment can be very difficult.

In a large company, there are similar pressures. The elite product designers probably have leading-edge 3D technology, but typically the data is locked up in a proprietary database to which no one else in the company has access. While the high-end, process-centric tools offer the technical ability to deploy their system throughout an organization with associativity and concurrent engineering, it isn't happening. The tools are too heavy, too complex, and too expensive for all but some aerospace and automotive manufacturers.

Compatibility Issues Restrict Mass 3D

Whenever a number of CAD systems must be used together on a project, there is always the problem of data translation. A few years ago, several vendors in the industry proposed that all CAD systems should use the same underlying geometry kernel. This would ensure that all data translation between systems would be more accurate and reliable than using intermediate formats such as IGES or STEP. Instead, there are two available commercial kernels today, ACIS and Parasolid. This defeats the purpose of having a standard. As well, many of the leading CAD systems still use their own geometry kernels.

While most CAD systems try to differentiate themselves from the competition through geometry creation features, it is perhaps becoming even more important to be able to work successfully with geometry from other systems. There are two separate issues related to data translation. First is the ability to import the data. Very reliable IGES and STEP translators still will be required for some time because of the large number of CAD systems with proprietary formats. In addition, direct translators are becoming very important in order to simplify the process and increase accuracy when working with the most common formats.

Once the data has been imported, it is important to be able to complete the design task regardless of the format of the incoming data. Some CAD systems work fine if they are given highly accurate solid models, but what if the data contains only surfaces, or incomplete solids, or just 2D? Often, the company receiving the data is not in a position to insist on the type or quality of the data being given to them. CAD users must have the tools to complete their design work on time and on budget, regardless of the quality of the data from their customer.

CAD systems are either too expensive and complex to roll out to a large number of users, or they are simplified tools that only meet the needs of a few users.

Requirements of Mass 3D

The idea of mass 3D is not new. Many CAD vendors have proposed the concept of a 3D CAD system for everyone in an organization that needs access to design data. However, existing systems have one of two problems. Either they are too expensive and complex to roll out to a large number of users, or they are simplified tools that only meet the needs of a few users within the organization.

In order to achieve the "Holy Grail" of mass 3D, a CAD system must have the following characteristics:

- **Low cost.** A mass 3D system must be priced affordably so that everyone across the organization and the extended enterprise can afford to have a desktop system. However, since the number of seats a company requires may change greatly from time to time, there must also be a flexible licensing model. For mass 3D, a flexible subscription model or ASP model, with no up-front fee, is the right approach.
- **Full functionality.** Because the goal is to encompass a large number of users, there most likely will be a wide variety of functionality required. This cannot come with the complexity of today's high-end systems. Users must be able to work with surfaces, parametric solids, or in standalone 2D, depending on the task at hand. At the same time, the tool must be intuitive and consistent in each environment.
- **Compatible.** No company will achieve mass 3D by using only a single system. There always will be a number of specialized or legacy tools, plus those of external partners. Each of these tools typically will not be a mid-range solid modeler. Specialty tools will be advanced surface modelers or high-end solid modelers. Legacy tools may be an old 2D system. It is important that the mass 3D system not only is able to import all of these kinds of data, but it must also be able to truly work with the data in its original format. It should be possible to make a design change to a 2D drawing without converting it first to 3D.
- **Easy to learn.** When deploying 3D CAD to a large number of users within an organization, it is unreasonable to expect everyone to attend long, structured classroom training courses. Instead, it is important to offer self-paced, computer-based training, where users can learn only what they need and take the training when it fits their schedule.
- **Interactive support.** To get support on most CAD systems today, users must call into rigidly structured, time-consuming hotlines. In today's web-centric environment, users should be able to help themselves if given an intuitive, friendly, informative knowledge base of solutions on the web.

The pressure to deliver complex molds faster, while constantly improving quality, continues to increase for companies in today's competitive marketplace. What companies will discover is that the data, file, and design process compatibility of a mass 3D solution can yield tremendous productivity benefits, and can be the key to keeping pace with customers' ever-changing needs and requirements.

This article was written by Dan Smith, Director of Technical Marketing at think3, Santa Clara, CA. For more information, call 408-987-2200, or visit www.think3.com.

Computer Code Generates Two-Dimensional Unstructured Grids

Shapes of grid cells are controlled by specifying point-insertion criteria.

John H. Glenn Research Center, Cleveland, Ohio

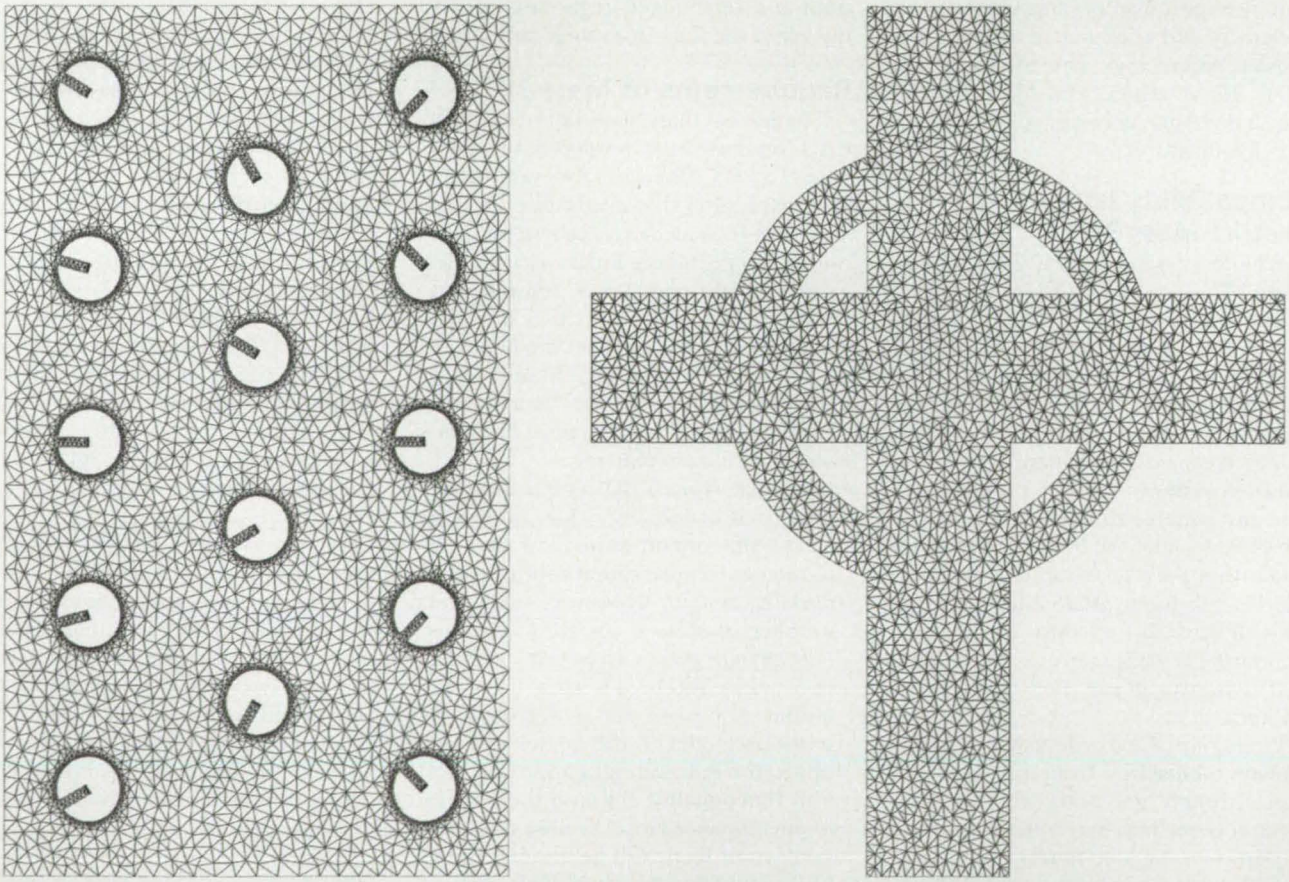
TRiangular Unstructured Mesh generator by Point insErTion (TRUMPET) is a computer program that generates meshes that are composed of triangular cells and are bounded by complex shapes. The bounding shapes can be singly or multiply connected two-dimensional regions. The figure depicts two examples of meshes that can be generated by use of TRUMPET.

The boundaries are specified by the user. The number of points used to describe a boundary can vary from 2 for a straight line to $n>2$ for a boundary with curvature. Once specified, the points are then splined. A point-distribution function can then be used to cluster or stretch the points along a given boundary segment.

The boundary points are then used to start a point-insertion process. First, the boundary points are triangulated on the basis of the Delaunay criterion. The result of this triangulation is usually not desirable. Points are then inserted in the domain to obtain a reasonable grid.

Five point-insertion criteria are used in TRUMPET. A new point is inserted at the circumcenter of a cell that meets whichever criterion is chosen. This enables one to control shapes of the cells that are added to the domain. One criterion produces a grid of cells that are more nearly equilateral; another criterion produces a grid with stretched cells (used for computing viscous flow). The criteria can be mixed to produce a grid most appropriate for the problem one is attempting to solve.

Upon completion, the code produces a file of Cartesian coordinate data as well as a complete set of connectivity files. These files give the cell-to-node, cell-to-edge, edge-to-cell, edge-to-node, node-to-node, node-to-edge, and node-to-cell information. Types of boundary conditions can be



Meshes of Triangular Cells, bounded by complex and/or multiply connected areas, can be generated by use of TRUMPET.

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specified by tagging the boundary edges. TRUMPET also includes a sorting routine that orders the cells and edges geometrically. A coloring algorithm is employed to produce a set of four-color files such that no cell lies next to a cell of the same color.

The code calls software libraries in OpenGL and GLUT to display the results of the triangulation procedure as it progresses. This feature enables visual inspection of the node distribution along the boundaries and the resulting grid.

This work was done by Philip C. E. Jorgenson of **Glenn Research Center**. *Further information can be obtained at the web site http://www.grc.nasa.gov/WWW/microbus/cese/jorgenson/jorgenson.html or from*

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LEW-16824

Designing Composite Repairs and Retrofits for Infrastructure

Techniques for designing laminated composites can be utilized for this purpose.

John H. Glenn Research Center, Cleveland, Ohio

A method of analyzing and designing laminated composite-material wraps for columns, arches, domes, and other large reinforced-concrete structures involves an extension of composite-mechanics concepts and computational techniques developed previously for the analysis and design of the composite materials only. As used thus far, "composite materials" denotes polymeric matrices reinforced with polymeric or nonpolymeric fibers — e.g., epoxy reinforced with glass fibers. Wraps made of composite materials can be applied to reinforced concrete structures to repair them or as retrofits for reinforcement against loads that are expected to exceed original design loads.

The method involves, among other things, recognition that reinforced concrete can also be regarded as a composite material and that a reinforced-concrete structure wrapped with a polymeric-matrix/fiber laminate can be regarded as a more-complex composite-material structure. The concrete can be regarded as a matrix, while the reinforcing steel bars embedded in the concrete can be regarded as fibers. Hence, the reinforced-concrete structure is amenable to the same finite-element analysis as that conventionally applied to polymer-matrix/fiber composites — of course, with appropriate modifications of the stiffness parameters and dimensions of the finite elements that represent the different constituent materials.

By analogy with laminated polymer-matrix/fiber composites, the overall laminate-wrapped reinforced-concrete structure can be treated computationally as a laminate that comprises (1) layers of concrete (matrix) only, (2) layers that contain both concrete and reinforcing bars (matrix and fibers), and (3) one or more layer(s) of the applied polymer-matrix/fiber laminate. Therefore, both without and with the composite wrap,

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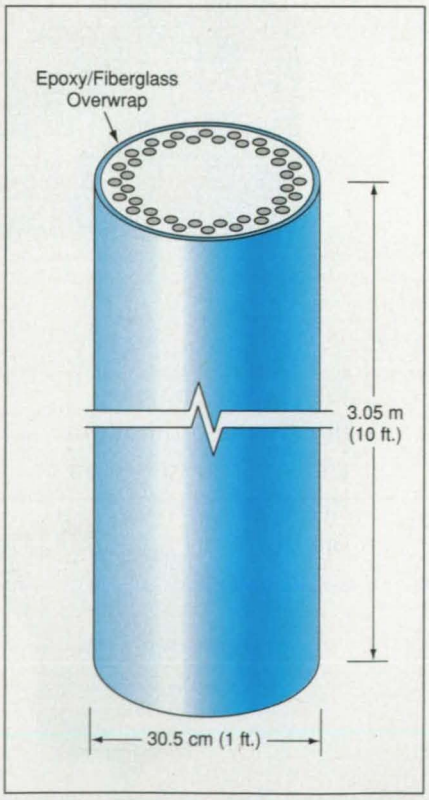

Epoxy/Fiberglass Composite Would Be Wrapped around a steel-reinforced concrete column. Even though the composite overwrap would be only 0.5 in. (12.7 mm) thick, calculations indicate that it could prevent collapse in the event that concrete was subjected to double its rated load.

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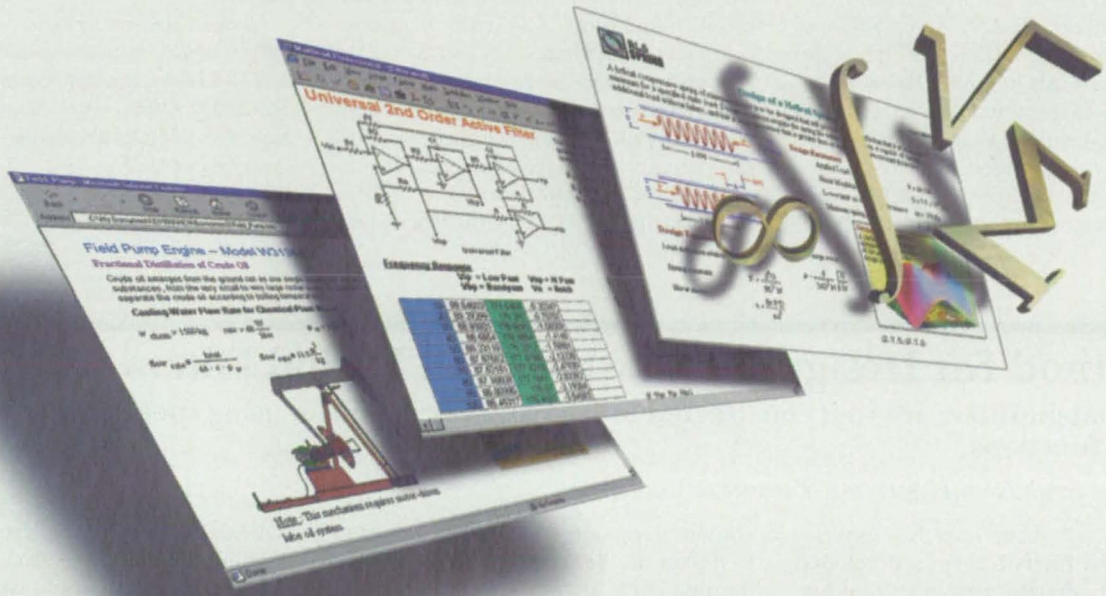

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For More Information Circle No. 502

the reinforced-concrete structure can be analyzed by use of general-purpose finite-element structural-mechanics computer programs and by composite-mechanics and progressive-structural-fracture computer programs developed previously for polymer-matrix/fiber composites. One can, for example, take advantage of all the features of the Integrated Composite Analyzer (ICAN) composite-mechanics program, which has been described previously in *NASA Tech Briefs*.

In some cases amenable to simplifying assumptions, the method can be practiced without need for a computer program. An example of such a case that illustrates the benefit of retrofitting is that of a composite overwrap to prevent or delay the collapse of a round concrete column reinforced with longitudinal steel bars. In this example, it is assumed that the concrete collapses to essentially a hydrostatic state when loaded to twice its rated ultimate load. Then using the dimensions indicated in the figure along with the associated material parameters and with a simple hoop-stress formula, one can calculate that collapse can be prevented (that is, the crumbled concrete can be contained) by an epoxy/fiberglass composite containing 50 volume percent E-glass fiber wrapped in one 0.1-in. (2.5-mm)-thick layer with fibers oriented longitudinally and in another 0.4-in. (10.2-mm)-thick layer with fibers oriented circumferentially.

This work was done by Christos C. Chamis and Pascal K. Gotsis of **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135.
Refer to LEW-16879.

A Method for Designing Low-Pass FIR Digital Filters

Time-domain filters are first constructed in the frequency domain, using special window functions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A class of finite-impulse-response (FIR) digital filters has been developed to perform certain frequency-limiting, decimation, and differentiation (with respect to time) functions on a time series of data samples. The method is implemented by use of design equations that contain parameters that can be adjusted to obtain the desired functionality while limiting such undesired effects as aliasing and gain ripple. The original application is processing of a time series of raw range data from the proposed Gravity Recovery and Climate Experiment (GRACE), in which microwave phase tracking between two small spacecraft orbiting the Earth would yield the time-tagged raw range data, which would be processed to extract information on the structure of the gravitational field of the Earth. The method is general enough to be applicable in other situations that involve similar signal-processing requirements.

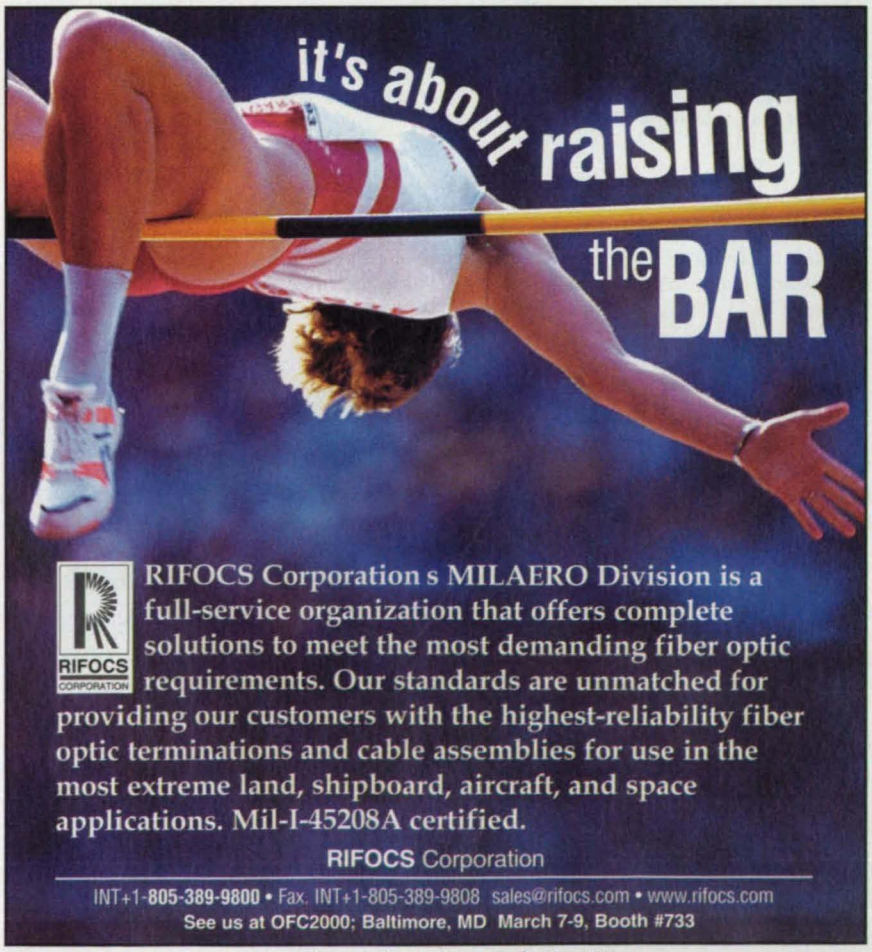
Consider a time series wherein R_i' denotes the raw datum at the jth sampling period. One seeks an FIR filter that can be convolved with the raw data in the time domain over a time window of an odd number, N_f, of sampling periods to obtain low-pass filtering plus decimation by a factor of N_f. The low-pass filtered, decimated time series is to be given by

$$R_i = \sum_{n=-N_h}^{N_h} F_n R_{i-n}'$$

where the F_n terms are the FIR filter coefficients and $N_h = (N_f - 1)/2$. One also seeks low-pass-filtering and decimating FIR filters $\dot{F}_n$ and $\ddot{F}_n$ to obtain the first and second derivatives of the data with respect to time (range rate and range acceleration in the original application). The corresponding equations are

$$\dot{R}_i = \sum_{n=-N_h}^{N_h} \dot{F}_n R_{i-n}'$$

$$\ddot{R}_i = \sum_{n=-N_h}^{N_h} \ddot{F}_n R_{i-n}'$$



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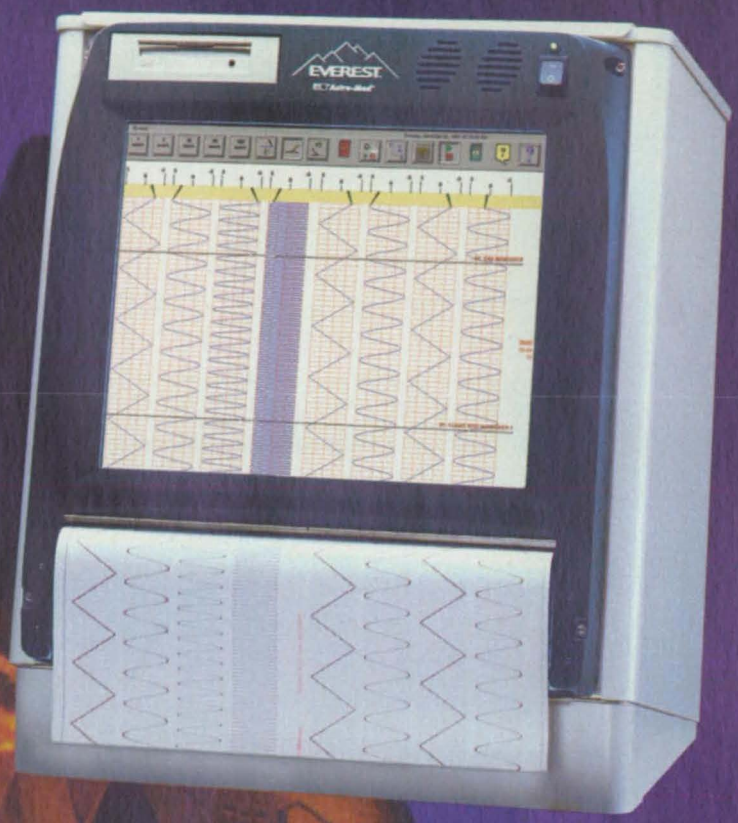

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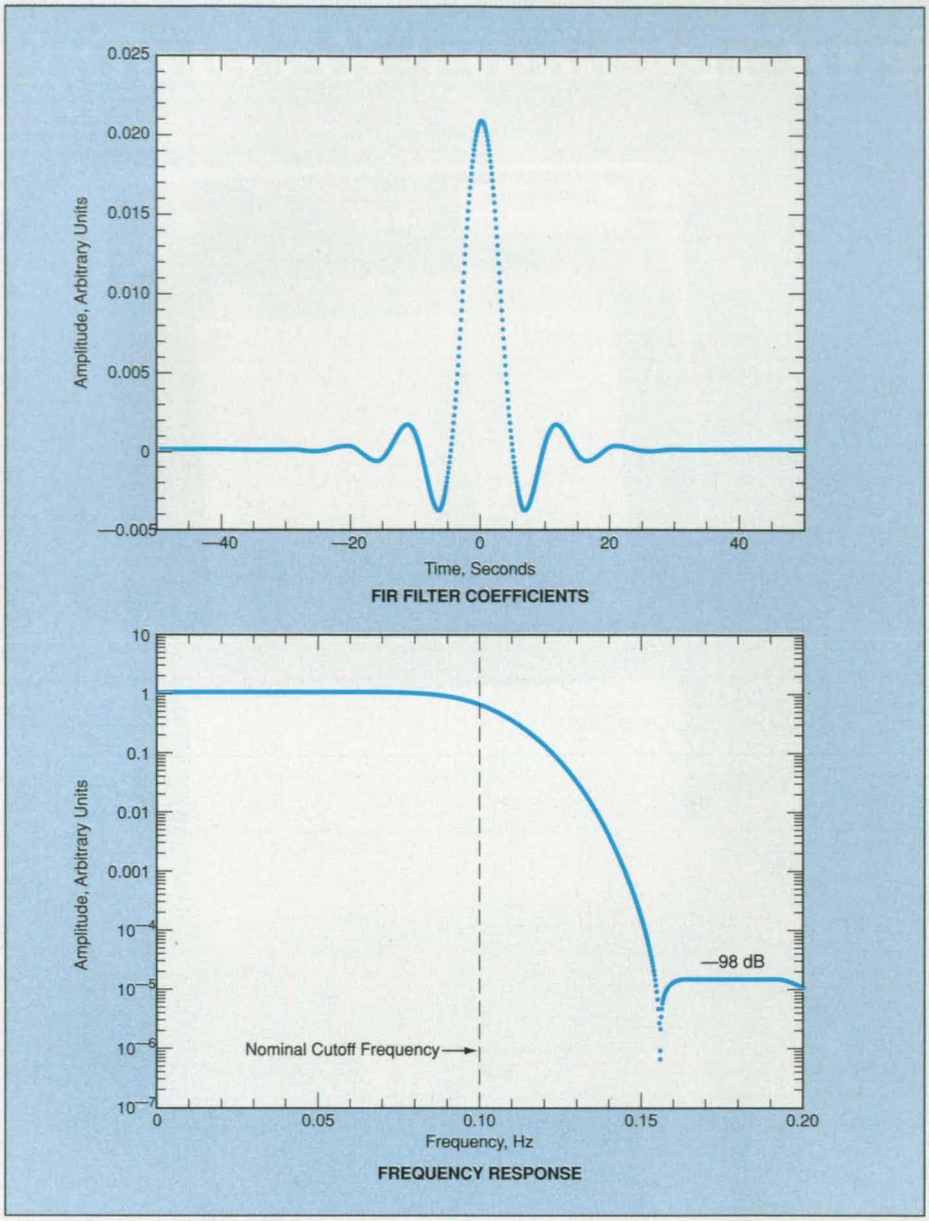


Figure 1. **Range FIR Filter Coefficients** and the frequency response of the filter were calculated for a test case of fs = 10 Hz, T_f = 5 s, and nominal cutoff frequency of 0.1 Hz.

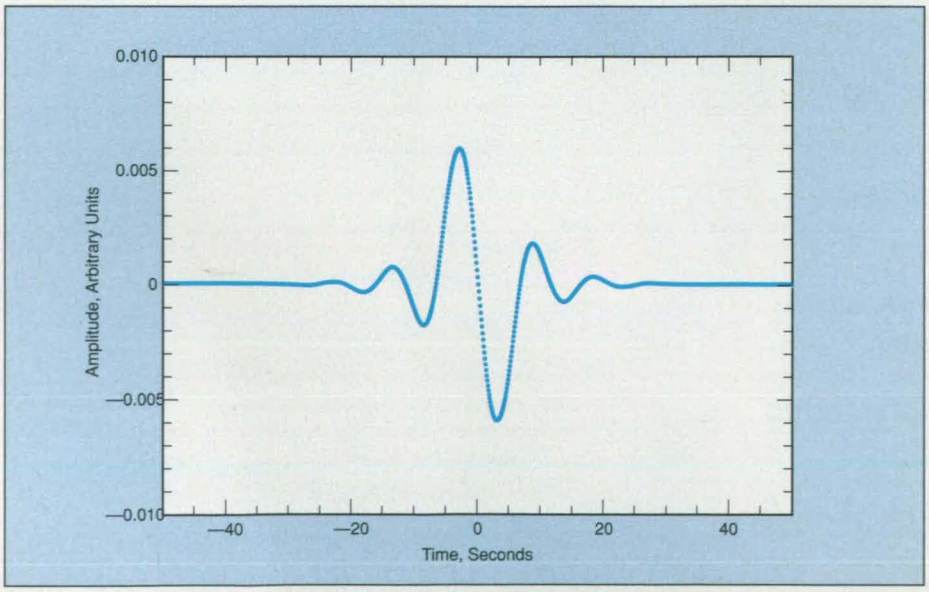


Figure 2. **Range-Rate FIR Filter Coefficients** were calculated for the test case of Figure 1.

Each FIR filter is required to differentiate to the desired order and to exhibit a nearly rectangular low-pass frequency response. To prevent aliasing of out-of-band noise into the desired low-pass band, the low-pass cutoff frequency should be set at or near the applicable Nyquist value, which is half the output data sampling frequency. The well-known window-function approach is used to formulate the FIR filter. The time-domain window function consists of a rectangular time-domain window self-convolved N_c times. The frequency-domain response of such a time-domain window is approximately given by a simple closed-form expression of the form $[\sin x/x]^{N_c+1}$. This class of filters is classified as CRN filters designating N convolutions of a rectangle.

In designing the filter, one must choose values for the nominal cutoff frequency (bandwidth), for N_c, and for the filter length $T_f = N_f/f_s$ (where f_s is the raw-data sampling frequency). The filter is first constructed in the frequency domain by convolving the desired rectangular low-pass frequency response with the known discrete Fourier transform, $[\sin x/x]^{N_c+1}$, of the selected N_c-self-convolution time-domain window function. The result of this convolution is then discrete-Fourier-transformed to the time domain to obtain the FIR coefficients. The advantage of this class of FIR filter is that the frequency-domain response can be approximately assessed "in advance" on the basis of the simple $[\sin x/x]^{N_c+1}$ function. Further differentiation can be easily applied by multiplying by $2\pi f$ in the frequency domain.

The upper part of the Figure 1 depicts the FIR coefficients and frequency response of a range filter designed according to this method for a test case, using $N_c = 6$. As one would expect, the FIR amplitude vs. time resembles a $\sin(x)/x$ function, except that it tapers toward zero in the outer time regions. This taper is caused by the window function. The lower part of Figure 1 shows the predicted frequency response of the range filter. Figure 2 depicts the FIR coefficients of a range-rate (first-derivative) filter for the same test case.

This work was done by J. B. Thomas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-20643

Software for Predicting Life of Metal-Matrix Composites

Fiber fractures are modeled according to statistical distributions of fiber strengths.

John H. Glenn Research Center, Cleveland, Ohio

LIPS (LIFE PREDICTION SOFTWARE) is a computer program for predicting the life of an object that is made of a unidirectional-fiber/metal-matrix composite (MMC) material and that is subjected to mechanical loading along the fiber direction. The program is derived from a theory formulated to be consistent with the experimental observation that progressive fiber fracture (more precisely, successive fractures of different fibers) is a dominant damage mechanism that leads to failure in MMCs. This theory is fundamentally different from other theories in which the effects of broken fibers are represented by artificially reducing the moduli of the fibers. In the present theory, progressive fiber fracture is addressed via a fiber-fracture criterion based on a statistical distribution of fiber strength.

The fiber material is assumed to be isotropic and linearly elastic at all temperatures. For the matrix material, one can use any constitutive model of elastic-viscoplastic, creep, or viscoplastic behavior. In the special case of a composite material in which all the fibers are intact and the inelastic-strain rate of the matrix material can be expressed in a simple power-law form, the theory yields a closed-form expression for the strain in the composite material

LIPS is a Windows™-based application program designed for convenience of use by engineers. It affords considerable flexibility for selection of input and for interpretation of output.

LIPS consists of three modules — denoted the material data-base, analysis, and postprocessor modules. The data-base module contains tables of temperature-dependent properties of fiber and matrix materials. Drop-down-menu controls enable the user to classify a material as elastic, elastic-plastic, or elastic-viscoplastic. The user can select or modify properties of materials already in the data base, and can define new materials for the data base and specify their properties. The user can gain access to the material data-base module both before and after entering the analysis module.

The analysis module enables the user to provide the input data necessary for using the progressive-fiber-break model implemented by the program. The analysis module also provides access to the postprocessor module.

The postprocessor module affords basic capabilities for displaying the results of computations in graphical form and for printing the results in graphical or textual form. This module provides a postprocessing window, within which there are several pull-down menus that enable the user to select data for plotting, change a previously generated graph, and/or print a graph. The user can also open two results-of-computation or experimental-data files at the same time and compare the results on the same plot.

This work was done by Jalees Ahmad of Research Applications, Inc., for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP) **free on-line at www.nasatech.com** under the Materials category.*

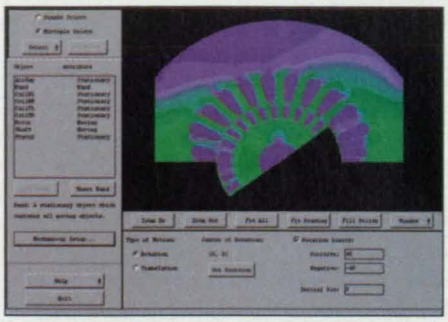
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16835.

For More Information Circle No. 416

Helix Capture **CAD/CAM software** from Microcadam, Los Angeles, CA, enables designers to create solid models based on 2D AutoCAD drawings. Starting from within the AutoCAD program, users are prompted to select views for 3D generation. The views are automatically transferred into Helix Modeling, which creates solid models using AutoSOLID™ and Gen3D™ functions.

The program uses intelligent algorithms to build models from geometric information in the 2D drawing. If cross-view inconsistencies are detected, Gen3D completes the model. Modeling features include integrated surfaces, motion simulation, mass properties, interference detection, and sheet-metal design.

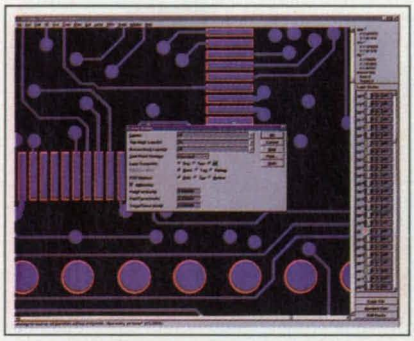
For More Information Circle No. 724



RMxprt™ rotating **electric machine design software** from Ansoft Corp., Pittsburgh, PA, allows users to design all types of motors and generators. It can be used to evaluate potential motor configurations and identify the most appropriate alternative prior to performing detailed analysis.

The user interface enables quick entry of motor-specific data, such as operating source, rotor, stator, lamination geometry, winding configuration, materials, mechanical load type, 3D effects, and commutation parameters. It automatically generates a 2D geometric model and calculates motor performance.

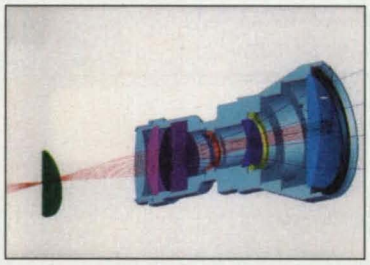
For More Information Circle No. 721



GraphiCode, Mountlake Terrace, WA, has announced GC-CAM 4.1.4 **printed circuit board design software** that controls manufacturing data, PCB design, and verification. An improved contour engine assists in the netlist extraction process and works on jobs with nets of up to 130,000.

An SPT file enables the tester to make a valid Discharge Reference test on boards with split planes, without shorting or connecting split sections of the reference plane together. An SIZ file enables the tester to adjust accuracy for ranges of test feature size. Other improvements include increased fabrication process speed, and compatibility with other PCB fab equipment.

For More Information Circle No. 720



TracePro® 2.0.4 **optomechanical 3D solid modeling software** for lighting design and biomedical applications from Lambda Research Corp., Littleton, MA, includes bulk scattering, updated luminaire design and analysis, and a tracing tool for arbitrary bitmap images. It provides enhanced support of standard illumination output formats, and DXF output for irradiance and illuminance maps.

The program is compatible with more than 200 CAD-based programs, and features an intuitive graphical interface for modeling stray light analysis, illumination analysis, and lighting design. Additional data is displayed on screen for multiple or single wavelengths. An optional bitmap module wizard translates standard BMP, JPEG, GIF, or PNG files into a TracePro source file.

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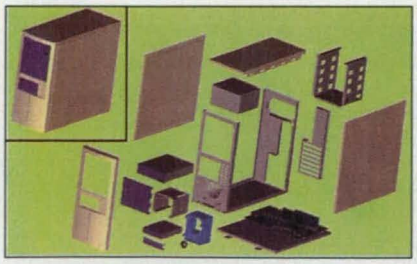
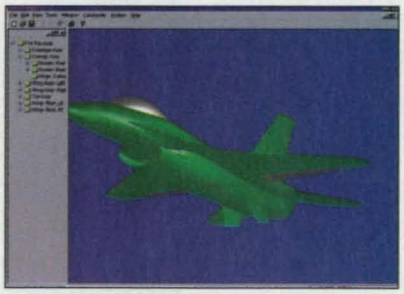


Varimetrix Corp., Palm Bay, FL, offers VX Vision FabDesign™ **CAD/CAM software** for creating sheet-metal parts. Users can design complex, multi-part assemblies with a mix of sheet metal, plastic, and other components. Designers create feature-based solid models of sheet-metal parts in the context of a full 3D assembly. They can fold and unfold an entire part or individual bends.

Features can be added to parts in the folded or unfolded state. As sheet-metal parts are designed, the program automatically creates bend allowances and reliefs. Other features include the ability to work with sheet-metal parts imported from other systems, and access to full hybrid modeling capabilities.

For More Information Circle No. 723



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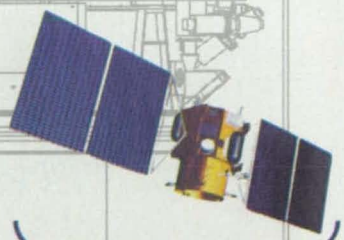

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AFFORDABILITY THROUGH INNOVATION

For More Information Circle No. 573

Security System Based on Bragg Gratings in an Optical Fiber

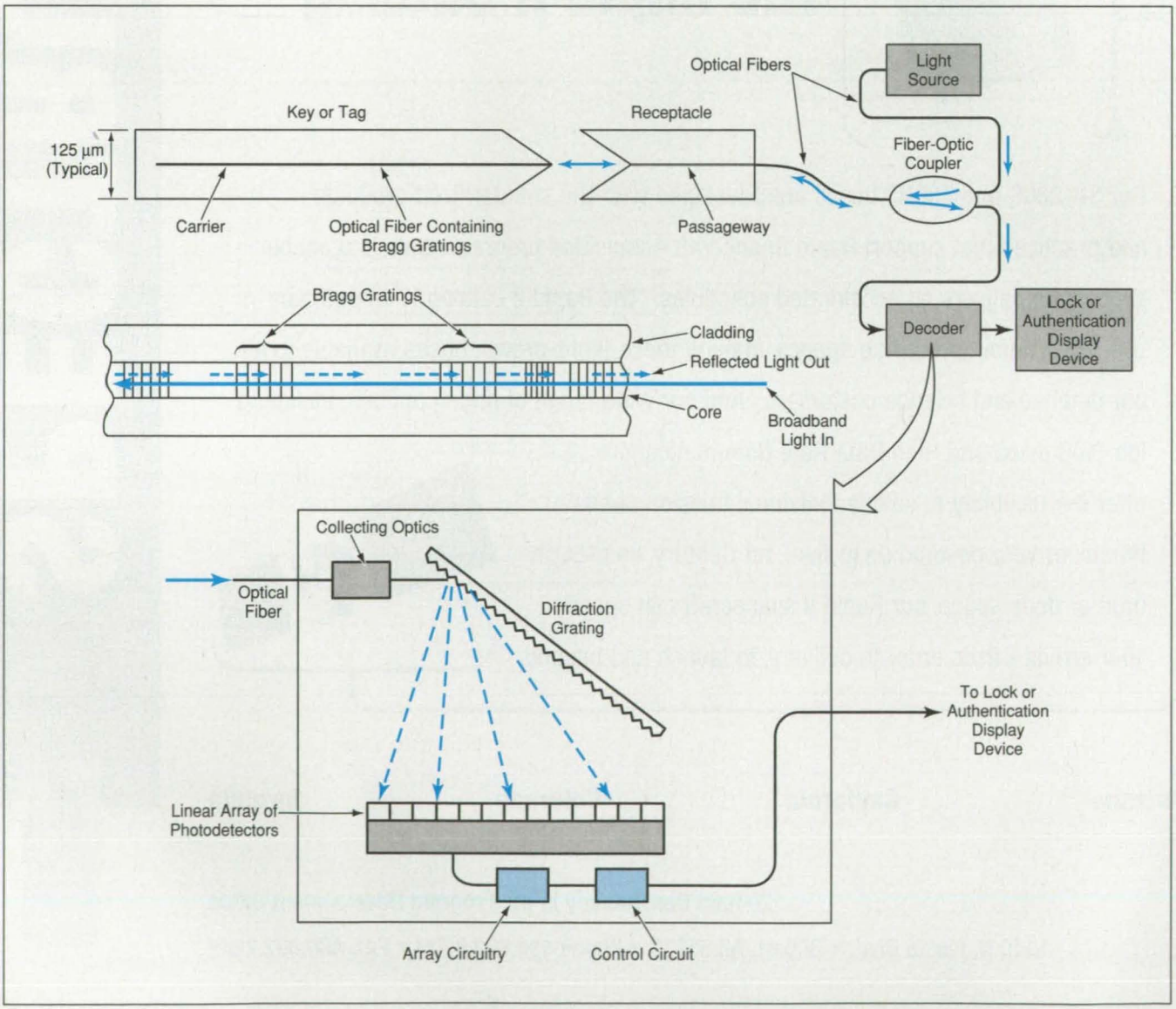
A fiber-optic key is small, rugged, and not easily duplicated.

Ames Research Center, Moffett Field, California

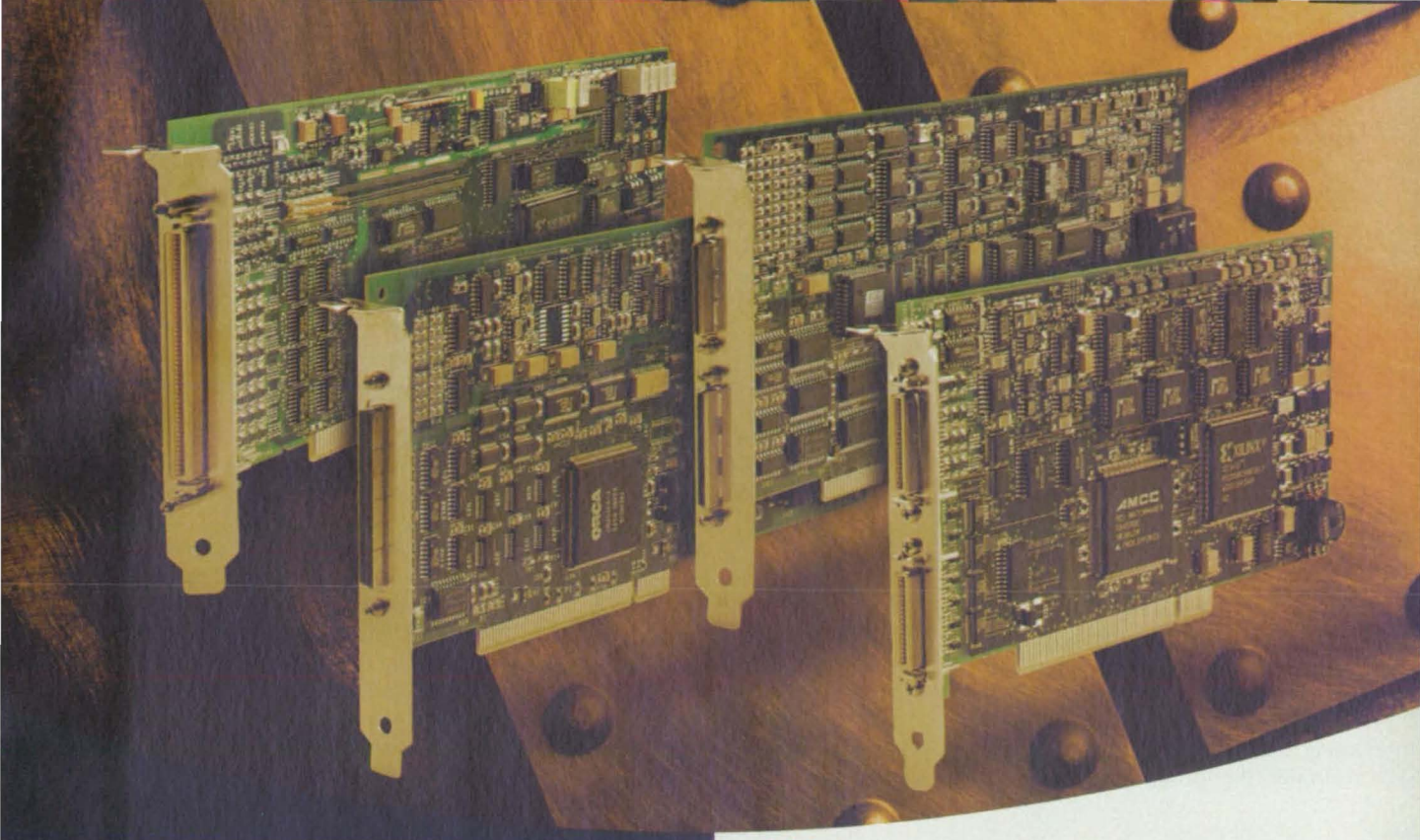
The figure schematically illustrates an optoelectronic security system in which binary information on the identity of a person or object is encoded in Bragg gratings in an optical fiber. This is not the first optoelectronic security system based on fiber-optic Bragg gratings, but it is the first in which such gratings constitute the basis of a key or an identification tag.

The system includes a source of broad-band light, which is fed into one of three terminals of a fiber-optic coupler. From the coupler, the broad-band light travels along an optical fiber to a central passageway in a receptacle, then travels along the passageway and emerges at the apex of a conical mouth in the receptacle. The system includes a key with a conical tip that mates with the conical mouth of the receptacle. The key comprises a carrier that holds the optical fiber that contains the Bragg gratings. When the key is inserted in the receptacle, this optical fiber is aligned with, and receives broadband light from, the passageway in the receptacle.

The Bragg gratings are in the form of periodic variations in the index of refraction along the core of the optical fiber in the key. The Bragg gratings are located at intervals along this fiber, interspersed with grating-free regions. Each grating has a unique spatial period, so that it reflects light maximally at a unique wavelength. As a result, when



In **This Optoelectronic Security System**, binary identifying information is encoded in Bragg gratings in the optical fiber in the key or tag.



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illuminated with broad-band light, the optical fiber in the key reflects light maximally at the wavelengths of the Bragg gratings; that is, the reflection spectrum is a series of spectral lines at these wavelengths. The presence or absence of a reflection-spectrum line at a given wavelength can be made to signify a one or a zero, respectively, in a binary identification code. Thus, the Bragg gratings can be fabricated to encode identity information.

The light reflected by the optical fiber in the key travels back along the route of the broad-band illumination to the fiber-optic coupler, then from the fiber-optic coupler to a decoder. The decoder contains a spectrometer, in which a diffraction grating disperses the light by wavelength onto a linear array of photodetectors. From the photodetector outputs as a function of position along the array, the array circuitry determines the presence or absence of each spectral line of interest, and thus determines the corresponding binary digit. A control circuit compares the binary number with a preselected binary number or set of numbers; if a match is found, then the control circuit generates an electronic command to open a lock. Alternatively, the key can serve as an identification tag for a person or object, in which case the control circuit generates a command that activates an authentication display device.

Among the advantages of this system are the ruggedness and compactness of the key or tag; typically, the carrier is made of metal and has a diameter of about 2 mm. The carrier portion of the key or tag need not be a cone-tipped cylinder as in the figure; alternatively, it could be a pen, a piece of jewelry, or any other convenient small object. In comparison with magnetic-card keys used in some electronic security systems, the key or tag is more easily carried and concealed, and less likely to be misplaced. Because of the smallness of the optical fiber, the key or tag cannot be duplicated easily; this feature enhances the degree of security. Finally, in common with other electronic security systems, this system makes it possible to tailor the system to accommodate multiple users, each of whom may have authority to open the same or a different set of locks in an installation.

This work was done by Charles K. Gary and Meric Ozcan of **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

This invention has been patented by NASA (U.S. Patent No. 5,633,975). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (650) 604-5104. Refer to ARC-12092.

Higher-Resolution Optoelectronic Shaft-Angle Encoder

This encoder is an improved version of a related prior encoder.

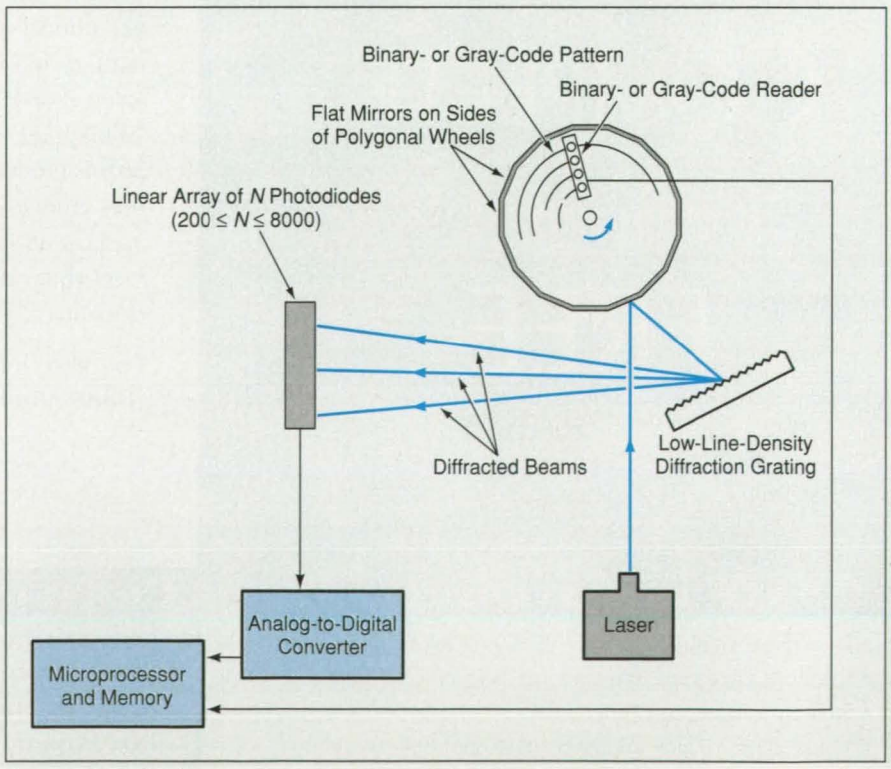
Goddard Space Flight Center, Greenbelt, Maryland

The apparatus shown schematically in the figure is an optoelectronic shaft-angle encoder that measures absolute angles with high resolution. This encoder is an improved version of the apparatus described in "High-Resolution Optoelectronic Shaft-Angle Encoder" (GSC-13543), *Laser Tech Briefs*, Vol. 2, No. 2, (Spring, 1994), page 32.

Like the prior encoder, this one includes a polygonal mirror wheel affixed to the shaft, the angular position of which is to be measured. A binary- or Gray-code pattern on the wheel is read by a binary- or Gray-code reader, thereby indicating the shaft angle, with coarse resolution, to within the increment of angle subtended by one side of the polygon. Equivalently, the output of the binary- or Gray-code reader identifies which side of the polygon lies along a given line of sight.

A helium/neon or other compact laser sends a narrow, low-divergence beam of monochromatic light toward the polygonal mirror wheel. One of the mirror facets reflects the laser beam onto a nearby low-line-density diffraction grating. The light diffracted from the grating strikes a linear array of photodiodes at several spots. The outputs of the photodetectors are digitized, providing fine-resolution data on the distribution of light diffracted onto the array. These data are fed to a microprocessor for calculation of the shaft angle as explained below.

The spatial distribution of light diffracted onto the array depends on the wavelength of the light, the precise nature and spacing of the grating lines, and the geometry of all of the optical components. Among other things, the positions of the diffraction spots on the array depend on the position and angle of in-



The **Locations of Diffraction Spots** on the array of photodetectors provide a sensitive indication of the angle of the reflecting facet.

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For More Information Circle No. 508

cidence of the reflected laser beam on the grating and these, in turn, depend on the angle of the facet, which depends on the angle of rotation of the shaft.

The distribution of light on the array is thus a known function of the angle of the facet. This function is inverted to compute the angle of rotation of the shaft, to fine resolution, modulo the coarse-resolution increment of angle. The coarse-resolution reading is then added to the fine-resolution angle to obtain the absolute shaft angle to fine resolution.

As explained thus far, the apparatus functions similarly to the prior encoder. The fundamental difference lies in the use of a single diffraction grating separate from the polygonal mirror instead of (1) a diffraction grating mounted on each face of the polygonal mirror in one prior encoder or (2) simple polygonal mirror facets with no diffraction grating in the other prior encoder. The geometric relationships among the optical components of the present apparatus result in approximate doubling of the number of diffraction orders available for measurement on the array; this provides additional design flexibility for doubling the angular resolution, or for making the apparatus more compact with a somewhat smaller increase in resolution.

The present design also reduces the cost significantly. Fabrication of a polygonal mirror with diffraction-grating facets for the prior encoder is difficult and time consuming and costs as much as $20,000. In contrast, a separate polygonal mirror and grating can be made in less time and with less difficulty, at a cost between $3,000 and $5,000.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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-13611.

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High-Power Laser Illuminator

Wavelength selectivity enhances tracking in the presence of background light.

Goddard Space Flight Center, Greenbelt, Maryland

A laser illuminator system has been developed for use in automated tracking of objects. In its original application, the system illuminates a 5° conical region expected to contain a small satellite at a distance up to 750 m from the space shuttle. If the satellite comes within this region, then a receiving optoelectronic system aboard the space shuttle actively tracks the satellite by locking onto the laser illumination reflected by small mirrors on the satellite. The laser illuminator system could be adapted to other outer-space and terrestrial applications that involve illumination with or without tracking, or could be used as a beacon on a moving platform for tracking by an optoelectronic system located on another moving or stationary platform.

The laser illuminator system is intended to replace a white light source that has been used for tracking. The white light source provides a relatively weak return signal, and this signal is readily contaminated by noise from background light. The laser illuminator system provides a stronger return signal, and since the laser light occupies a very narrow wavelength band, background

light can readily be filtered out to increase the signal-to-noise ratio.

The source of light is a commercially available array of AlGaAs semiconductor laser diodes in a fiber-optic-coupled package. This source emits continuous-wave optical power of 5 W from the outer end of a sheathed optical fiber 1 m long with a core diameter of 400 μm. The beam as emitted from the bare outer end of the fiber is multimode (non-diffraction-limited), with nearly uniform intensity across a divergence of < 50° full width at half maximum. The full length of the optical fiber is used to ensure adequate "mode-scrambling" to make the intensity distribution as nearly uniform as possible.

The optical fiber is flexible and can easily be moved to illuminate locations or directions that might otherwise be difficult to illuminate. The bare outer end of the fiber is covered by a commercial fiber-optic connector that has been modified to contain a single molded glass aspherical lens and a monitor photodiode. The lens reduces the divergence of the beam emitted from the bare fiber to narrow the field of illumination to the required 5° cone. This optical assembly at the outer end of the fiber is only 10 mm in diameter and therefore introduces only minimal obscuration into the telescope optics of the receiving optoelectronic system.

The system consumes a total power of about 20 W. Active feedback control circuitry ensures that the current to the laser remains constant. The laser current can also be adjusted manually by remote control. Additional electronic circuitry amplifies the output of the monitor photodiode for remote determination of the health of the system.

This work was done by Donald M. Cornwell, Jr., of **Goddard Space Flight Center**, *Jimmie D. Fitzgerald of Allied Signal Corp., and Valerie Dutto of USRA. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
GSC-13823

Communication Controller Board for a Wind-Tunnel Model

This would be a key component of a miniature, distributed, modular data-acquisition system.

Langley Research Center, Hampton, Virginia

A communication controller circuit for a wind-tunnel model is undergoing development. The circuit is intended to serve as part of a highly miniaturized, distributed, modular electronic analog/digital data-acquisition system that would be installed inside a wind-tunnel model (see Figure 1). The data-acquisition system would include pressure, temperature, angle, shear-stress, and other sensors plus analog signal-conditioning modules in clusters of as many as eight sensors. The sensors and signal-conditioning modules in each cluster would be connected to a data-acquisition-system (DAS) module, which would contain additional analog signal-conditioning circuits and analog-to-digital converters. Each DAS module, in turn, would be connected to the communication controller, which would effect all digital control and data communications (1) among the sensor modules and (2) between the sensor modules and a remote host computer.

Each cluster of sensors and signal-conditioning circuits connected to a DAS module would constitute a sensor module. The sensor modules would be configured from the host computer by way of the communication controller. After data had been collected and buffered, the communication controller could send the data to the host computer via a fiber-optic cable or a radio telemetry system. Thus, the host computer would have to be equipped with a fiber-optic or radio-telemetry interface circuitry.

A serial bus would be installed within the wind-tunnel model to provide for communications between the sensor modules and the communication controller. The combination of distributed, modular architecture and the serial bus would impart a high degree of flexibility, in that the number of sensors could readily and efficiently be changed through the addition and/or removal of sensor modules, with minimal changes in power- and communication-bus wiring. Sensors and/or sensor modules could be added by connecting them to the internal bus, without need for redesigning the entire data-acquisition system. Small volumes could be carved out in places dis-

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For More Information Circle No. 418

tributed throughout the inside of the model to accommodate the small modules of the data-acquisition system, making it unnecessary to find a single internal volume large enough to hold the entire system.

Thus far, a prototype communication controller and prototype sensor modules have been fabricated on printed-circuit boards. The prototype communication controller (see Figure 2) is based on a commercially available field-programmable gate array (FPGA) chip to provide for reconfigurability. In addition to the FPGA chip, the prototype communication controller includes a buffer random-access memory; a nonvolatile electrically erasable, programmable, read-only memory that retains configuration information; drivers for internal and external communication ports; and passive components. Eventually, as now envisioned, the sensor modules and part of the communication controller would be fabricated as application-specific integrated circuits (ASICs).

This work was done by William C. Wilson of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
L-17816

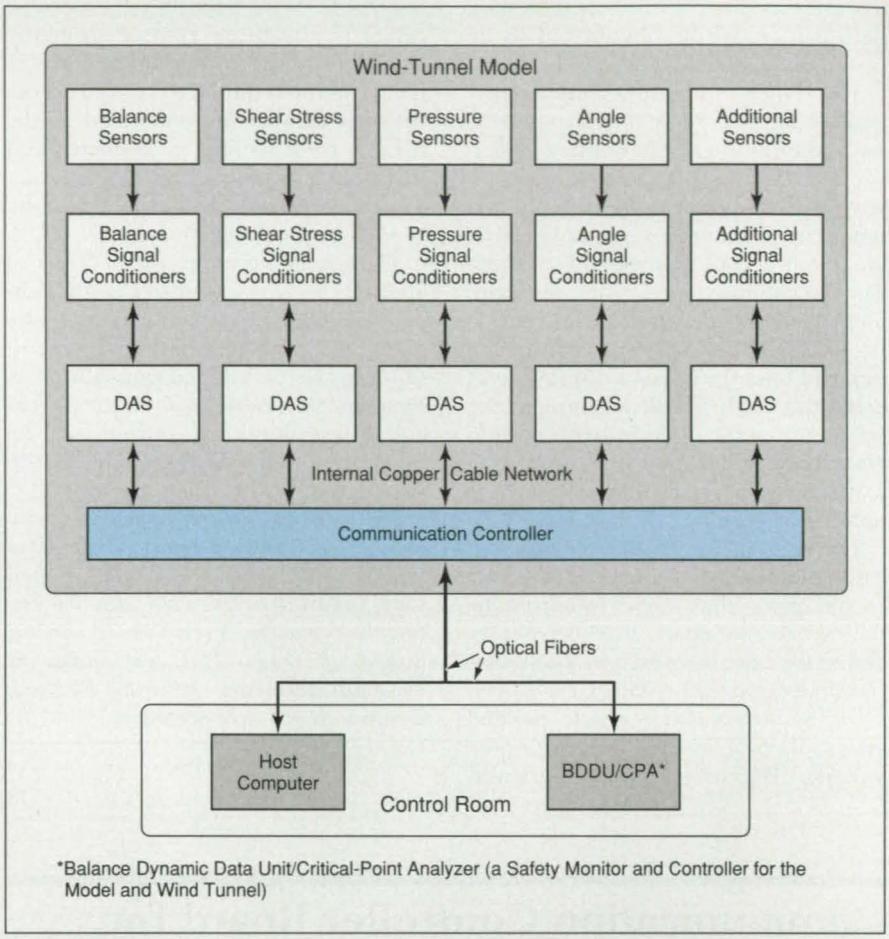
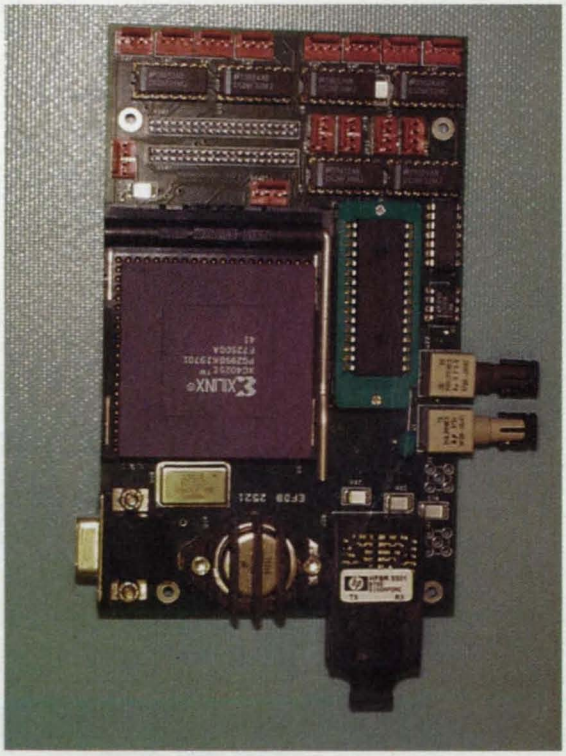
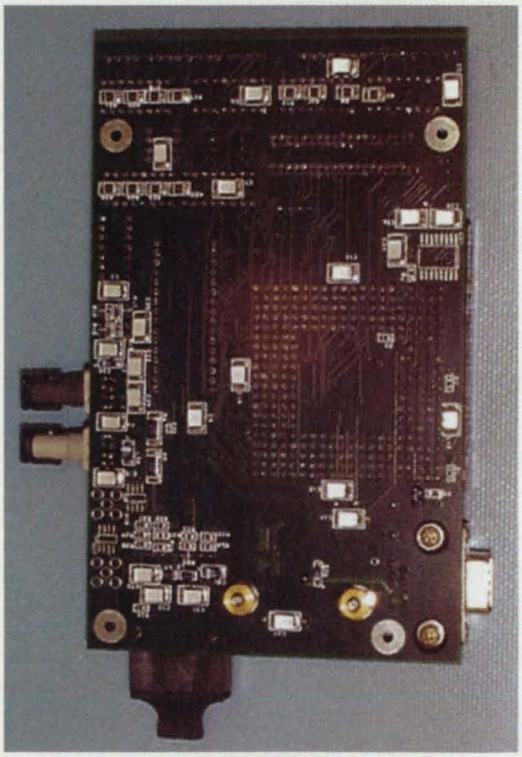


Figure 1. The **Communication Controller** would effect all digital communications among sensor modules and between the wind-tunnel model and the host computer in the control room.



TOP VIEW



BOTTOM VIEW

Figure 2. This **Prototype Communication Controller** includes an FPGA, integrated circuits, and some discrete components on a printed-circuit board. In planned further development, further miniaturization would be achieved by fabricating part of the communication controller as an ASIC.

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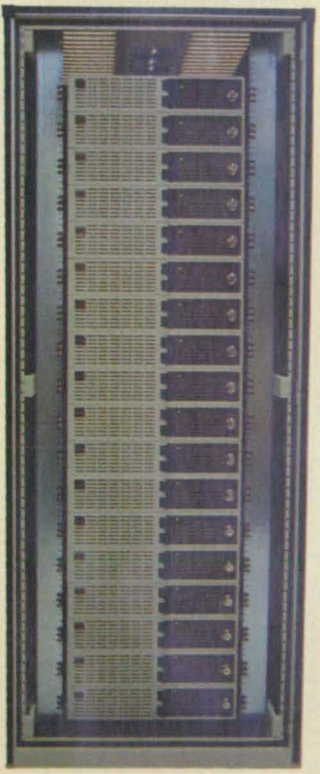

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Software for Simulating Progressive Fracture in Braided PMCs

Simulations provide guidance to increase efficiency of design and testing efforts.

John H. Glenn Research Center, Cleveland, Ohio

GENOA-PFA is a commercial version of the Composite Durability Structural Analysis (CODSTRAN) computer program, which simulates the progression of damage ultimately leading to fracture in polymer-matrix composite (PMC) material structures under various loading and environmental conditions. GENOA-PFA offers a number of capabilities beyond those of programs developed previously for the same purpose; these capabilities make GENOA-PFA preferable for use in analyzing the durability and damage tolerance of complex PMC structures in which the fiber reinforcements are in the forms of two- and even three-dimensional weaves and braids.

GENOA-PFA implements a progressive-fracture methodology, the basic concept of which is that a structure fails when flaws that may initially be small (even microscopic) grow and/or coalesce to a critical dimension such that the structure no longer has an adequate safety margin to avoid catastrophic global fracture. Damage is considered to progress through five stages: (1) initiation, (2) growth, (3) accumulation (coalescence of propagating flaws), (4) stable propagation (up to the critical dimension), and (5) unstable or very rapid propagation (beyond the critical dimension) to catastrophic failure. The computational simulation of progressive failure involves formal procedures for identifying the five different stages of damage, quantifying the amount of damage at each stage, and relating the amount of damage at each stage to the overall behavior of the deteriorating structure.

In GENOA-PFA, mathematical modeling of the physics of a PMC involves an integration of simulations at multiple, hierarchical scales ranging from macroscopic (lamina, laminate, and structure) to microscopic (fiber, matrix, and fiber/matrix interface) [see figure]. GENOA-PFA includes algorithms needed for simulating the progression of damage from various source defects; examples include (1) through-the-thickness cracks, and (2) voids with edge, pocket, internal, or mixed-mode delaminations.

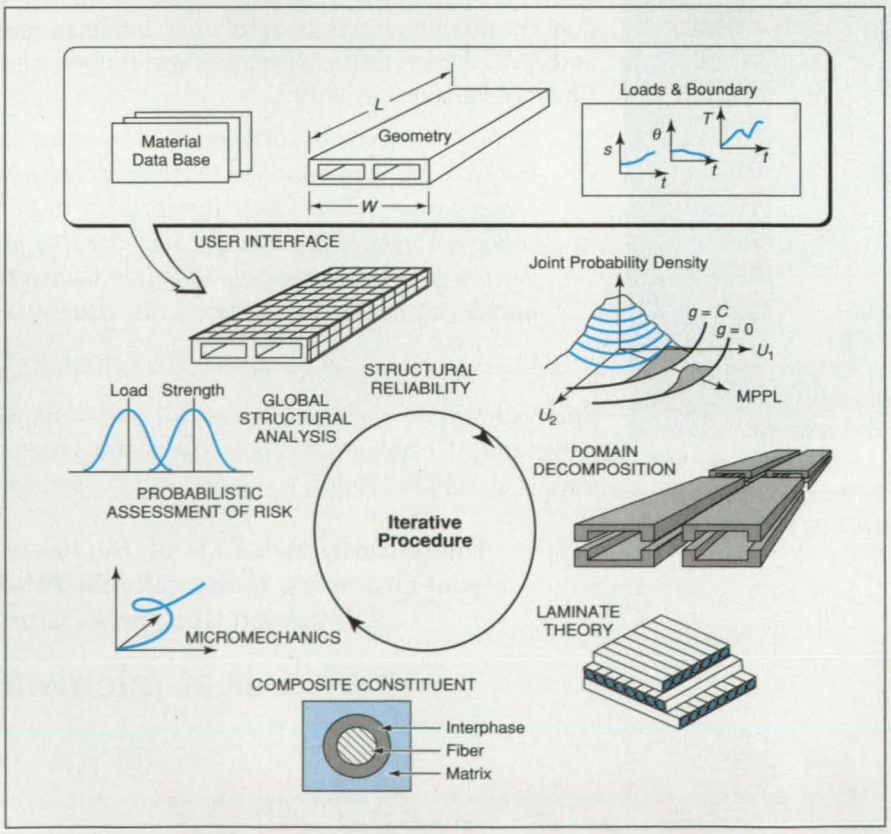
The elements of a GENOA-PFA simulation include the following:

- Ply-layering methodology utilizing finite-element analysis with through-the-thickness representation;
- Simulation of effects, on global static- and cyclic-fatigue strengths, of material defects and conditions, which can include voids, fiber waviness, and residual stresses;
- Inclusion of nonlinearities of materials through periodic updating of material-property parameters and inclusion of geometrical nonlinearities through Lagrangian updating;
- Simulation of the initiation and growth of cracks to failure under static, cyclic, creep, and impact loads;
- Progressive-fracture analysis to determine durability and damage tolerance;
- Identification of the fractional contributions of various possible composite failure modes involved in critical damage events; and
- Determining sensitivities of failure modes to such design parameters as fiber volume fractions, ply thicknesses, fiber orientations, and thicknesses of adhesive bonds.

GENOA-PFA can be used to investigate the deterioration of two- or three-dimensional PMC structures subjected to static, cyclic (fatigue), creep, and impact loading in hygrothermal environments. The use of GENOA-PFA can be expected to facilitate targeting of changes in design parameters for greatest effectiveness in reducing the probabilities of given failure modes.

This work was done by Frank Abdi of Alpha Star Corp. and Levon Minnetyan of Clarkson University for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

LEW-16845



GENOA-PFA is a parallel-processing program for analysis of PMC structures. Simulations at macroscopic and microscopic scales are integrated to predict the overall degradation of a structure under prescribed loading and environmental conditions.

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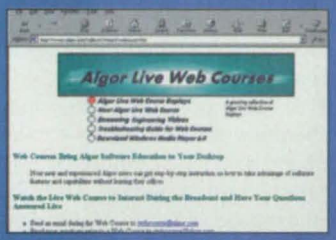

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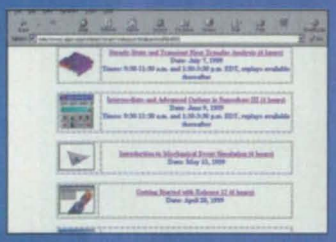

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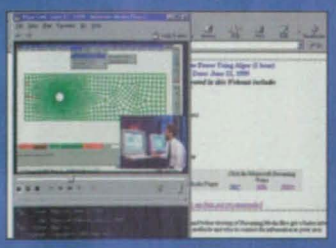

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Molecular-Sieve Type 3Å

This clay-based material removes trace water and iron from nitrogen tetroxide/nitric oxide mixtures.

Lyndon B. Johnson Space Center, Houston, Texas

The term "Molecular-Sieve Type 3Å" denotes a clay-based, zeolite material that revolutionizes a fluid-purification process by removing trace water and iron from nitrogen tetroxide/nitric oxide (MON-3) mixtures used as oxidizer components of spacecraft propellants. Older processes of this type removed only water or iron effectively, but never both. Because contamination of nitrogen tetroxide by trace amounts of water elevates the corrosion level of spacecraft hardware, the reduction of such contamination decreases the cost of facility maintenance and increases propellant-storage time. Consequent further benefits include increases in the usable lifetimes of rocket engines, flight components, deep-space probes, and satellites, along with reductions in their failure rates. All this is achieved by a process that involves the use of a revolutionary material and that supplants less-effective, energy-intensive distillation process.

In the past, trace amounts of water were distilled from MON-3 mixtures. While distillation effectively removes iron, it removes trace water only poorly. Applications that involve two types of molecular sieves remove water but remove iron only poorly, thus excessively increasing system temperatures — something Molecular-Sieve Type 3Å never does. Only Molecular-Sieve Type 3Å can remove both water and iron equally well, and without any deleterious side effects.

Molecular-Sieve Type 3Å is a zeolite material with a nominal pore size of 3 Å. Zeolites are used in many industrial applications because they can selectively remove chemicals from fluid systems on the basis of molecular sizes. Water and iron, with molecular diameters less than 3 Å, are adsorbed by Molecular-Sieve Type 3Å. But because MON-3 molecules are larger than those of either water or iron, MON-3 is not adsorbed by Molecular-Sieve Type 3Å.

In the U.S. space program, water and iron must be removed from MON-3 mixtures to reduce the risk of failure of primary reaction control system (PRCS) valves in the space shuttle. Molecular-Sieve Type 3Å does this completely, with-

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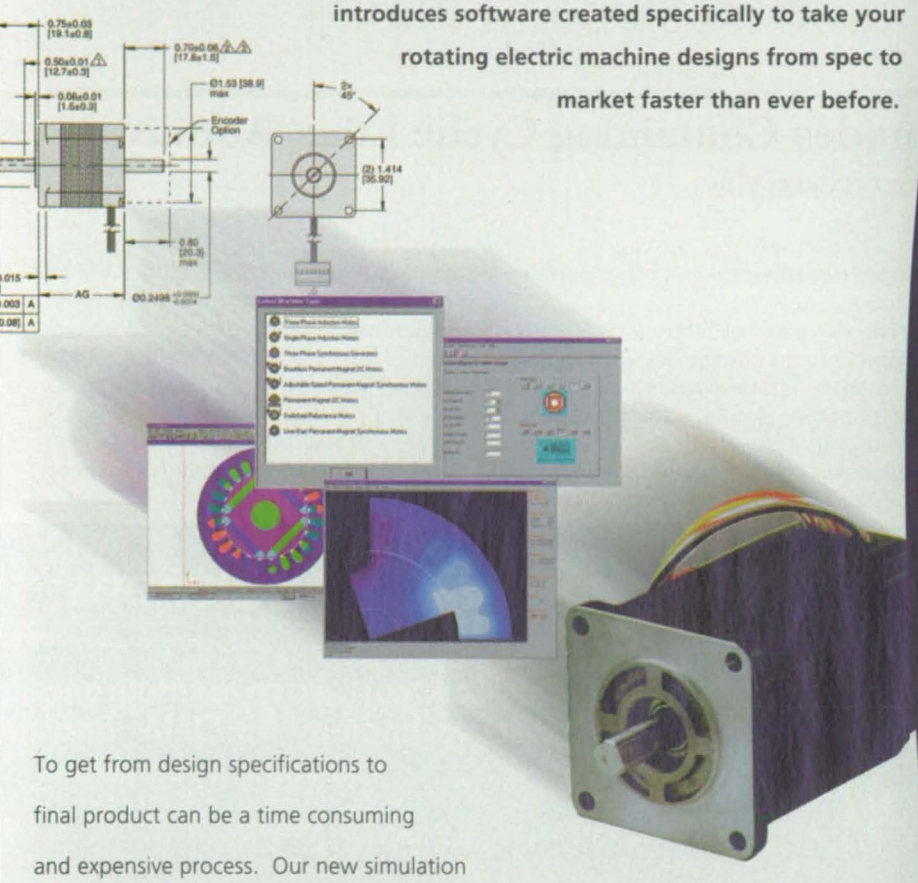

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out deteriorating and without polluting the nitrogen tetroxide. Reduction of the amount of water in MON-3 reduces corrosion; reduced corrosion rates reduce PRCS failures. Not only do reduced corrosion rates increase the usable lifetimes of the space shuttle PRCS valves; they also increase the usable lifetimes of rocket engines, flight components, deep-space probes, and satellites while reducing failure rates. All of this naturally leads to significant reductions of costs.

Significant cost savings are already being realized at Kennedy Space Center, White Sands Test Facility, and Vandenberg Air Force Base, where Molecular-Sieve Type 3Å is in use. This revolutionary molecular-sieve material could also be put to use by the manufacturer of MON-3 oxidizers to satisfy procurement specifications; moreover, it could be transferred to a commercial line in its existing form, or with minor modification, for use in removing impurities from other industrial fluids.

Molecular-Sieve Type 3Å embodies a major improvement of the state of the art. Production of highly purified MON-3 would increase orbital times for satellites and deep-space probes. Reduction of system weights owing to better protection against corrosion would increase payloads and profits. The largest single benefit that can be attributed to the use of Molecular-Sieve Type 3Å is reduction of corrosion with consequent increases in reliability of affected systems. Not only will increased reliability significantly affect the U.S. space program, but its effects will be felt in other government industries and in the commercial world as well — indeed, in any industry in which MON-3 oxidizers are used and system reliability is important.

This work was done by Ari Ben Swartz and Louis A. Dee of the Rockwell Space Operations Company for **Johnson Space Center.**
MSC-22763

Composite Graphite Anodes Containing Cyclic Ether Additives

Lithium-ion cells can be made more rechargeable.

Lyndon B. Johnson Space Center, Houston, Texas

Scientists have developed a type of composite graphite anode that will benefit the U.S. space program and private industry by increasing the rechargeability of lithium-ion batteries. Rechargeable lithium-ion batteries, which are used on the space shuttle and Space Station, are also used in laptop computers, portable telephones, and other portable electronic devices.

The chemistry of lithium-ion batteries differs from the chemistries of other types of batteries. The development of the present composite graphite anode addresses one aspect of this chemistry: In a typical lithium-ion cell, a graphite anode is part of a composite that also includes a solid polymer electrolyte of composition [polyacrylonitrile (PAN)-ethylene carbonate (EC)]/[propylene carbonate (PC)-$LiPF_6$]. Reduction of PC on graphite occurs at a potential of about 0.8 V versus Li^+/Li, whereas intercalation of Li into graphite takes place at potentials between

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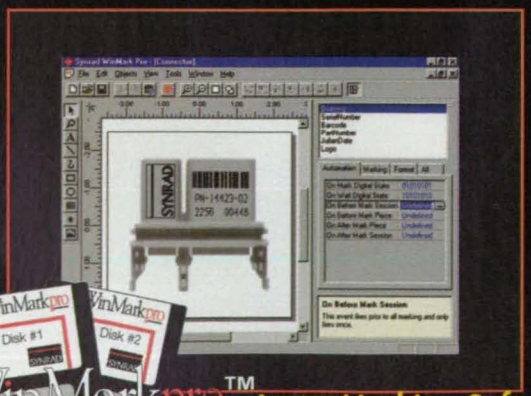

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0.1 and 0.0 V versus Li^+/Li. When, as a result, the PC becomes extensively reduced, there remains little reversible capacity for intercalation of lithium; in other words, the cell loses capacity for recharging.

The scientists found that by adding cyclic ethers to graphite-electrode/[(PAN-EC)/(PC-$LiPF_6$) solid electrolyte] composites, they were able to mitigate the reduction of PC, thereby preserving high capacities for reversible intercalation of lithium into the graphite electrodes. Through their design of the composite graphite anode, these scientists achieved a reversible capacity of close to 1 mole of lithium per six moles of carbon — a remarkable degree of reversibility.

Reversible composite graphite anodes based on this concept can be expected to prove beneficial to the U.S. space program and, indeed, to any commercial venture in which rechargeable lithium-ion batteries are used. While rechargeable batteries based on other chemistries are already available, rechargeable lithium-ion batteries fill a unique niche and are highly marketable. The development of highly rechargeable composite graphite anodes could contribute significantly to success in the future development of portable electronic devices and of systems in which those devices are used.

This work was done by Zhiping Jiang, Kuzhikalail Abraham, and Mohamed Alamgir of EIC Laboratories, Inc., for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

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

Zhiping Jiang
EIC Laboratories
111 Downey Street
Norwood, MA 02062

Refer to MSC-22789, volume and number of this NASA Tech Briefs *issue, and the page number.*

Polypyrrole and Polyaniline Doped With Lignosulfonic Acid

John F. Kennedy Space Center, Florida

Experiments have shown that electrically conductive polymers with water-soluble fractions can be synthesized by polymerization of pyrrole or aniline in the presence of lignosulfonic acid, which is a polymeric acid that can be derived relatively easily from the spent sulfite liquor byproducts obtained from processing of wood pulp into paper. In these syntheses, the lignosulfonic acid serves as both a dopant and a template for polymerization. Like other lignin derivatives, lignosulfonic acid can be photochemically and thermally cross-linked. The electrical conductivities of the polymers range from 10^{-6} to 10^{-3} $S \cdot cm^{-1}$. The combination of electrical conductivity, water-solubility, and cross-linkability provides additional versatility for the development of electrically conductive polymers for such applications as antistatic coating of fabrics and shielding electronic equipment against electromagnetic interference.

This work was done by Tito Viswanathan of the University of Arkansas at Little Rock for **Kennedy Space Center.** *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, Kennedy Space Center, (407) 867-6225. Refer to KSC-11940.*

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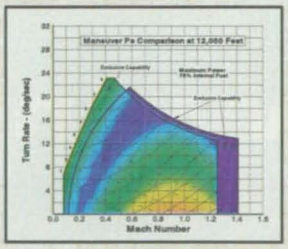

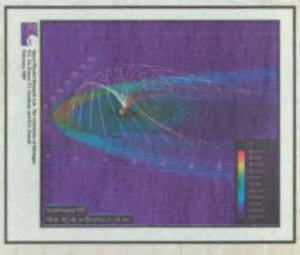

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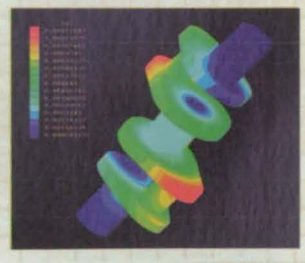

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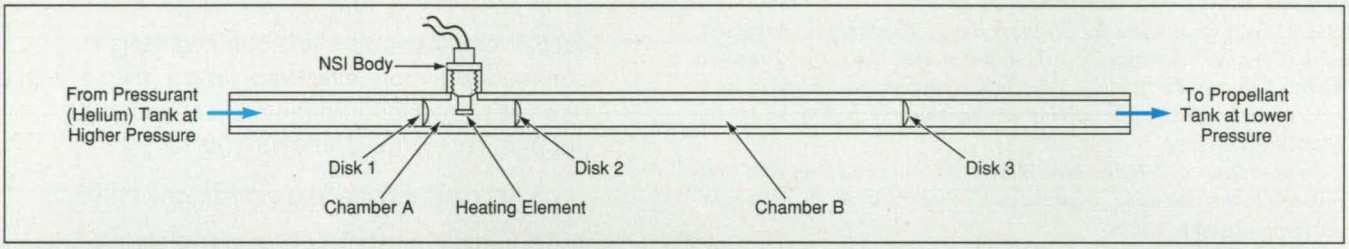
Leak-Free Pressurizing Valve

This one-time-opening valve would be an alternative to a pyrotechnically actuated valve.

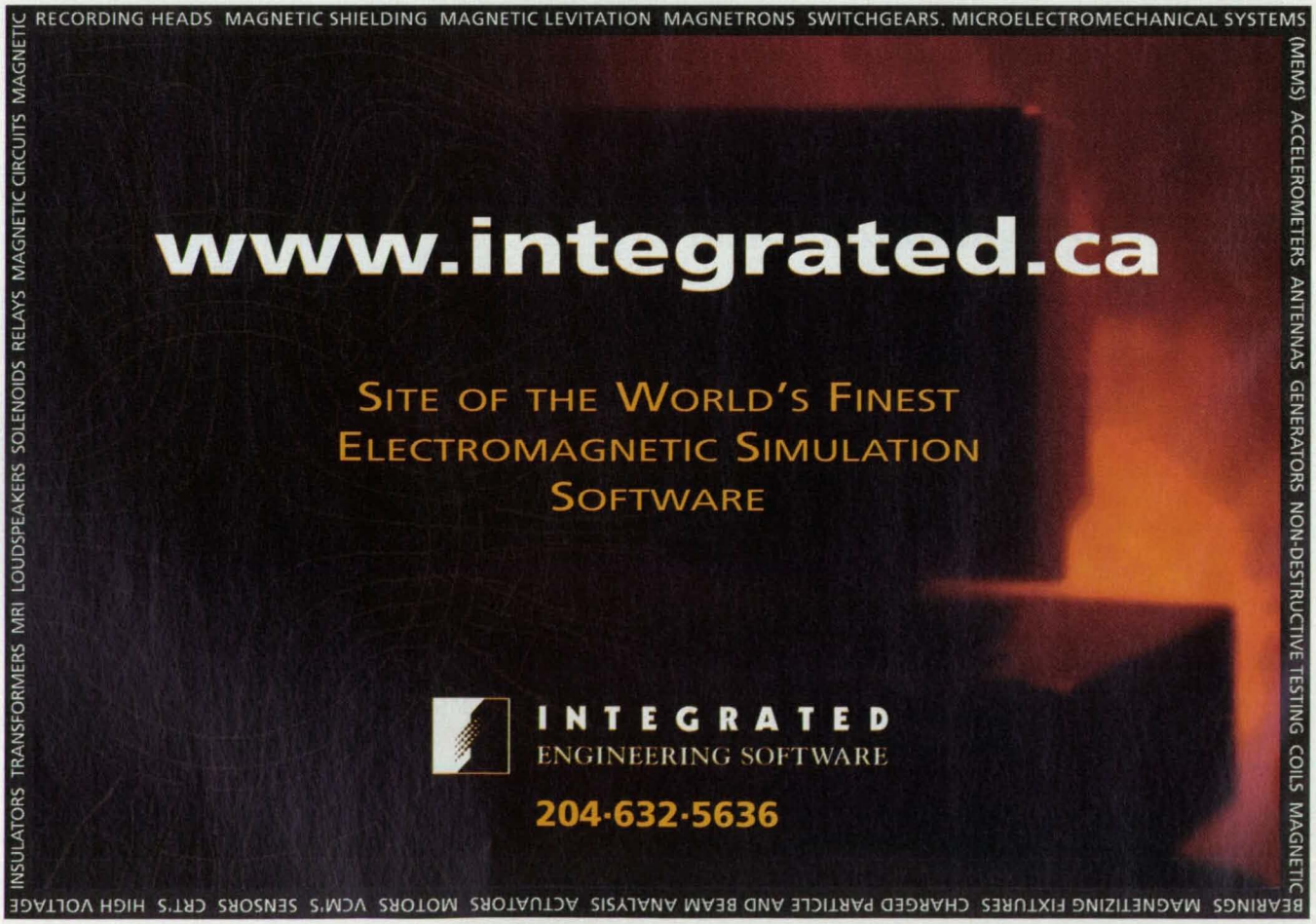
Lyndon B. Johnson Space Center, Houston, Texas

A leak-free valve has been proposed as a more reliable, less expensive, adaptable alternative to a one-time-opening, pyrotechnically actuated valve (pyrovalve). In the original intended application, the pyrovalve serves, before it is actuated, to isolate a pressurant gas (helium) from a propellant fluid aboard a spacecraft. Like a typical pyrovalve, the proposed valve would be triggered electrically, but unlike in the case of a pyrovalve, no pyrotechnic material would be present; all of the actuation energy would be supplied electrically and none pyrotechnically. Consequently, there would be no risk of premature detonation or of contamination of the pressurant gas by combustion products.

Because the proposed valve would not contain any pyrotechnic material, it would have an essentially unlimited storage life. The valve would be small, lightweight, and resistant to shock. It would be invulnerable to detonation by inter-



The **Disks Would Burst in Rapid Succession** (in the sequence 2,1,3) once the heating element was energized, allowing gas to flow from the higher-pressure to the lower-pressure side.



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nal discharge of static electricity, even if its wires were not short-circuited. It would have no moving parts, and could be designed to operate for a wide range of pressures. Unlike a pyrovalve, the proposed valve could be triggered multiple times in the event it failed to open on the first try. The design of this valve could be adapted to non-aerospace uses in systems in which there are requirements for highly reliable, one-time-opening valves; examples include fire-suppression systems, emergency power units for aircraft, and emergency cooling systems.

The valve (see figure) would contain a cascade of three rupture disks welded in place. The use of industry-standard welded, domed rupture disks would ensure leak-free operation. During assembly, chambers A and B sealed by the disks would be filled with the pressurant gas (helium in the original application) at different pressures. Chamber A would be filled to the same pressure as that of the pressurant tank. Chamber B would be filled to a lower pressure equal to that in the propellant tank. Prior to actuation of the valve, there would be no difference in pressure across rupture disks 1 and 3, but there would be a pressure difference across rupture disk 2.

Chamber A would contain an electrical heating element mounted on a leak-free electrical feedthrough [the particular feedthrough would be the non-pyrotechnic part of a pyrotechnic device called a "NASA standard initiator" (NSI)]. Actuation would be effected by applying electric current from a bank of capacitors to the heating element, causing the helium in chamber A to become heated and thereby causing its pressure to increase. Chamber A would be made small enough that the available electrical energy would be sufficient to heat and thus pressurize the gas to a level sufficient to burst disk 2; this level would lie at a pressure difference between 20 and 50 percent above the storage pressure difference across disk 2.

The expansion of gas immediately following the bursting of disk 2 would cause the pressure in chamber A to fall rapidly to value almost as low as that of the propellant tank. The expansion would also cool the gas and thus the heating element. This action would give rise to a large difference of pressure across disk 1, thereby causing disk 1 to burst. The resulting inrush of pressurant gas into chambers A and B would further cool the heating element and would give rise to a large difference in pressure across disk 3, thereby causing disk 3 to burst. The bursting of disk 3 would remove the last barrier, allowing the pressurant gas to flow to the propellant tank. The flow of pressurant gas would also complete the cooling of the heating element.

This work was done by Douglas G. Dobbin of Rockwell Space Operations Co. and Larry J. Bamford of Allied Signal Technical Services Co. for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
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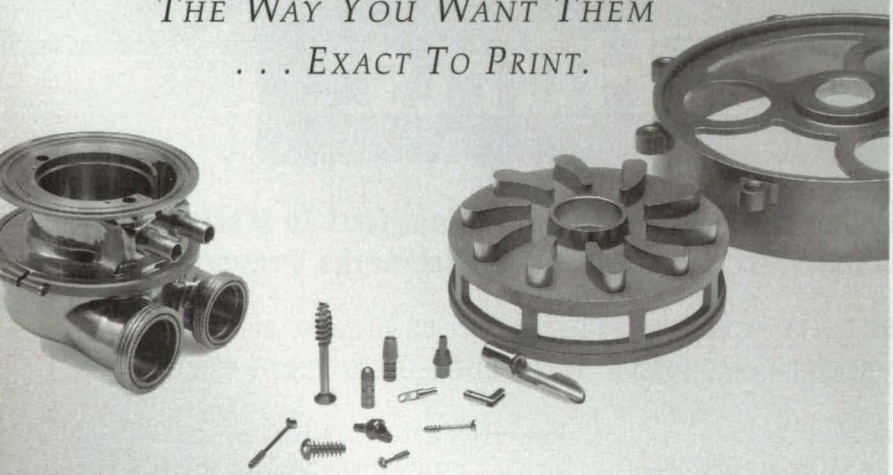

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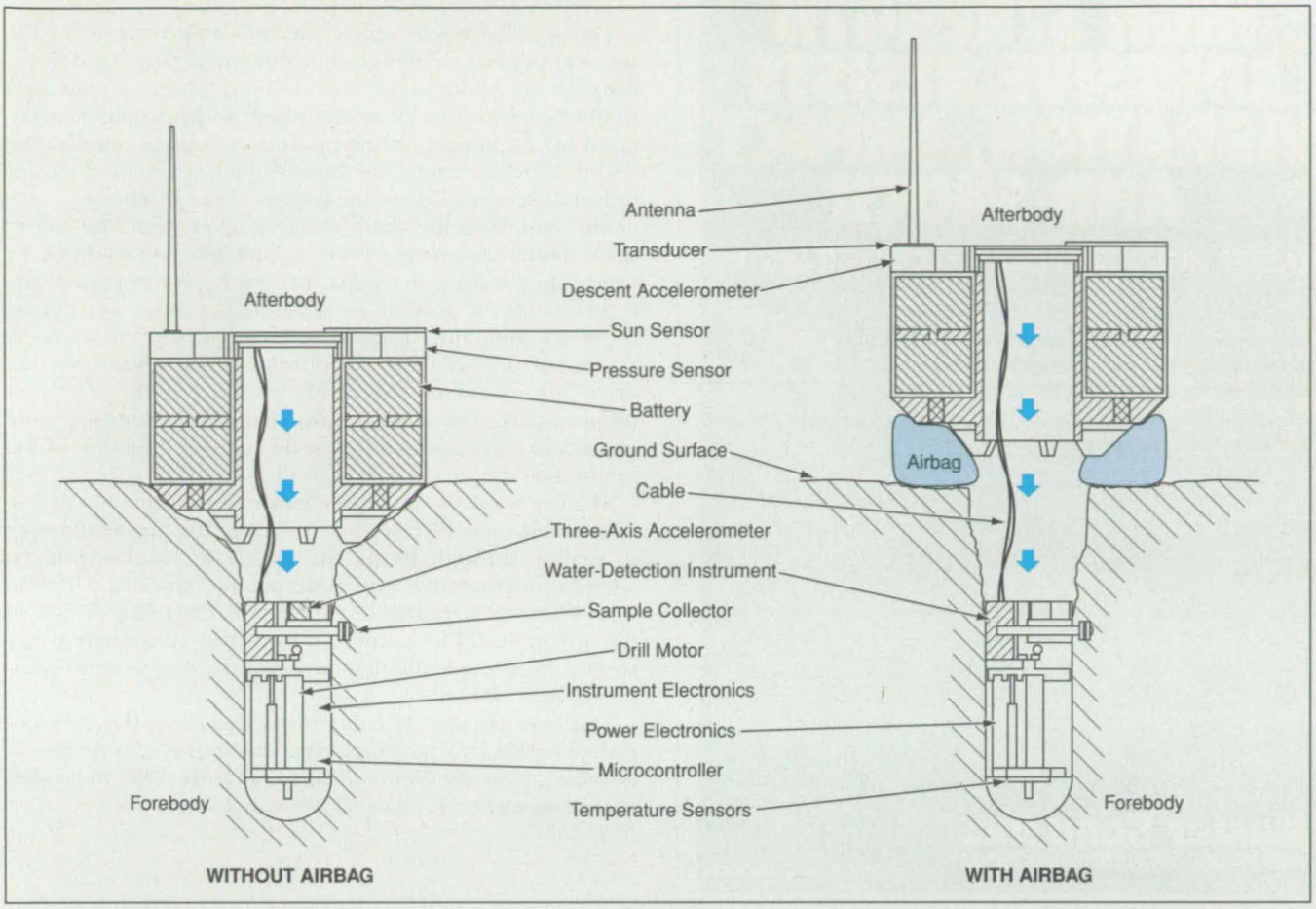
Afterbody Cushions for Instrumented Penetrator Projectiles

Impacts would be softened by miniature versions of automotive airbags.

NASA's Jet Propulsion Laboratory, Pasadena, California

Pneumatic cushions have been proposed for protecting the afterbodies of two-body instrumented soil-penetrator projectiles. These cushions would be, essentially, doughnut-shaped miniature



The **Airbag Would Be Inflated** milliseconds before impact, to reduce the magnitude of deceleration of the afterbody.

versions of automotive airbags, designed for rapid inflation upon impact.

The concept of the two-body instrumented soil-penetrator projectile was described in "Penetrator Projectile Tolerates Some Misalignment" (NPO-20295) *NASA Tech Briefs,* Vol. 22, No. 10 (October 1998), page 74. To recapitulate: In the original intended application, the projectile would be launched from a spacecraft to impinge on Mars, where it would sample the soil. The design of the projectile might also be adaptable to sampling materials in sand, soil, mud, snow, or ice in hostile or inaccessible environments on Earth. The two bodies of the penetrator would be (1) a forebody that would contain instrumentation and machinery needed to penetrate the ground and (2) an afterbody that would contain batteries, radio-communication circuitry, and those sensors that must not penetrate the ground. Prior to impact, the forebody would be stowed in a longitudinal cylindrical recess in the afterbody. Upon impact, a flange on the bottom of the afterbody would become braked upon contact with the ground. As the afterbody decelerated, the forebody would slide out of the recess, penetrating the ground underneath the afterbody. The forebody and afterbody would remain connected by a flexible cable that would pay out from the forebody during impact.

The forces generated by the expected deceleration (80,000 times normal Earth gravitational acceleration) could damage instrument components in the afterbody. The proposed scheme for pneumatic cushioning is intended to reduce the deceleration to a safe level. The scheme could be implemented with little modification of the basic penetrator design (see figure); one need only add the airbag with its inflation device and electronic inflation-triggering circuit.

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The scheme would utilize the following features of the original penetrator design and operation: During descent through the atmosphere, the forebody/afterbody assembly would be protected by an aeroshell, which would be shattered by the impact on the ground. A crash accelerometer would detect the impact of the aeroshell, which would occur only milliseconds before the impact of the forebody.

The output of the crash accelerometer would be fed to the inflation-triggering circuit, so that inflation could be accomplished during the short interval before impact of the forebody on the ground. At full inflation, the outer diameter of the doughnut-shaped bag would exceed the outer diameter of the afterbody. The inflated bag would hug the lower portion of the afterbody, cushioning the afterbody upon impact. The central hole of the bag would be large enough to let the forebody pass through on impact as in the original design.

The bag would be made of a fabric or combination of fabrics so that immediately after inflation, the bag would start to deflate through its pores. Optionally, vents could be added to increase the rate of deflation. Typically, deflation would be completed in less than 1 second. The design of the airbag would be optimized to provide the desired protection for the specific penetrator-probe design and operational environment.

This work was done by Julian Blosiu and Fotios Deligiannis of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
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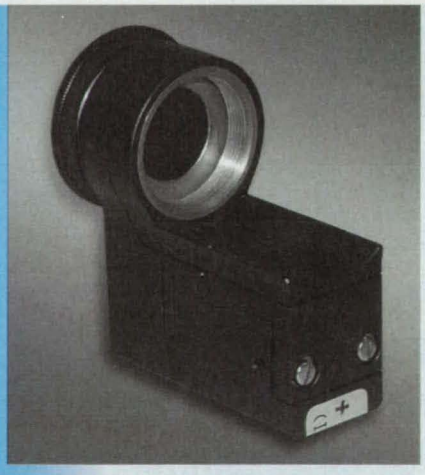

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For More Information Circle No. 424

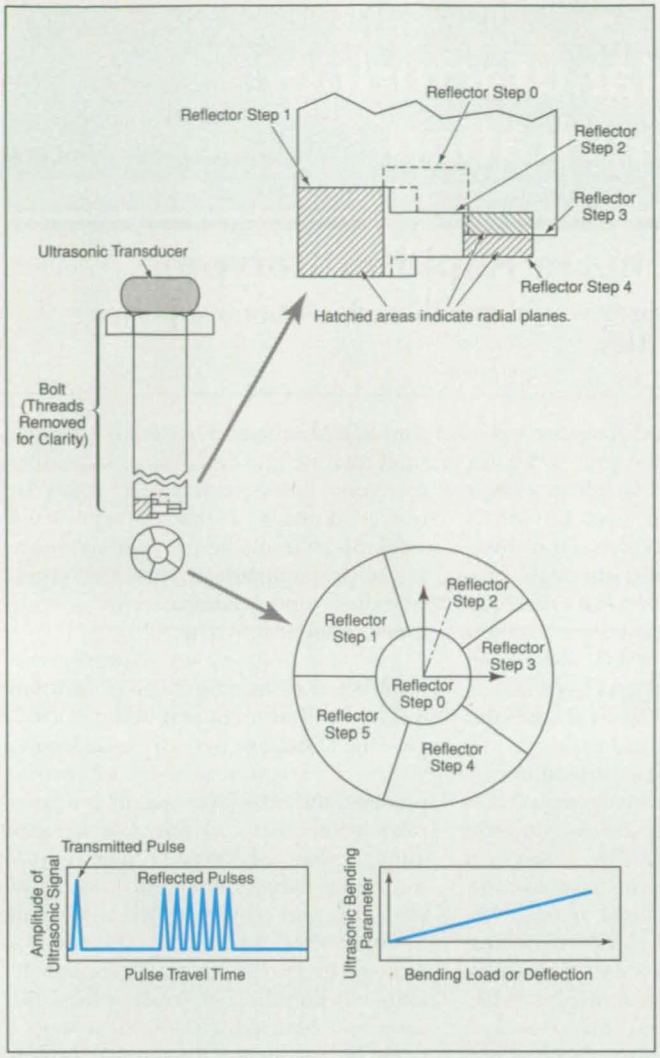
Ultrasonic Measurement of Bending of Bolts

Ultrasonic measurements are superior to strain-gauge measurements.

Lyndon B. Johnson Space Center, Houston, Texas

Work performed at Johnson Space Center has brought about a major improvement in the means for measuring the bending that occurs whenever stress is applied to a bolted joint. This major improvement is a measurement method based on ultrasonics. The strain gauges used heretofore in the space program in efforts to measure bending loads or deformations in bolted joints have proven inadequate, in that it has been difficult to perform accurate measurements by use of them. The art of ultrasonics offers an alternative and superior means of performing such measurements; as such, it can be expected to contribute to cost savings and increased safety, not only in the space program but also in military and commercial applications — wherever there are stressed bolted joints that could pose bending hazards. The ability to measure stresses in joints accurately can be expected to contribute to understanding the mechanisms that produce stress failures in critical joints and thereby contribute to the success of efforts to design safeguards that will lower risks to both vehicles and personnel.

In the present method, an ultrasonic transducer is bonded to one end (normally, the head end) of the bolt of interest. The other end (normally, the tip of the threaded shank) is modified to a stepped end; that is, one machines that end to form sector-of-circle facets (steps) perpendicular to the longitudinal axis, each located at a different axial



An **Ultrasonic Pulse Is Reflected** from the steps at different times. The pulse travel times change when the bolt is bent, and can be processed to determine the bending load.

position (see figure). The transducer generates an ultrasonic pulse, which travels to and is reflected by the steps. The reflection from each step becomes a separate pulse, each of which returns to the transducer at a different time, depending on the position of the step and thus the effective ultrasonic path length. The reflected pulses received by the transducer are converted to electronic signals, which are processed by associated instrumentation to obtain a time trace of the ultrasonic signal and to extract information on the timing of the reflections.

When the bolt is subjected to bending, there occur geometry- and stress-related changes in the effective speed of sound and path lengths for reflections from some or all of the steps. These changes give rise to changes in pulse travel times. In the processing of the ultrasonic signals, the changes in pulse travel times are used to compute an ultrasonic bending parameter, which can be used to calculate the bending deflection and/or load. The proportionality between the bending parameter and the bending deflection and/or load is obtained by correlating various values of the ultrasonic bending parameter with known bending loads applied in calibration measurements.

This work was done by Ajay M. Koshti of Rockwell International for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
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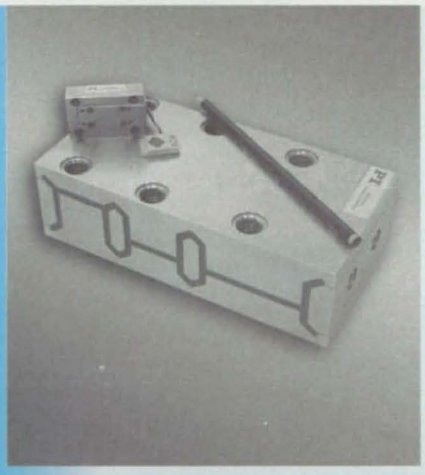

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Manufacturing/ Fabrication

Improvements in Rapid Prototyping

Molecular structures would be tailored to obtain superior structural properties.

NASA's Jet Propulsion Laboratory, Pasadena, California

Several improvements have been proposed for the fabrication process known as "rapid prototyping." In this process, a model or prototype of a solid object is built up by controlled ejection of molten polymeric material through programmed orifices to form patterned layers. The second layer is deposited on top of the first layer, the third layer is deposited on top of the second layer, and so forth, until the stack of layers reaches the desired final thickness and shape.

In rapid prototyping according to current practice, the polymeric material is one that has low molecular weight, little or no cross linking, and few (if any) active functional groups in its molecular structure. Such a material is used because (1) it lends itself readily to melting and solidification over a narrow temperature range and (2) when molten, it has a relatively low viscosity that makes it amenable to passage through small orifices. The disadvantage of such a material is that the low molecular weight and absence of cross linking result in a model that has very little strength; this characteristic limits the utility of models fabricated by rapid prototyping.

The first proposed improvement would be the addition of photoactive functional groups to the polymer. The second proposed improvement — a concomitant of the first — would be provision of a radiant source to blanket the model with ultraviolet light to activate the photoactive functional groups. The photoactive functional groups and their locations in the molecular structure of the polymer would be chosen so that upon exposure to ultraviolet light of selected wavelengths, the molecular structure would become lengthened and cross-linked in such ways as to impart greater strength and other structural benefits.

In rapid prototyping incorporating the first and second improvements, each layer of the photoactive-modified polymer would be printed in the same manner as in current practice. However, prior to deposition of the next layer, each layer would be exposed to the ultraviolet illumination to obtain a higher-molecular-weight, cross-linked molecular structure. Subsequent layers would be treated similarly, so that the completed solid model would be stronger and more useful, in comparison with the corresponding model fabricated by conventional rapid prototyping.

The first and second improvements would offer other advantages in addition to increased strength and utility of models. One advantage pertains to molecular weight: In a typical instance of current practice, the molecular weight is a compromise between (a) one that is large enough that the polymer has at least minimum acceptable hardness and strength and (b) one that is small enough that when the polymer is molten, its viscosity is small enough to allow ejection through small orifices. Because the desired high molecular weight could be obtained in the photoactivation step, the proposed first and second improvements would make it possible to start with a base polymer of lower molecular weight and thus lower viscosity; this, in turn, would make it possible to use smaller ejecting orifices, thereby improving the reliability and increasing the level of detail achievable in the deposition of each layer.

Another improvement — also made possible by the first and second improvements — would be the addition of nonreactive plasticizers and/or solvents to the base polymer. Solvents could be used to enhance ejection. Solvents could be removed by heating each layer immediately after deposition and before exposing it to ultraviolet light. Plasticizers could be used, along with suitable amounts of molecular lengthening and cross linking, to tailor the mechanical properties of the finished model.

This work was done by Frank Hartley and Steve Bolin of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*

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For More Information Circle No. 503

Efficient Ionizer for an Array of Mass Spectrometers

Electron- and ion-beam optics are designed to maximize generation and extraction of ions.

NASA's Jet Propulsion Laboratory, Pasadena, California

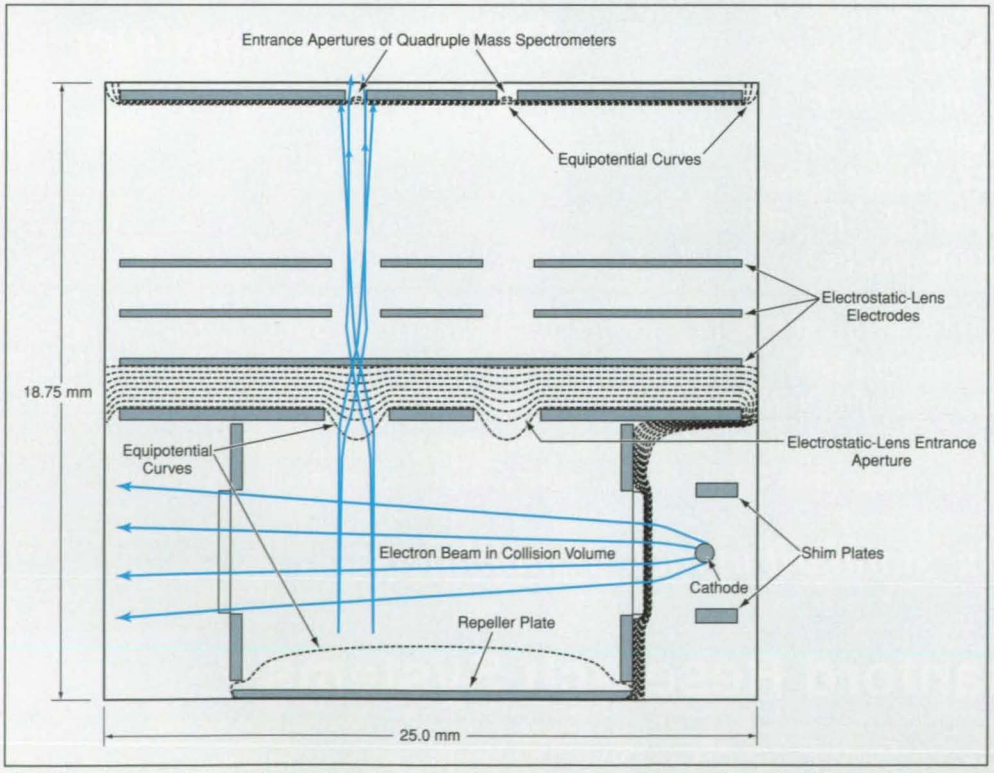
An electron-beam ionizer has been designed to deliver ions to the entrance apertures of nine miniature quadrupole mass spectrometers in an array. A similar electron-beam ionizer could also be designed for an array of more or fewer mass spectrometers. Principal issues that had to be addressed in formulating the design were (1) generation of a collimated, suitably dimensioned electron beam that passes near all the entrance apertures so that ions are generated for each aperture at a sufficient rate; (2) application of suitable extraction potentials to nearby, suitably configured electrodes so that a large flux of ions can be extracted from the electron-beam region wherein the analyte is ionized; and (3) choosing a configuration and potentials for a system of electrostatic lenses (that is, assemblies of electrodes and apertures) to transport and focus the extracted ions into beams of desired diameters and kinetic energies that impinge on the entrance apertures of the mass spectrometers at the desired angles.

The design process began with the initial choice of an ionizer geometry compatible with the input-beam requirements and other aspects of the design of the miniature mass-spectrometer array, and with regard to the locations of such fixtures as grounded screws, nuts, and posts. A commercial software package was then used to compute the performance of the ionizer and iterate upon the design. The computational modeling involved taking account of phenomena that are difficult to visualize, including electron space charge, the effect of the space charge on ion trajectories, and effects of electrostatic fringing fields.

The final design reached after iteration provides for a space-charge-limited electron beam that passes near all the spectrometer entrance apertures, optimal extraction of ions via penetration of the electric fields of the electrostatic lenses into the electron-beam ionization region, and optimal focusing of the extracted ions by the electrostatic lenses, which are arrayed in a compact system.

The figure presents a cross section of the ionizer in a plane that contains two of the spectrometer entrance apertures. Electrons are emitted from the cathode, which is a straight wire perpendicular to the page. The two shim plates help to collimate the emitted electrons into a ribbon beam. The beam passes through a collision volume (the ionization region) and makes its exit to the left. Within the collision volume, the electron beam knocks electrons off analyte molecules, which thereby become positive ions.

Two electric fields act together to extract ions from the collision volume into the electrostatic lenses above the collision volume. One of these electric fields is that generated by the repeller plate at the bottom. The other field is the one that is generated by the lowermost electrostatic-lens electrode and that penetrates the collision volume via the electrostatic-lens entrance apertures. The electrostatic lenses focus the extracted ions into beams that impinge on the mass-spectrometer entrance apertures with the desired characteristics as described above. The focusing action occurs over a range of nascent ion trajectories and energies in the collision volume.



The **Electron-Beam Ionizer** is integrated with electrodes for extraction of ions and focusing the ions into beams that impinge on the entrance apertures of quadrupole mass spectrometers.

This work was done by Ara Chutjian, Murray Darrach, and Otto Orient of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to NPO-20252, volume and number of this NASA Tech Briefs *issue, and the page number.*

Analyzing Rocket Exhaust by Atomic-Absorption Spectroscopy

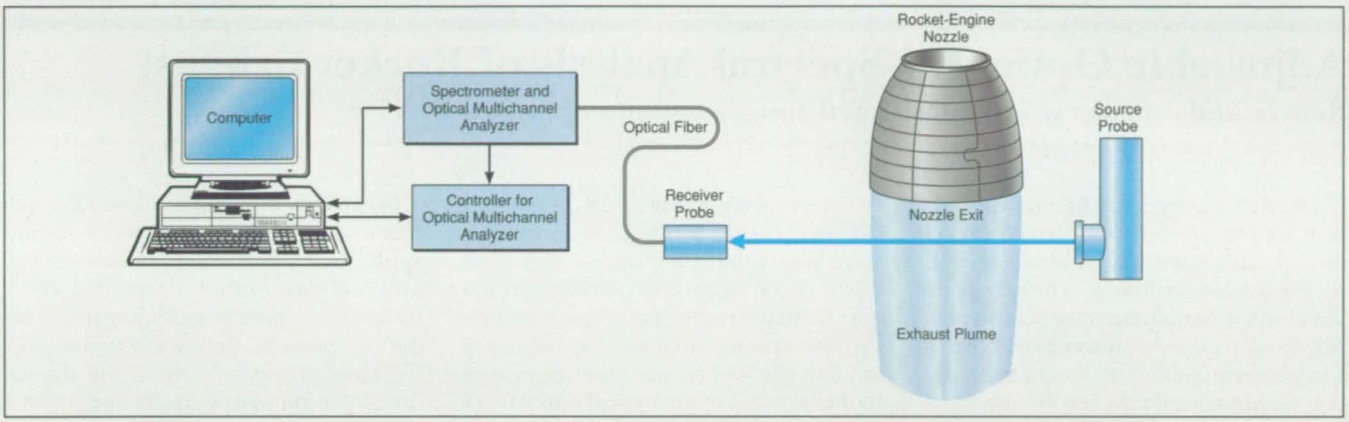
To save time and money, instrumentation was assembled from commercially available parts.

Stennis Space Center, Mississippi

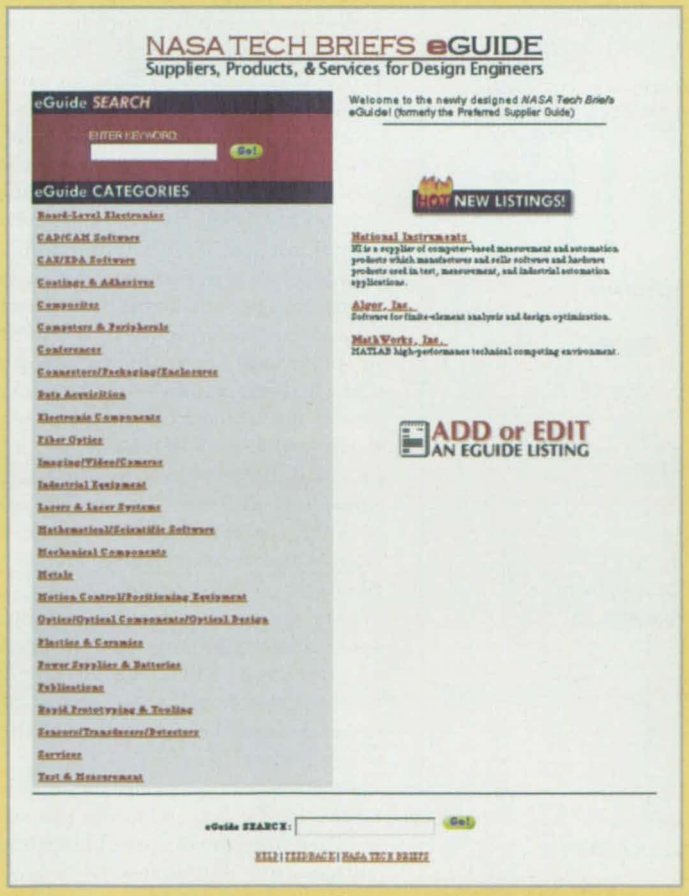
A computer-controlled instrumentation system has been developed for use in measuring concentrations of various atomic species in the exhaust gases of a space-shuttle main engine on a test stand. The system is based on established techniques of atomic-absorption spectroscopy (AAS). Although the design of the system is specific to this rocket-engine-testing application, it may be adaptable to other applications that involve similar geometry, physical conditions, and chemical constituents of flowing gases.

To save time and money, the system was constructed largely from commercial equipment used previously in atomic-emission spectroscopy (AES). (The reason for choosing AAS instead of AES is that under the flow conditions in the specific application, the temperatures are too low to obtain adequate optical emission from the atomic species of interest.)

The elements Cr, Fe, Ni, Co, Cu, and Ag are introduced into the rocket exhaust through wear/erosion of the engine. The system schematic includes a source probe that generates an optical emission spectrum characteristic of the



This **Instrumentation System** measures the absorption spectrum of rocket-engine exhaust to determine concentrations of atoms eroded from the engine.



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atomic species expected to be entrained in the rocket exhaust. The source probe contains a multielement hollow-cathode lamp containing the above elements plus neon as a fill gas and a collimating lens. Unlike traditional AAS systems, which chop the source signal to enable correction for background fluctuations and attenuation, the Stennis system ratios absorbing to nonabsorbing spectral lines. This method allows data to be continuously acquired and displayed.

The source probe is aligned so that the optical signal passes through the center line of the exhaust plume downstream from the rocket-engine nozzle where it is collected by the receiver probe. As the beam passes through the exhaust plume, metallic contaminants in the plume will alter the transmitted spectrum by absorbing light at specific wavelengths inherent to each atomic species of interest. The receiver probe collects the resulting signal, where internal optics transfer the signal to an optical fiber. The optical fiber transmits the signal to the detector/spectrometer assembly, where the signal is both dispersed into its component wavelengths and the signal levels are measured. An optical multichannel analyzer reads the data from the detector and sends the raw data to a remote computer for processing and near-real-time display.

This work was done by Gregory P. McVay of Lockheed Martin for **Stennis Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
SSC-00062

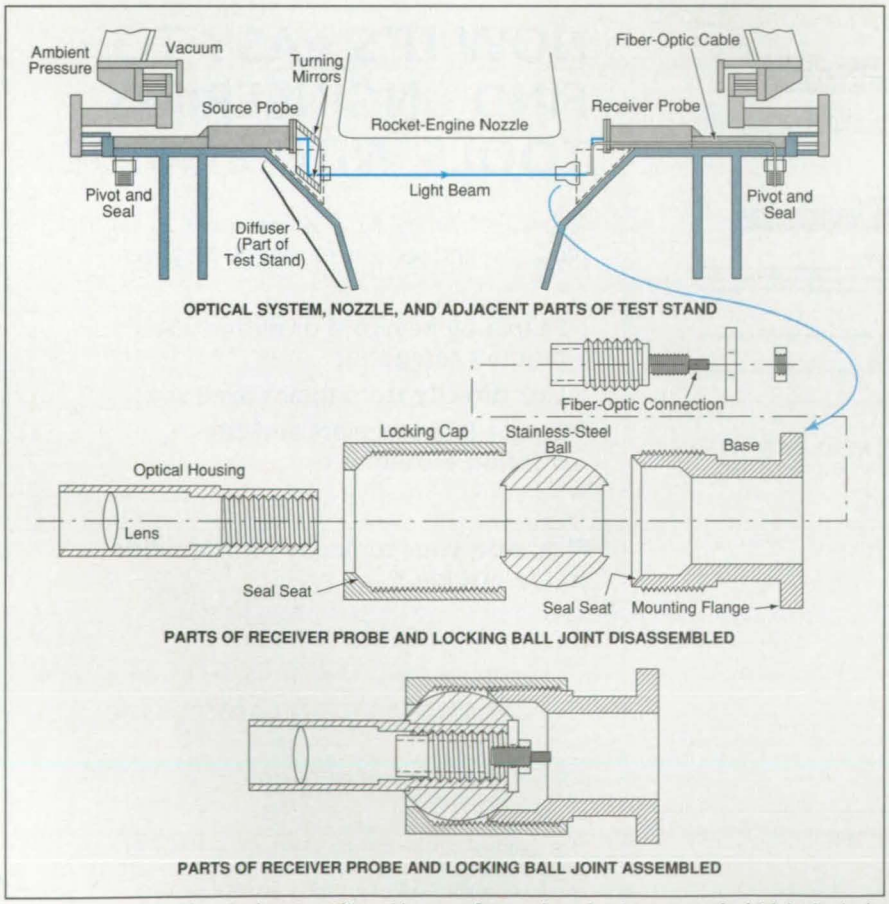
Adjustable Optics for Spectral Analysis of Rocket Exhaust

Source and receiver probes are aimed along a common line of sight.

Stennis Space Center, Mississippi

The figure presents additional information on the optics of the atomic-absorption-spectroscopy (AAS) system described in the preceding article. The optics include (1) a periscopic optical subsystem for access to a measurement optical axis in a plane different from that of the input and output optical axes and (2) mechanical and optoelectronic features for aligning the input and output optics.

To recapitulate: the AAS system includes a source probe that contains a lamp plus collimating optics, and a receiver probe that contains collection optics. To make it possible to perform absorption spectral analysis, it is necessary to align the source and receiver probes so that the axis of the optical signal from the source probe coincides with the optical axis of the receiver probe.



The **Source and Receiver Probes Are Aligned** by use of several mechanisms, one of which is the locking ball joint on the receiver probe, shown in the detail view.

Because of design considerations specific to the original rocket-engine-testing application, the source and receiver probe bodies must be mounted on a plane that coincides approximately with the exit plane of the rocket-engine nozzle, while the optical axis for the absorption measurements must lie in a plane 4 in. (≈10 cm) downstream from the exit plane. The source probe, which requires a large aperture to accommodate the spectral lamp, uses a two-mirror periscopic assembly to produce the required downstream offset. The receiver probe uses an optical fiber to produce the offset.

Since the environment inside the diffuser is a vacuum, the point where each probe penetrates the diffuser must provide both a seal and serve as the primary mount for the probes. Directional adjustments of the probes pivot at these points and are mechanically limited angular adjustments of 15° in the horizontal plane and 3° in the vertical plane. The ideal optical axis would be a line between the two pivot points displaced downward 4 in. (≈10 cm). However, mechanical obstructions in the diffuser make this difficult. To compensate, a locking, sealed gimbal mount that houses the receiver optics and optical fiber interface is attached to the input end of the receiver probe. The gimbal, which allows a 30° angular adjustment in any direction, allows the alignment of the optical axis of the receiver to be independent of the orientation of the receiver body.

Adjustment is performed in two stages. In the first stage, the probes are adjusted until the beam of light from the source probe illuminates the face of the gimbal locking cap. In the second stage,

a laser is operated in a back-lighting arrangement to generate a beam of light that emerges from the input aperture of, and marks the optical axis of, the receiver probe; the receiver probe is adjusted until the laser beam enters the aperture of the source probe.

The principal innovative feature of the system is the locking ball joint in the receiver probe. For a previous version of the system, which did not include the ball joint, it was necessary to alternately adjust and secure one probe and then the other, repeatedly, in an iterative cycle necessitated by dependence of the target alignment angles of each probe on the adjustment of the other probe. The locking ball joint reduces this dependence and thereby aids the alignment process.

This work was done by Gregory P. McVay of Lockheed Martin for **Stennis Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. SSC-00066*

Thickness-Independent Ultrasonic Characterization of Tubes

This single-transducer technique was previously applied to plates only.

John H. Glenn Research Center, Cleveland, Ohio

A technique for ultrasonic characterization of plates has been extended to tubes and curved structures in general. In this technique, as explained in more detail below, one performs measurements that yield a thickness-independent value of local through-the-thickness speed of sound in a specimen. From such measurements at numerous locations across the specimen, one can construct a map of velocity as a function of location. The gradients of velocity indicated by such a map indicate through-the-thickness-averaged microstructural parameters that affect the speed of sound. Such parameters include the pore volume fraction, mass density, fiber volume fraction (in the case of a composite material), and chemical composition.

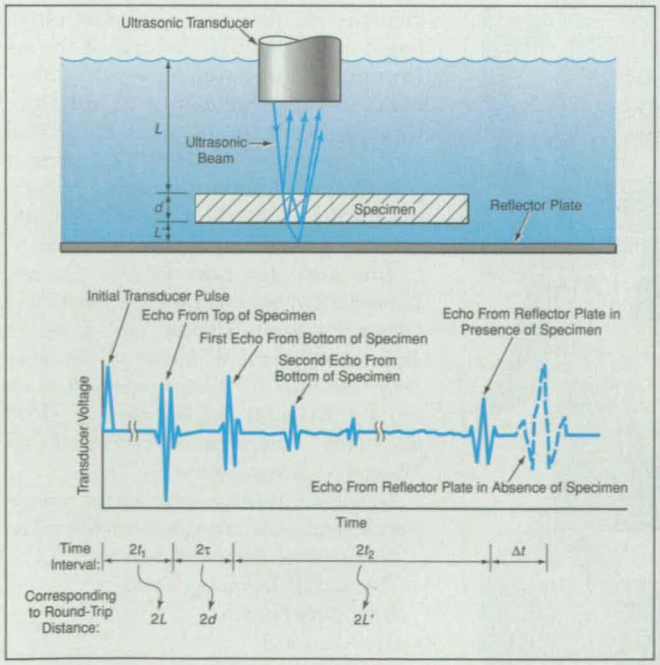


Figure 1. **Ultrasonic-Pulse/Echo Time Intervals** are measured in the absence and in the presence of the specimen. These intervals are used to calculate a thickness-independent value of through-the-thickness speed of sound in the specimen.

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Figure 1 schematically depicts the technique as applied to a plate specimen. An ultrasonic transducer is placed in a tank of water at a fixed distance above a horizontal reflector plate. The transducer is operated in a pulse/echo mode, and the round-trip travel times for ultrasonic pulses are determined from the intervals between transmitted pulses and received echoes. At first, the pulse/echo interval for the first echo from the reflector plate is measured without a specimen present in the tank.

Next, a plate specimen is placed in the tank, approximately parallel to the reflector plate. The plate can be moved horizontally to obtain measurements at various surface locations. At each location, one measures the interval (2τ) between the first echo from the top surface and the first echo from the bottom surface of the specimen, as well as the pulse/echo interval for the first echo from the back surface of the specimen. These measurements can then be used to calculate the local through-the-thickness speed of sound (V) in the specimen from the thickness-independent right side of an equation derived from the basic equations for the pulse/echo intervals. The equation is $V = c[(\Delta t/2\tau)+1]$, where c is the known speed of sound in water and Δt is the difference between the reflector-plate pulse/echo intervals without and with the specimen present.

In an apparatus used to apply the technique to a tubular specimen, the specimen is mounted on a horizontal turntable in a water tank, with its axis vertical and coincident with the turntable axis. A machined metal reflector plate narrow enough to fit within the inner diameter of the specimen is suspended vertically from above and positioned inside the specimen about 1 cm from the inner tube wall. A horizontally oriented ultrasonic transducer is positioned outside the specimen, facing the reflector plate. Pulse/echo measurements are taken in basically the same manner as for plate specimens. The transducer is translated vertically to obtain measurements at various axial positions (e.g., increments of 1 mm) and the turntable is rotated to obtain measurements at various azimuthal positions (e.g., increments of 1°).

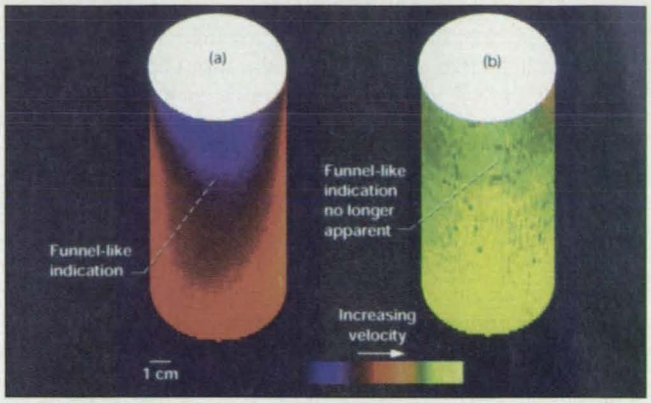

Figure 2. **Non-Thickness-Independent Versus Thickness-Independent Velocity Maps** for silicon nitride tube.

The technique has been demonstrated in experiments on tubular specimens of mullite (silica/alumina), a polymer-matrix composite, a composite of SiC fibers in an SiC matrix, and a high-temperature-structural grade of silicon nitride. Although the turntable, specimen, reflector plate, and transducer should be aligned as nearly perfectly as possible and the specimen should approximate a perfect round tube, it was observed that in general, some misalignment and out-of-roundness can be tolerated; this is an advantage over peak-amplitude-based ultrasonic techniques in which measurements are altered drastically by refractive effects associated with out-of-roundness. The present technique made it possible to eliminate most of the effects of variations in tube-wall thicknesses upon velocity maps (through-the-thickness velocities as functions of axial and azimuthal positions), except that edge effects associated with discontinuous changes in thickness were not eliminated completely. In the case of the silicon nitride tube (see Figure 2), differences between velocities at different locations were found to be correlated with differences between densities and pore volume fractions revealed by x-radiography and destructive metallographic analysis at those locations.

This work was done by Don J. Roth, Dorothy V. Carney, and George Y. Baaklini of **Glenn Research Center** *and James R. Bodis and Richard W. Rauser of Cleveland State University. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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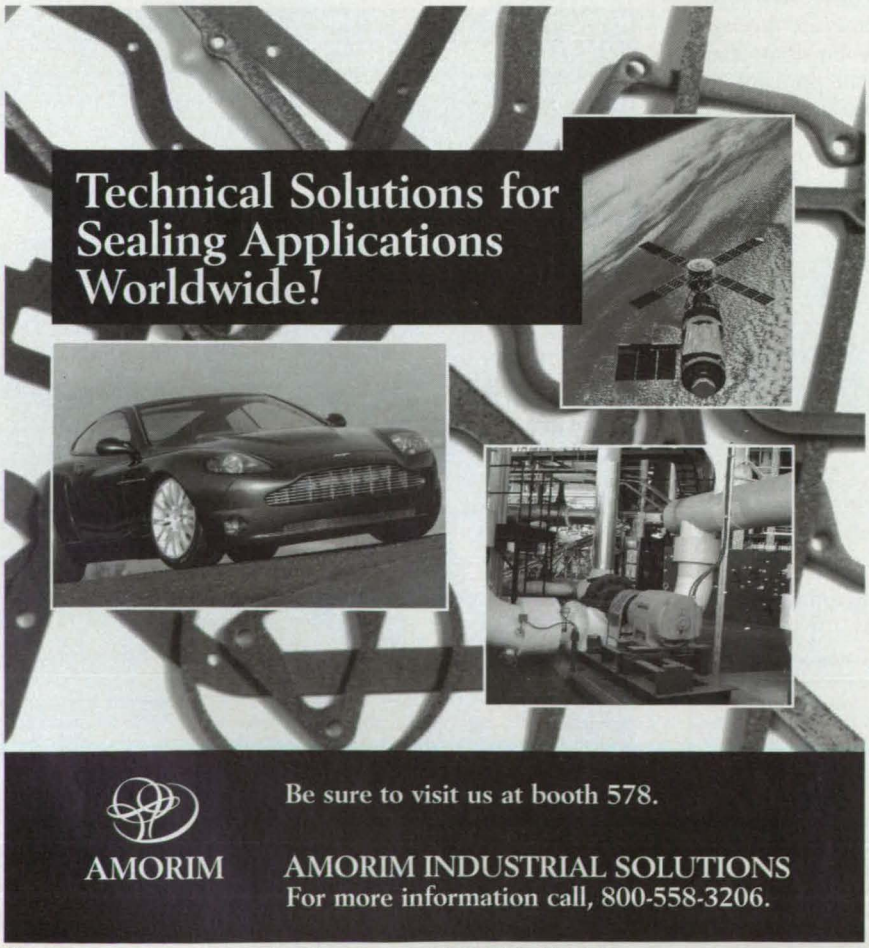

For More Information Circle No. 450

Detecting Metal Ions by Voltammetry Using Diamond Electrodes

Multiple ion species can be detected in a single voltammetric scan over a wide potential range.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have demonstrated the feasibility of detecting multiple species of toxic metal ions and other ions of interest dissolved in water, by means of voltammetry with electrically conductive artificial diamond electrodes. Diamond is attractive as an electrode material because it is highly chemically stable and exhibits the greatest useable range of potential (from +2 to –2 V in aqueous solution) than any known material.

The electrode material used in the experiments was a film of artificial diamond doped with boron to enhance electrical conductivity. The electrode film was grown on a molybdenum substrate by microwave plasma chemical vapor deposition from a gaseous mixture of methane and hydrogen in the presence of a disk of B_2O_3 as a dopant source. The diamond electrode was installed in an electrochemical cell along with an Ag/AgCl/NaCl reference electrode and a platinum-foil counter electrode. For each experiment, the cell was filled with a 0.5 M HNO_3 containing the dissolved ions of interest and the experiment was performed at room temperature.

Initially, the diamond electrode was conditioned at +1.5 V vs the reference electrode for 30 seconds and the system was allowed to attain equilibrium. Then the voltammetric measurements were performed. The measurement techniques implemented by use of the electrodes included (1) differential pulse voltammetry (DPV) at a scan rate of 36.36 of mV/s, pulse height of 25 mV, pulse duration of 25 ms, scan increment of 2 mV, and step time of 55 ms and (2) square-wave voltammetry (SWV) at a pulse height of 25 mV, frequency of 60 Hz, and scan increment of 2 mV.

Each voltammetric procedure typically consists of the following events: The diamond electrode is first held at an anodic potential at which either oxygen or some other gas evolves (which gas depends on the specific solution). The potential applied to the electrode is scanned in the cathodic direction to reduce the metal ions present in the solution, and the resulting currents are measured. As the potential approaches the value at which the ions of each species are reduced, current begins to flow, eventually reaching a maximum. If multiple species are present in the solution, then several peaks are observed, either separately or superimposed on a rising baseline current as the potential is shifted cathodically. The current peaks thus obtained correspond to the complete reduction of each metal ion species from the solution. By determining the total charge or current corresponding to each peak and by comparing this charge or current with that obtained in a calibration solution, one can calculate the concentration of each species of ion in the solution.

The data from the experiments showed that cations of three species (Hg_2^{2+}, Ag^+, and Cu^{2+}) can be detected in a single DPV or SWV scan over the range of potential from +0.799 to 0.1 V vs. a standard hydrogen electrode. This range is suitable for detecting the most toxic mercury ions in aqueous solutions.

It should eventually be possible to use diamond electrodes in place of conventional electrodes that contain mercury. It should also be possible to fabricate miniature diamond electrodes for electroanalytical detection of metal ions in ground water, plating solutions, and other aqueous solutions in hostile environments. The advantages of miniature diamond electrodes may include no need for stirring of electrolytes, low background currents, low double-layer capacitances, and no need to add supporting electrolytes or to cover electrochemical cells with neutral gases.

The conductive artificial diamond electrodes may be useful in analyzing Martian soil and sulfuric acid on Venus. Diamond is stable in sulfuric acid and can therefore be used to survey Venusian atmosphere and also to detect water.

This work was done by Rajeshuni Ramesham of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Physical Sciences category.*

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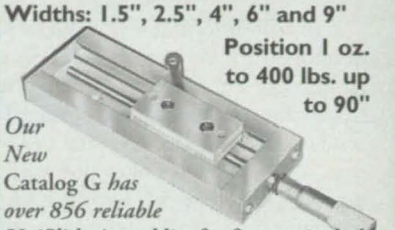

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Preconditioning the Helmholtz Equation for a 2-D Duct

Numerical solutions converge quickly to exact steady-state solutions.

Glenn Research Center, Cleveland, Ohio

A preconditioning technique has been developed for numerical solution of the Helmholtz equation as applied to the steady-state propagation of sound in a semi-infinite, two-dimensional (2-D) rigid duct. As explained below, the technique involves the use of two pseudo-time parameters in a finite-difference approximation of the equation that describes the propagation of sound. The use of these parameters makes the solution proceed much faster than in older transient- and steady-state-analysis-based numerical solution methods.

Figure 1 illustrates the 2-D duct geometry and the finite-difference mesh. The governing differential equation for the propagation of sound in nondimensionalized form is

$$f^2\phi'_{tt} = \phi'_{xx} + \phi'_{yy}$$

where f is a dimensionless frequency, ϕ' is a dimensionless transient potential or amplitude of the propagating signal, t is dimensionless time, x and y are the dimensionless coordinates indicated in the figure, and subscripts represent partial differentiation with respect to the noted variables. The spatial unit for nondimensionalization is the width (y dimension) of the duct; the temporal unit for nondimensionalization is the width of the duct divided by the speed of sound; and the unit for nondimensionalization of transient potential is the width of the duct multiplied by the speed of sound.

Suppose that either the transient potential comprises a single frequency or else the time dependence of the transient potential has been Fourier-transformed into the frequency domain. One can express the transient potential in the form

$$\phi'(x,y,t) = \psi(x,y)e^{-i2\pi t}$$

where $\psi(x,y)$ contains the spatial dependence of the Fourier component or single-frequency signal. Using this expression, one can transform the governing equation into the classical Helmholtz equation

$$\psi_{xx} + \psi_{yy} + \omega^2\psi = 0$$

where $\omega = 2\pi f$. In this formulation, the Fourier amplitude $\psi(x,y)$ is independent of time, as in the case of steady excitation of the duct with sound of a single frequency.

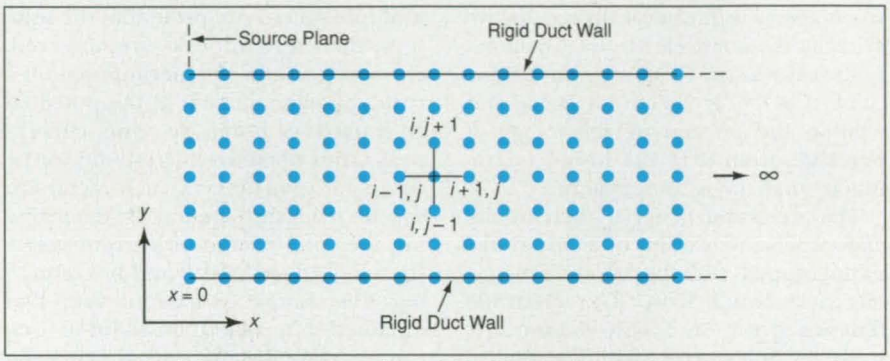


Figure 1. A **Semi-Infinite Rectangular Duct** is overlaid with Cartesian coordinates that are nondimensionalized in that lengths are expressed in units of the duct width along the y axis. The dots represent increments of a finite-difference mesh.

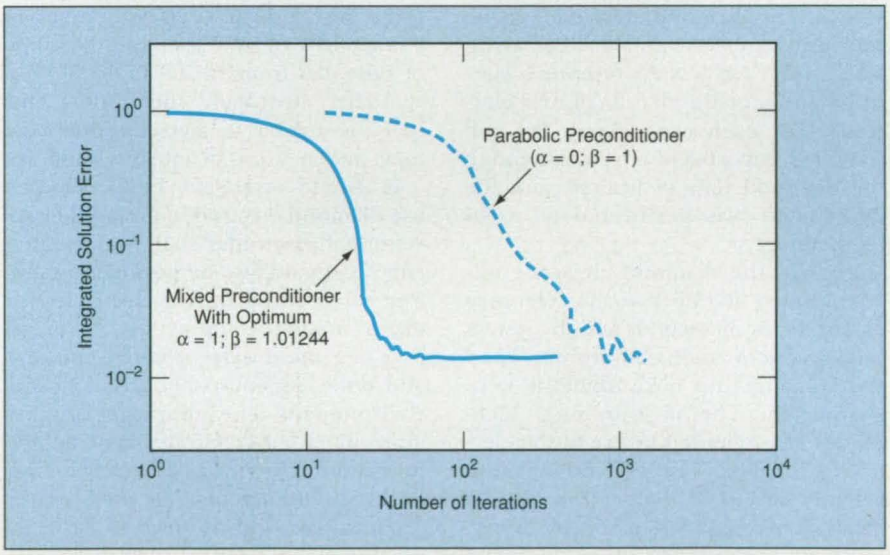


Figure 2. The **Integrated Solution Error** as a function of the number of iterations was computed for a test case of a plane sound wave of $f = 1$ propagating into the duct from the left, using a parabolic preconditioner and a mixed preconditioner with optimum α and β.

In general, what one seeks is the steady-state solution $\psi(x,y)$. This can be accomplished indirectly via a time-dependent formulation. The Helmholtz equation is preconditioned by expressing the transient potential in the form

$$\phi'(x,y,t) = \phi(x,y,t)e^{-i2\pi t}.$$

The time dependence in $\phi(x,y,t)$ can be used to represent what happens if the duct is initially quiet and then the source of sound is turned on at $t = 0$. In this formulation, the governing equation becomes

$$f^2\phi_{tt} - 2if\omega\phi_t = \phi_{xx} + \phi_{yy} + \omega^2\phi.$$

This is a preconditioned Helmholtz equation. In the steady state, $\phi'(x,y,t)$ becomes $\psi(x,y)$, causing the left side of this equation to vanish and thus causing reversion to the classical Helmholtz equation.

In previous research, it was found that in the special case (called the "parabolic" preconditioner) in which one neglects $f^2\phi_{tt}$, the numerical solution for $\phi'(x,y,t)$ converges to $\psi(x,y)$ for long times; that is,

$$\lim_{t\to\infty} \phi'(x,y,t) = \psi(x,y)$$

In effect, the finite-difference solution for the steady-state spatial dependence is found by iterating in time or pseudo-time.

One can generalize the preconditioned Helmholtz equation by incorporating pseudo-time parameters α and β as follows:

$$\alpha f^2 \phi_{tt} - \beta 2 i f \omega \phi_t = \phi_{xx} + \phi_{yy} + \omega^2 \phi.$$

The choice of α=0, β=1 yields the parabolic approximation. The more general case of $\alpha \neq 0$ and $\beta \neq 0$ (the "mixed" preconditioner) is the basis of the present technique. In formulating the finite-difference approximation of the preconditioned Helmholtz equation, one can choose nonzero values of α and β, in conjunction with increments of t, x, and y, to accelerate convergence to a steady-state solution. The acceleration achievable by use of optimum values of α and β is considerable; for example, in one test case (see Figure 2), the number of iterations needed for convergence with optimum α and β was about one-tenth the number of iterations needed to achieve the same degree of convergence with a parabolic approximation.

This work was done by Kenneth J. Baumeister of **Glenn Research Center** *and Kevin L. Kreider of the University of Akron. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16692.

Analytic Technique for Separation of Cochannel FM Signals

In the absence of noise, two signals can be separated perfectly.

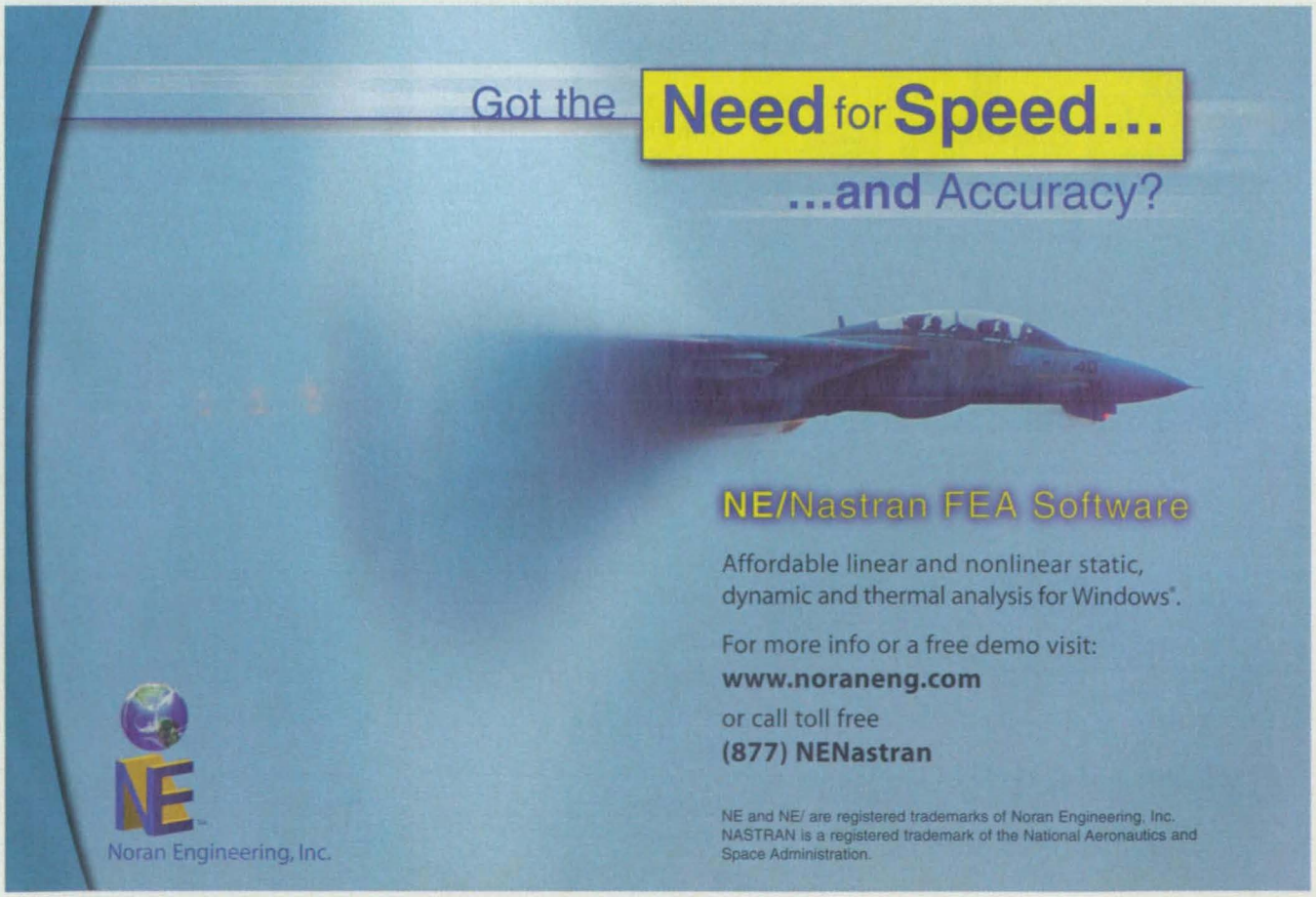
NASA's Jet Propulsion Laboratory, Pasadena, California

A digital processing technique for separating two cochannel frequency-modulation (FM) signals involves a partial algebraic solution that gives the phases of the two signals to within one of two possibilities, plus the use of a two-state trellis algorithm to trace the most likely correct sequence of possibilities. Other techniques for separating cochannel FM signals do not yield perfect separation under any circumstances; however, the present technique can yield perfect separation in the absence of noise.

The mathematical derivation of the technique begins with the complex-amplitude baseband representation of the pair of cochannel signals sampled at small time intervals. The total signal at the nth sampling interval is given by

$$r(n) = A(n)e^{j\theta(n)} + B(n)e^{j\phi(n)},$$

where A and B are the known magnitudes of the two signals, and θ and ϕ are the unknown phases of the signals. Initially, it is assumed that there is no noise and that A and B vary slowly, relative to θ and ϕ. The problem is to estimate θ and ϕ, given A, B,



and r. The equation above can be manipulated algebraically to obtain the following equations:

$$\theta = \arg\left[r\left(A + BD \pm jB\sqrt{1-D^2} \right) \right]$$

$$\phi = \arg\left[r\left(B + AD \mp jA\sqrt{1-D^2} \right) \right],$$

where

$$D = \frac{\left(\|r\|^2 - A^2 - B^2 \right)}{2AB}.$$

Thus, each of the two unknown phases has been determined to within two possible exact values.

For a single sample $r(n)$, there is no reason to prefer one of the two possibilities over the other. However, one can choose a sequence of solutions ...$\theta(n-2)$, $\theta(n-1)$, $\theta(n)$... and ...$\phi(n-2)$, $\phi(n-1)$, $\phi(n)$... that yields the bandwidth or the spectral density expected of the phase modulation. The sequence can be chosen with the help of a two-state trellis, in which the first state represents the solution

$$\theta = \arg\left[r\left(A + BD + jB\sqrt{1-D^2} \right) \right]$$

$$\phi = \arg\left[r\left(B + AD - jA\sqrt{1-D^2} \right) \right]$$

and the second state represents the solution

$$\theta = \arg\left[r\left(A + BD - jB\sqrt{1-D^2} \right) \right]$$

$$\phi = \arg\left[r\left(B + AD + jA\sqrt{1-D^2} \right) \right].$$

The sequence of solutions is traced through the trellis by use of a Viterbi algorithm. The solution chosen for each time step n is the one for which the instantaneous frequency disagrees minimally with a value predicted from values of instantaneous frequency chosen tentatively for previous time steps. In these computations, the instantaneous frequencies at the time steps are approximated by use of finite differences between tentative phase solutions. The predicted instantaneous frequency is the finite-difference value obtained by applying, to the phase samples, an mth-order (where m is an integer > 1) Levinson-Durbin linear predictive coder (LPC), which is a linear minimum-mean-squared-error estimator.

The metric for the trellis branch from the kth state at time n–1 to the lth state at time n is the square of [(the frequency for the hypothesized θ solution for state l at time n) – (the frequency predicted by the Levinson-Durbin LPC for time n on the basis of θ solutions on the path leading up to state k at time n–1)] plus the square of [the corresponding quantity for ϕ]. The Viterbi algorithm operates by computing all four branch metrics at each time step, storing an accumulated metric, and tracing backwards through the trellis to find the correct sequence.

This technique was tested in a computational simulation, using five test cases involving two FM voice signals sampled at a rate of 132.3 kHz and a 5th-order LPC. In all cases, the two signals were separated perfectly; that is, to within the floating-point precision of the computer. In other words, the correct branch of the trellis was chosen at every time step. Additional research would be needed to provide for the case in which estimation of A and B in situations in which they are unknown, and to determine whether the technique is robust in the presence of noise.

This work was done by Jon Hamkins of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
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Books & Reports

Tribological Characterization of Solid Surfaces

Reports labeled as chapters 2, 3, 4, 7, 8, 9, and 10 of a NASA technical memorandum that addresses topics in tribology have been compiled into a document that emphasizes those aspects of the subject matter that pertain to chemical-vapor-deposited (CVD) diamond and diamondlike films. The titles of the reports are the following: "Solid Lubrication Fundamentals and Applications [—] Characterization of Solid Surfaces," "Solid Lubrication Fundamentals and Applications [—] Properties of Clean Surfaces: Adhesion, Friction, and Wear," "Solid Lubrication Fundamentals and Applications [—] Properties of Contaminated Surfaces: Adhesion, Friction, and Wear," "Aerospace Mechanisms and Tribology Technology: Case Studies," "Structures and Mechanical Properties of Natural and Synthetic Diamonds," "Chemical-Vapor-Deposited Diamond Film," and "Surface Design and Engineering Toward Wear-Resistant, Self-Lubricant Diamond Films and Coatings." The collection is accompanied by a single-page preface that summarizes the economic and technological significance of CVD diamond as a solid lubricant and as a mechanically, chemically protective coating material.

This work was done by Kazuhisa Miyoshi of **Glenn Research Center.** *To obtain a copy of the documents, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16969.

Small Balloons for Local Aerial Exploration of Mars

A report proposes the use of lightweight balloon-borne instrumentation systems for exploration in the vicinity of a lander on the surface of Mars. Each system would comprise instrumentation with a mass of about 0.2 kg and a balloon with a mass of about 0.8 kg and volume of about 50 m^3. The balloons would be inflated with H_2 or He by use of an apparatus based on the automatic inflation equipment used on Earth to launch weather balloons. Of course, the apparatus would incorporate special design features to ensure successful launches in the thin, cold, windy Martian atmosphere and to minimize damage to balloons on the rock-strewn Martian terrain.

This work was done by James Cutts and Andre Yavrouian of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Mars Microballoon for Multiple Ground Launched Deployments New Technology Report," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20634

Using Electromagnetic Drag on Tethers To De-Orbit Spacecraft

Two papers propose the use of electrically conductive tethers to remove spent or dysfunctional spacecraft from orbit around the Earth in order to reduce the hazard of orbital debris. In comparison with onboard rockets, these tethers would be more cost-effective, more reliable, and less massive. Once deployed, a tether would not require an onboard power supply. Both ends of the tether would be equipped with electrodes to make electrical contact with the ionosphere and thereby complete an electrical circuit. The orbital motion of the tether across the Earth's magnetic field would induce an electrical current in the tether. The consequent electrical heating of the tether would gradually dissipate the orbital kinetic energy of the spacecraft. It has been estimated that a typical spacecraft could be removed from orbit in weeks or months in this way, whereas the satellite might otherwise remain in orbit for years or even centuries.

This work was done by Robert L. Forward and Robert P. Hoyt of Tethers Unlimited and Chauncey Uphoff of ACTA Consulting Group for **Marshall Space Flight Center.** *To obtain copies of the papers, "The Terminator Tether™: a low-mass technology for end-of-life deorbit of LEO spacecraft" and "The 'Terminator Tether™': An Efficient Mechanism for End-of-Life Deorbit of Constellation Spacecraft," please contact the company via e-mail at TU@tethers.com or visit their web site at http://www.tethers.com.*

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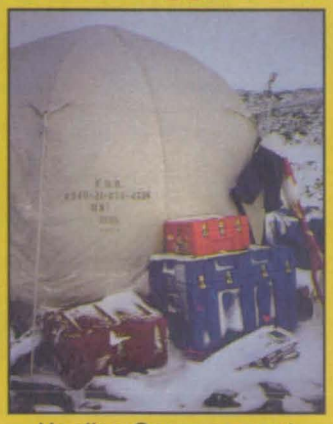

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Apparatus and Technique for Measuring Distance Between Axles

A combination of optoelectronic modules takes much of the tedium out of the measurements.

John F. Kennedy Space Center, Florida

An optoelectronic apparatus and a technique for its operation have been developed to facilitate and accelerate the measurement of distances of the order of tens of feet to within error limits of about ±1/8 in. (about 3 mm). In the original application, the distance to be measured [≈66 ft (≈20 m)] is that between the axes of rotation of the front and rear tires of the space shuttle orbiter as it rests in a ground-based processing facility. Previously, this distance was determined in a tedious procedure that involved measurements of component horizontal distances between floor points found by dropping plumb bobs. (This distance is used, along with other measurements, to locate the center of gravity of the orbiter.) The apparatus and technique could also be used for similar purposes in other settings; for example, to measure perpendicular distances between wall frames in situations in which tape measures cannot be used, to establish fence lines, or to lay out football grids.

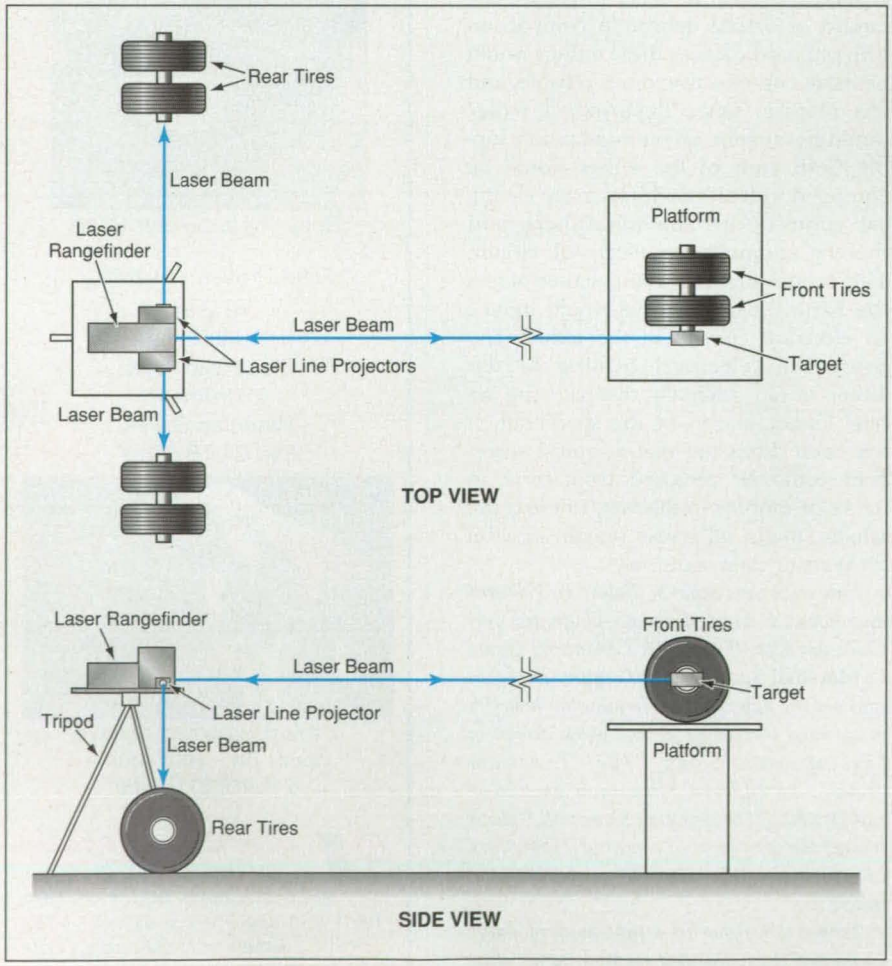
The figure illustrates the apparatus and its use in the original application, in which the rear tires rest on the floor and the front tires rest on a platform about 3 ft (≈0.9 m) above the floor. The major components of the apparatus are (1) a laser rangefinder and (2) laser line projectors that include two battery-powered laser-diode modules with collimating optics. Each laser-diode module generates a continuous-wave beam with a power of 3 mW at a wavelength of 670 nm. The modules are aimed to point the beams downward, and the beams are made to pass through a cylindrical diverging lens to spread the beams into fans oriented in a nominally vertical plane; the modules are aligned to project coincident vertical lines as viewed from the side and collinear horizontal lines as viewed from the top.

The rangefinder is aligned precisely with respect to the laser-diode modules and the diverging lens so that the line of sight of the rangefinder is perpendicular to the plane defined by the beams from the laser-diode modules. This line of sight is thus nominally horizontal.

The apparatus is mounted on a tripod between the rear tires, with the rangefinder at approximately the height of the front tire hub. (Exact matching of heights is not necessary in this application because the geometry is such that even at a height difference as large as a few inches, the difference between the horizontal distance and the measured distance is less than the allowable error of 1/8 in.) A target is mounted on the front tire hub. The position and orientation of the apparatus are adjusted until the bright lines projected by the fan beams strike the hubs of both rear tires and the beam from the rangefinder strikes the center of the target. Then the distance is measured by use of the rangefinder, which produces a digital readout. The measurement range is from <1 ft (<0.3 m) to about 300 ft (≈91 m).

This work was done by James P. Strobel, Jimmy D. Polk, William D. Haskell, and Robert C. Youngquist formerly of I-NET, Inc., for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11980.



A **Laser Rangefinder and Laser Line Projectors** have been combined into an instrument for measuring the horizontal distance between the central axes of the front and rear tires. These drawings depict the basic measurement geometry, but are not to scale.

Miniature, Low-Power, Digital, Wireless Electronic Camera

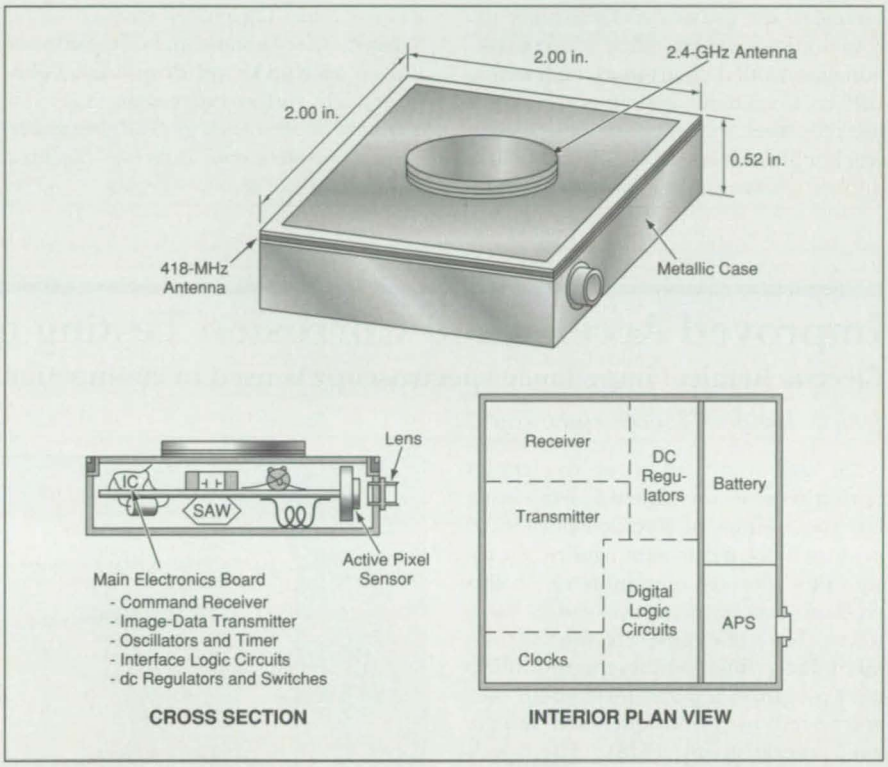
This portable unit can be programmed to operate in a variety of modes.

NASA's Jet Propulsion Laboratory, Pasadena, California

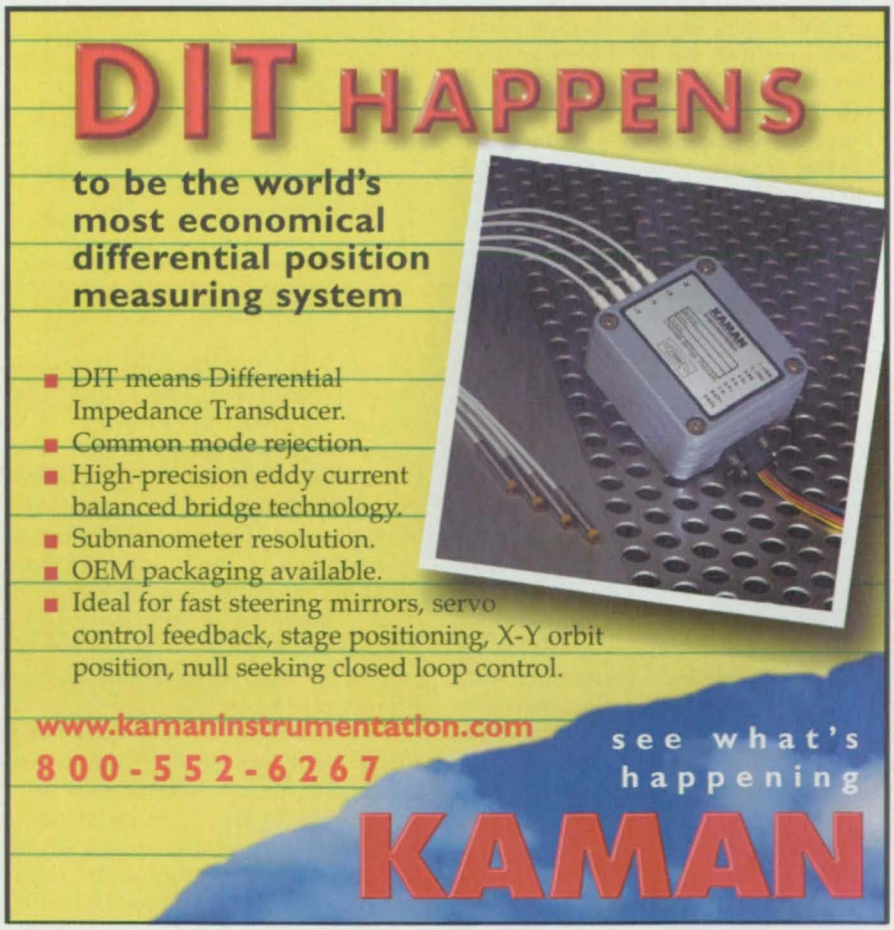
A portable, battery-powered camera unit contains a programmable digital camera that is implemented on a single chip utilizing active-pixel-sensor (APS) technology, plus circuitry for digital radio communication between the camera and a base station. A laboratory-bench-top version of this digital wireless camera has been demonstrated to function as intended, and continuing development efforts are directed toward miniaturization (see figure). The fully miniaturized unit is intended to serve as a prototype of low-power, long-battery-life, portable, digital, wireless electronic cameras for such applications as surveillance in military and civilian settings, home security, and remote monitoring of babies.

The APS-camera portion of the circuitry was described in "Active-Pixel-Sensor Digital Camera on a Single Chip" (NPO-20262), *NASA Tech Briefs*, Vol. 22, No. 10 (October 1998), page 44. To recapitulate: A complementary metal oxide/semiconductor (CMOS) integrated-circuit chip contains a 256 × 256 photogate APS sensor array, 256 on-chip analog-to-digital converters (ADCs) to digitize the pixel data, timing and control circuitry, and four digital-to-analog converters (DACs) to provide the analog references necessary for the imager and ADCs. From an external source (the base station), the chip can be programmed to perform a variety of imaging operations; for example, to obtain a desired exposure time and/or to operate in any of a number of imaging modes to reduce power consumption; for example, windowing, subsampling. The chip can also be programmed to establish a required digital interface configuration; this feature affords flexibility for integration with a variety of base-station digital systems. The total power consumption of this portion of the camera (that is, the camera without the radio-communication portion of the circuitry) is of the order of tens of milliwatts in full operation. After obtaining an image or set of images, the camera chip automatically enters a low-power idle mode where it uses about 40 μW of power. In contrast, a typical charge-coupled-device (CCD) camera circuit with analog output consumes 1 to 2 W when turned on, and cannot be commanded to operate in multiple lower-power modes.

The camera communicates with the base station over a bidirectional radio link, with a range of about 1 km. The camera transmits video data to the base station at a rate of 2.455 Mb/s at a carrier fre-



The **Digital Wireless Camera** will eventually occupy a volume of only about 2 in.³ (≈33 cm³).



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quency of 2.4216 GHz and receives command data at a rate of as much as 2.4 kb/s at a carrier frequency of 418 MHz. Spread-spectrum modulation is used to reduce the probability of interception. In an attempt to minimize the power consumed by the camera and maximize the communication link efficiency, convolutionally-encoded binary phase shift keying (BPSK) is used for coding and modulation, together with a coherent detection receiver at the base station. By use of half-duplex protocols, the base station can communicate with as many as 254 such cameras. The miniature low-power communication system can be extended to be used with other sensor systems.

This work was done by Martin Agan, Eric Fossum, Robert Nixon, Brita Olson, Bedabrata Pain, Christopher Pasqualino, Ed Satorius, Timothy Shaw, and Gary Stevens of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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-20331, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Accelerated Corrosion Testing of Zinc-Rich Primers

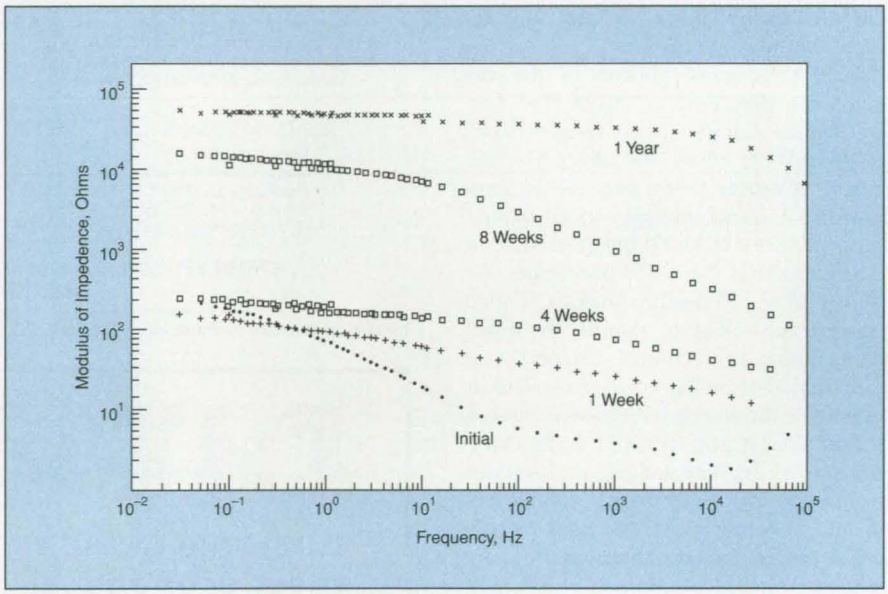
Electrochemical impedance spectroscopy is used in conjunction with atmospheric exposure.

John F. Kennedy Space Center, Florida

An improved method of accelerated testing reduces the time needed to analyze the abilities of zinc-rich primers to protect steel substrates against corrosion in a seacoast environment. In this method, specimens are placed in racks where they are exposed to the environment. From time to time, the specimens are brought to a laboratory, where they are tested by electrochemical impedance spectroscopy (EIS). The specimens are then returned to the racks for further exposure.

Accelerated testing methods have been sought in this field because when using conventional testing methods, it takes between 1-1/2 and 5 years of exposure to obtain definitive results under natural environmental conditions. Previous attempts at accelerated testing in this field have involved the use of artificial salt sprays and salt fogs to increase rates of corrosion. Unfortunately, the results of experiments conducted under such artificial conditions have been found not to correlate well with results of experiments under natural conditions. In contrast, the improved method drastically reduces (typically to about 8 weeks) the time and thus also the cost of testing, without need for artificial conditions that distort the results.

In the improved method, each specimen from the exposure rack is immersed in a 3.55-percent NaCl solution in the test cell of a commercial EIS apparatus. Impedance measurements are taken in a typical frequency range from 0.01 Hz to 100 kHz. The results of the measurements are digitized and processed to extract parameters of an equivalent-circuit model of the galvanic and barrier mechanisms that have been postulated to explain the corrosion-inhibiting effects of the primers. The results of the impedance measurements are also typically presented as Bode plots (plots of the phase angle of impedance and of the logarithm of the modulus of impedance as functions of the logarithm of frequency) and Nyquist plots (showing the negative of the imaginary component of impedance as a function of the real component of impedance). The figure presents Bode plots for one specimen taken after various exposure times up to 1 year.

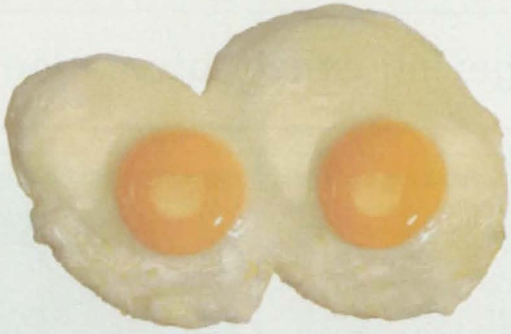


These **Bode Plots** were obtained in EIS measurements on a carbon-steel coupon coated with a zinc-rich primer after exposure to seacoast air for the indicated times. Even after as little as 1 week, the plots show an increase in impedance corresponding to a decrease in the galvanic mechanism and an increase in the barrier mechanism of protection. The plots also indicate that the capacitance decreased.

In general, the EIS measurements indicate early changes in electrical properties of primers associated with deterioration of the primers at metal/primer interfaces, before macroscopic deterioration becomes apparent. In experiments, it has been found that these properties and their changes are correlated with the long-term performances of the primers. Further research in this field will be devoted to refining the analysis of changes and improving the capability for utilizing the impedance data in their full complexity to predict long-term performances.

This work was done by Louis G. MacDowell, III and Luz M. Calle of **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11850.



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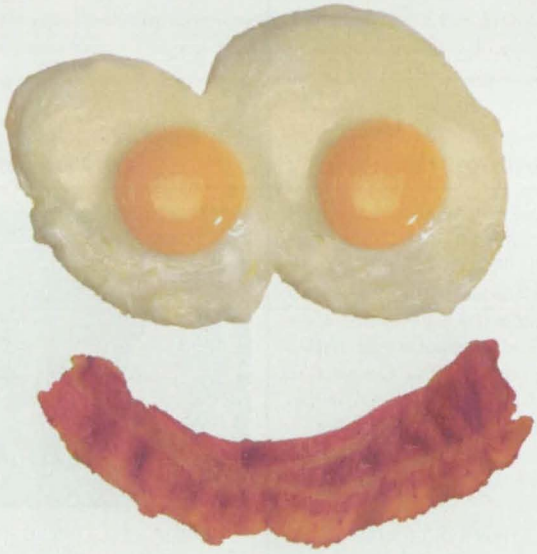

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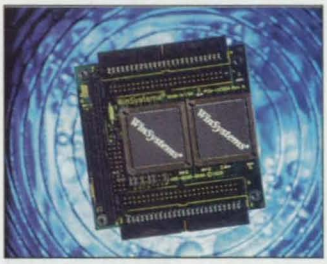
For More Information Circle No. 526

Special Coverage: Industrial Automation

The Tracer2000™ **automated test platform** from Acculogic, Markham, ON, Canada, integrates commercial off-the-shelf products in an open architecture design with a software environment based on industry standards. The PC-based platform is designed to accommodate integration of VXI, RS-232, IEEE-488, or PC-based instruments. It uses a scaleable test environment to configure and build a range of test technologies, including analog functional test, digital test, manufacturing defect analyzer, and boundary scan.

The system offers a programming environment based on National Instruments' TestStand™ test management software. Other industry standard software tools such as LabView, LabWindows, Visual Basic, and HP VEE can be applied. The system includes a PC with rack-mounted color monitor, keyboard, mouse, UUT Programmable Power Supplies, system cooling, vacuum hook-up, and master power control panel.

For More Information Circle No. 730



WinSystems, Arlington, TX, offers the PCM-UIO96A **digital I/O interface** with automatic event sense lines. The PC/104 Bus, TTL-compatible, 96-point digital interface card can monitor both rising and falling digital edge transitions, latch them, and then signal the host processor that a change of input status has occurred. It senses and signals the CPU of real-time events without continuous polling of the 96 points.

Each I/O line is programmable for input, output, or output with read-back operation. The interface features Event Sense, which is the controller's ability to monitor each input line and then generate an interrupt whenever an event occurs. The system measures 3.6 x 3.8" and weighs 7 ounces, and has an operating temperature range of -40 to +85°C.

For More Information Circle No. 731

National Instruments, Austin, TX, has introduced the PXI-1002 four-slot, 3U **PXI chassis** for test and measurement, data acquisition, and industrial automation applications. The chassis can harbor three peripheral PXI/CompactPCI modules and an embedded controller or remote controller. It includes modular construction, integrated cooling, and a backplane with integrated timing and triggering features.

The chassis is available with options for a variety of different implementations in many automation systems. Users can select the rack-mount option for installation in instrument cabinets or wall-mount configurations. A handle and feet kit provides benchtop and portable solutions.

For More Information Circle No. 726

The TorsionMaster™ low-torque, high-rotation **automated testing system** from MTS Systems Corp., Eden Prairie, MN, is designed for testing small material specimens, products, and components. It features a torque capacity of ±20 Nm, and includes the test instruments, collet grips, digital control system, and software.

The computer-automated system includes TestWorks® 4 material testing software that enables users to analyze, review, graph, plot, and archive material testing data. The system also performs ASTM A938 tests on fine wire and ASTM 1622 or ISO 6475 tests on medical screws.

For More Information Circle No. 727

Cincinnati Industrial Automation, Covington, KY, offers the EZ Vision Sensor PLC-based **machine vision system**, an integrated image processing and programmable logic controller designed for static or high-speed inspections (up to 15,000/minute) and programmable machine control. PC-based software is available for set-up and training.

The system features two camera inputs for simultaneous image capture of two views of the device, 16 inspection programs, template matching with normalized correlation, rotational correction, and general-purpose measurement/inspection tools. It also features 15 I/O points, 128 internal registers, eight timers, and eight counters.

For More Information Circle No. 728

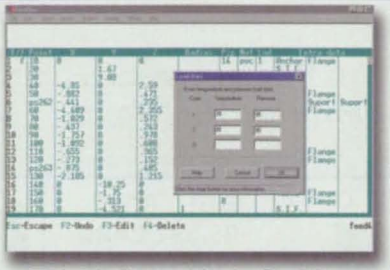
Scout™1 **one-camera inspection system** from PPT Vision, Eden Prairie, MN, provides automated inspection with user-friendly programming and the ability to upgrade to two or four cameras. The turnkey inspection system consists of an integrated processor, 15" SVGA monitor, camera and lighting system, keyboard, trackball, cables, and Vision Program Manager™ software.

The system provides image capture rates up to 1,800 parts-per-minute at 640 x 480 resolution, and can be upgraded with a high-speed camera to achieve speeds over 10,000 ppm. The integrated, networkable PC platform provides continuous display of inspection images and data for real-time process monitoring and control. Options include a touchscreen monitor and a sealed flatscreen monitor.

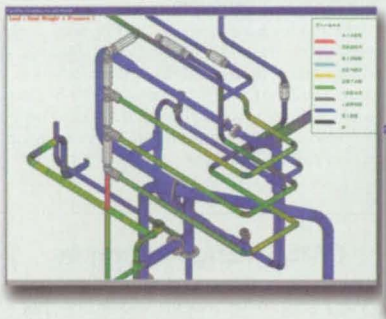
For More Information Circle No. 729

See The All-New Algor PipePak at www.pipepak.com

Design a piping system easily and quickly in a highly graphical CAD environment using Superdraw III...

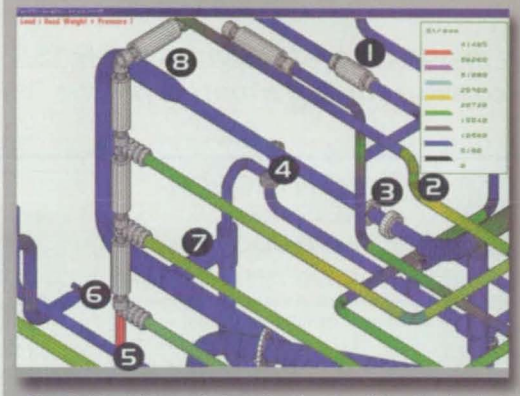


...or build and edit a model using PipePak's new Windows-style spreadsheet interface and data input screens.



View the analysis results of the piping model using PipePak's realistic graphical display to study displacements and stresses in the design.

Generate a customized report by selecting desired model input and output data, graphics and company logo. Print or post the report to a web site so engineers in different divisions can view the results concurrently or on demand.



PipePak's enhanced visualization provides the tools to zoom in tight so you can study the elbows, flanges, bellows or other piping components. Notice the image above provides the detail necessary to recognize the following piping components:

1. Valve (300 rating)
2. Long Radius Elbow
3. Socket Weld Flange
4. Flange/Bellows
5. Expansion Joint
6. Customized Valve
7. Unreinforced Fabricated Tee
8. 14" to 8" Reducer

Algor's PipePak Provides a Better Way to Perform Piping Design, Analysis, Visualization and Reporting

Three Flexible Design Methods

1. *Superdraw III's CAD-like interface.* Engineers can quickly convert lines into a piping system, automatically create valves, flanges, etc. with icon toolbars and specify model parameters such as masses or forces.
2. *Windows-style spreadsheet interface.* This enhanced interface enables tabular data entry of piping system parameters while all-new interactive graphics let engineers visualize the model from the first step.
3. *Third-party piping design systems.* Engineers can import models created with AutoCAD, CADPIPE, CAESAR II, Intergraph PDS and others.

Highly Accurate Analysis

PipePak features PipePlus for static and dynamic stress analysis of piping systems. PipePlus complies with well-known, world-wide codes, including:

- ASME B31.1 power piping code
- ASME Section III Class 2 and Class 3 component piping code
- ASME B31.3 chemical plant and petroleum refinery piping code
- ASME B31.4 liquid transportation piping code
- ASME B31.8 gas transmission and distribution piping code
- British Standard BS806 piping code

Powerful Visualization

Built-in visualization capabilities enable engineers to view deflected shapes, forces and moments, stress spectrums and mode shapes as well as animate transient stress analysis results over time.

HTML-Based Report Generation

PipePak's new Report Wizard generates customized HTML reports that summarize input, analysis results and equipment data. Engineers can add a company logo and model graphics and print the report or save it to the Internet or Intranet for client or multi-divisional access.

Look for the Following Features in Algor's New PipePak 7.0:

- Increased image-saving capabilities allow engineers to save graphics as JPEG , TIF, PCX, PNG, TGA and BMP files.
- A new interface ties all PipePak elements into one menu accessible from within Superdraw III.
- Standard Windows screens provide Windows-style functionality to support ease of use.
- Enhanced visualization prominently displays mode shape plots and clearly shows elbows, flanges and anchors.
- Enriched help features are displayed in Windows message boxes and include context-sensitive help for all data fields to prevent input errors.
- A direct link provides access to DocuTech, Algor's on-line software documentation system with powerful search capabilities.

For more information about PipePak, please visit www.pipepak.com, Algor's new website dedicated to PipePak and piping design, or contact an Algor representative at +1 (412) 967-2700.

See PipePak in Action with Algor's Webcasts and Web Courses

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HIGH-PRECISION PRESSURE TRANSDUCER

OMEGA's PX624 Series transducers combine the precision and stability of the photo-optical sensor with state-of-the art SMD electronic circuits. These features provide exceptional performance with accuracies of ±0.05% of span or better. For barometric and absolute ranges up to 30 psia, long-term stability is ensured by inclusion of a getter material in the evacuated reference chamber. Each unit has a 20-point certificate of calibration traceable to NIST.

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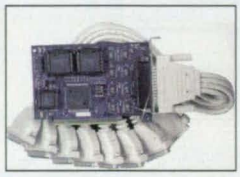
For More Information Circle No. 600



EIGHT-PORT RS-232 CARD FOR THE PCI BUS

The model OMG-COMM8-PCI plugs into any IBM or compatible computer with the PCI bus and provides eight RS-232 Async ports for communications servers, terminals, point-of-sale (POS) systems, and other data-collection devices. The onboard interrupt status port provides maximum flexibility. Features include the 16554 UART, providing a 16-byte FIFO to keep data-communications applications running error free. An eight-port RS-232 cable is included.

OMEGA Engineering Inc.

For More Information Circle No. 601

PORTABLE PLC FOR TEST LABS

Model OM-LMPLC is a flexible I/O controller designed for test labs performing on/off cycling tests such as pneumatic cycling, electronic power cycling, and other durability testing. All user interactions occur through the front panel, which has two buttons, a key-switch, and a large digital display. The controller accepts eight opto-isolated DC voltage inputs from 5 to 35 Vdc. Windows software is included.

OMEGA Engineering Inc.

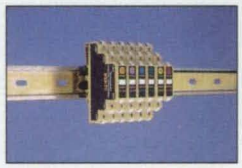
For More Information Circle No. 602

OM-DL DATALOGGERS

OM-DL Series dataloggers are economical and tamperproof, with storage capacity for more than 800 readings. Models are available for temperature, dual temperature, and temperature and humidity inputs. Connect the datalogger to a PC's parallel printer port and use the available Windows software to set recording parameters. Once the logger is set up, it can be disconnected and put in the field to record data. The recording function can be locked on to prevent disruptions.

OMEGA Engineering Inc.

For More Information Circle No. 603



ANALOG TO PULSE I/O MODULES

The MSP family of analog-to-pulse I/O modules allows use of any analog sensor with almost any PLC model. Each MSP module provides one analog input or one analog output interface between the PLC and the analog world. Communication between MSP unit and PLC is via patented "single wire" communications. Modules are available for thermocouple, RTD, current, voltage, potentiometer, and frequency inputs, and voltage or current outputs.

OMEGA Engineering Inc.

For More Information Circle No. 604

DIGITAL OPEN CHANNEL WATER VELOCITY METER

OMEGA's FLR1000 Series flow sensors can measure extremely low flowrates from 20 ml/min to 5 liters/min in a wide variety of industrial, commercial, and laboratory flow applications. These sensors operate on 12 Vdc power and have been designed for incorporation into data acquisition systems that supply 12.5 Vdc to sensors and receive 0 to 5 Vdc linear signals from such sensors. They are highly repeatable, stable, and have excellent resolution.

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WIDE RANGE INFRARED TEMPERATURE TRANSMITTERS

The OS6000 is a self-contained Fiber Optic Infrared system that provides 2-wire 4 to 20 mA linear output, repeatability ±0.25% rdg, and fast response 50/100 msec. It has a wide temperature range: 300 to 1600°C with a 0.8 to 1.6 μ spectral response. The OS8000 provides 2-wire 4 to 20mA linear output and the same repeatability and response time as the OS6000. Features include temperature range of -40 to 1700°C and seven spectral-response ranges.

OMEGA Engineering Inc.

For More Information Circle No. 606

NON-CONTACT INFRARED PYROMETERS

The OSP500 to OSP2000 series are accurate, rugged, easy-to-use non-contact infrared pyrometers. No focus is required. Features include laser pointing and circular laser options (on selected models); temperature display; alarms (high/low); thermocouple input (Type K and S for emissivity determination); analog input; and calibration report. A software package is available on selected models.

OMEGA Engineering Inc.

For More Information Circle No. 607

WIRELESS TRANSMITTER SILICON-ON-SAPPHIRE

OMEGA's PX921 Series wireless transmitters provide safe operation in tough industrial installations — without hard wiring. The PX921 operates by radio telemetry. A low-power RF transmitter safely transmits the signal up to 500 meters to a receiver/retransmitter, where it is converted into a 4-20 mA signal. The rugged stainless steel construction features SOS technology with custom IC amplifier, giving the PX921 Series high stability, low drift, and long life.

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For More Information Circle No. 608

TECHNICAL REFERENCE GUIDE 9

Plastic tubing, hose, and fittings for the design engineer are found in NewAge® Industries' catalog, Technical Reference Guide 9. Technical specifications and data are presented on 30 stock tubing and hose product lines from PVC, polyurethane, nylon, TPR, Teflon®, and Viton®, to medical-grade silicones. An expanded custom capabilities section, including coiling, thermal tube bonding, and hose assemblies, proves this company to be an industry leader. NewAge Industries, Southampton, PA ; Tel: 215-657-3151; Fax: 215-657-6594; e-mail: psales@newageind.com; www.newageind.com

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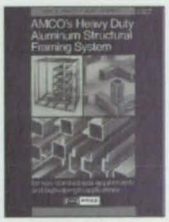

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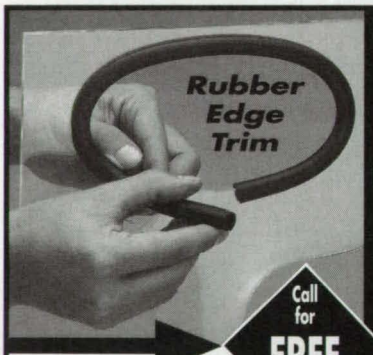

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P48

For More Information Circle No. 437

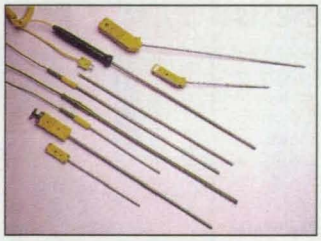
New on the MARKET

DSP-Based Filter Instrument

Signal Processing Solutions, Redondo Beach, CA, has introduced the Versa-Filter System™, a DSP-based electronic filter and signal conditioning system with analog I/O. Features include two independent channels; programmable gain amplifiers; and fully tunable, low-pass, high-pass, band-pass, band-stop, and inverse-notch filters that operate from DC to 20-KHz with a 1-Hz tuning resolution. The system is user-programmable with custom filter coefficients. A liquid crystal display shows the filter settings, or bar-graph type VU meters display the I/O signal dynamics. **Circle No. 711**

Rotary Position Sensor

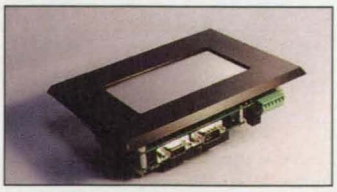
The RS-50 non-contact rotary position sensor from Power Components of Midwest, Mishawaka, IN, utilizes Hall-effect technology in a hermetically sealed, encapsulated plastic body. Features include custom mounting configurations, programmable rotational range, and idle validation. The sensor operates in temperatures ranging from -40°C to +135°C (+150°C is available). It is designed to operate with or without a return spring, and with or without rotational stops. **Circle No. 712**



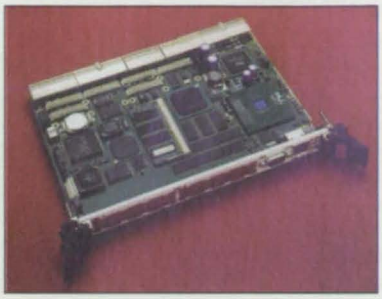
Temperature Probes

OMEGA Engineering, Stamford, CT, offers temperature probes, including mineral insulated probes in Quick Disconnect or Transition Junction styles in diameters from 1/16 to 1/4"; pockets with mating thermocouple or RTD probes with industrial protection heads; and insulated, self-adhesive, and unsheathed fine-gage thermocouples available in five-packs. Also available are surface and extension probes, handle probes, and thermocouples for extruders available to mate with various read-out devices. Thermocouple probes are available in standard calibrations of J, K, T, or E, as well as materials suited to high-temperature applications. **Circle No. 713**

Embedded Computer



The SmarTouch Controller™ from Mosaic Industries, Newark, CA, is a C-programmable embedded computer with a built-in touchscreen/graphical user interface (GUI). It can be commanded remotely from a PC or used as a standalone. The system features hundreds of pre-coded device drivers, 256 Flash, 128K RAM, eight 12-bit analog input channels, eight 8-bit analog inputs, 24 digital I/O, four high-current drivers, and two RS-232/485 ports. Also included is menuing software to facilitate application control using buttons, menus, graphs, and bitmapped pictures. **Circle No. 714**



CPU Board

Concurrent Technologies, Ann Arbor, MI, offers the PP EMB/P3x single-slot 6U CompactPCI® CPU board featuring the Flip-Chip Pentium® III processor. It also features up to 256 Mbytes of DRAM, 10 or 100 Mbps Ethernet, battery-backed SRAM, keyboard, mouse, real-time clock, USB, floppy disk, and printer ports. A transition module provides connectivity for rear panel I/O. The board supports Windows NT, VxWorks, Solaris, QNX, and Linux operating systems. **Circle No. 715**

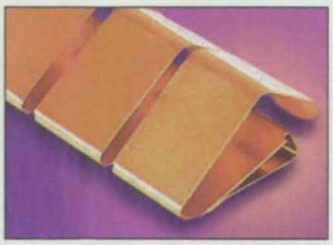
PCI-Bus Data Acquisition

ADAC Corp., Woburn, MA, offers data acquisition boards for the PCI Bus. The PCI-5500 line consists of 12- and 16-bit resolution analog input boards with features such as FIFOs, DMA, channel gain RAM, autocalibration, clocked analog input options, and a custom PCI-Bus interface for high-speed data transfers. The plug-and-play boards are compatible with most DAQ software packages, including LabVIEW, TestPoint, and LabTech Notebook. **Circle No. 716**

Temperature Controllers

Cole-Parmer Instrument, Vernon Hills, IL, has introduced the Digi-Sense® Models 89000-00, -05, -10, and -15 temperature controllers that feature a two-line display with plain-English menus. Multiple safety features include user-settable over temperature, loop break, and timer cutoffs. The controllers also accept RTDs and YSI thermsistor probes, in addition to thermocouples. Models 89000-10 and -15 feature ramp and soak RS-232. **Circle No. 717**

Clip-On Shielding



An RFI-EMI shielding gasket series from Omega Shielding Products, Randolph, NJ, is available in four sizes for clip-on mounting. Applications include those in which perpendicular and/or parallel compression loading occurs between mating surfaces. The free-hanging finger end travels in open space, yielding low deflection forces. Gripping lances on the clip assure stable locking to surfaces. **Circle No. 718**

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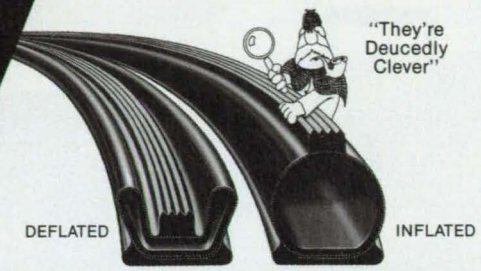

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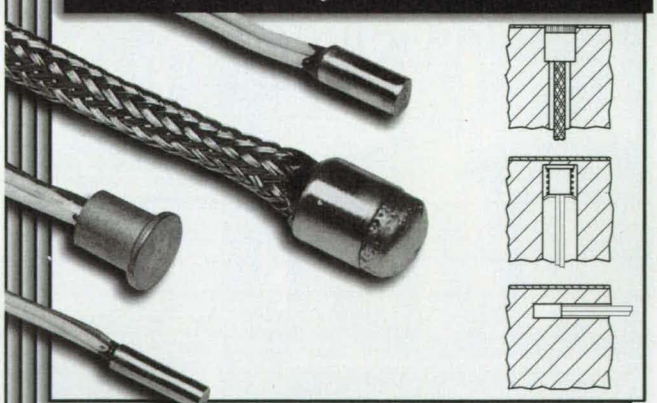

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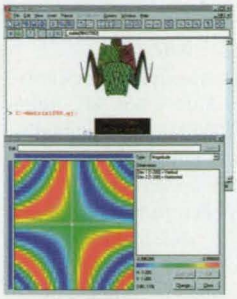


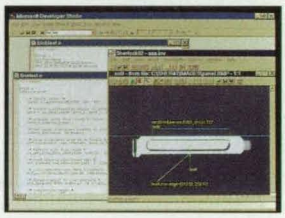
Mathematical Software

Waterloo Maple, Waterloo, Ontario, Canada, has released Maple 6 mathematical computation software for Windows, UNIX, Macintosh, and Linux. The program's new math engine combines Waterloo Maple's symbolic computation algorithms with a numerical solver from Numerical Algorithms Group (NAG). Enhancements include improved signal and image processing, dynamic simulation, and mathematical modeling. Other features include large-scale floating point data handling and an improved user interface. The software connects to Microsoft Excel 2000 and exports to RTF. **Circle No. 700**

CAD Viewer

Cyco International, Atlanta, GA, offers AutoManager® View 3.1 multiformat CAD viewing software that incorporates Autodesk's ObjectDBX technology to allow extended support for viewing AutoCAD 2000 designs. Users can access and view external references of AutoCAD documents; raster and hybrid files; Mechanical Desktop; Visio and MS Office spreadsheets; and word-processing documents. The software integrates with Cyco's AutoManager® WorkFlow™ document-management system. **Circle No. 701**

Machine Vision



Sherlock™ and MVTools™ 5.6 software-development environments for machine vision are available from Imaging Technology, Bedford, MA. MVTools provides expanded capabilities, including more than 200 new image-processing functions. Sherlock supports custom-written algorithms and includes a new "Find Angle" tool to measure an object's rotation around its center point. Together, the packages form an integrated development environment. Once an application is sketched out and tested in Sherlock, it can be coded using MVTools. On completion of the code, MVTools becomes the runtime environment for the machine vision application. **Circle No. 702**

Flow Calibration

Calware™ flow calibration software from Flow Technology, Phoenix, AZ, is designed to simplify and enhance control and monitoring capabilities of primary and secondary standard calibration systems. The Windows® 95/98/NT and LabVIEW-based environment provides a user interface that presents all calibrator controls and parameter settings on a single active screen. Calware's qualitative and quantitative analysis tools allow for multiple graph plotting. The software also supports data manipulation in both numeric and graphical formats; provides enhanced, real-time diagnostics and full-color graphics; and allows data export in Excel® format. **Circle No. 703**

Geographic Imaging

ERDAS IMAGINE® 8.4 geographic imaging software from ERDAS, Atlanta, GA, includes features designed to speed production processes and increase accuracy, including an expert systems-classification tool for geographic applications. Features include several wizard-based processes, on-the-fly re-projection, and extended native raster file handling. The software also supports data files exceeding 2 GB in size. The IMAGINE Expert Classifier™ enables users to graphically build knowledge-based systems for image classification, post-classification refinement, and advanced spatial modeling. **Circle No. 704**

New LITERATURE

Polyurethane Design

An eight-page design guide from Stevens Urethane, Holyoke, MA, describes the characteristics of thermoplastic polyurethane (TPU). TPU offers several key properties such as durometer range; tear strength and elongation; abrasion resistance; and resistance to hydrocarbons, chemicals, ozone, bacteria, and moisture. Applications include medical and industrial uses. **Circle No. 705**

Data Acquisition and Instrumentation

IOtech, Cleveland, OH, has released a year 2000 catalog featuring more than 50 new data acquisition and instrumentation products. These include the DaqBoard/2000™, a low-cost plug-in board; the standalone LogBook/360™; and the Ethernet-based NetScan™/1500. The 320-page catalog also includes application-specific selection guides and a product overview section. **Circle No. 706**

Timer Catalog

A timer catalog from Control Co., Friendswood, TX, features more than 100 new timers. Models include: pocket, alarm, digital, countdown, stopwatch, printing, 4-channel, decimal, QC, vibrating, clock, memory, mechanical, and talking. Each timer includes an individually serial-numbered Traceable® Certificate indicating traceability to NIST (National Institute of Standards and Technology). **Circle No. 707**

Cabinets and Racks

Hoffman, Anoka, MN, offers an eight-page brochure describing cabinets and racks for voice/data and network applications. The brochure introduces preconfigured PROLINE® voice/data cabinet packages, server cabinet packages, new wall-mount cabinets, seismic cabinets, and open-frame networking racks. It also includes information on thermal-management accessories. **Circle No. 708**

Silicone Materials

A selection guide of silicone materials from NuSil Technology, Carpinteria, CA, includes adhesives, sealants, and coatings. Other products include Controlled Volatility (CV) silicones, thermally conductive materials for use in heat transfer processes, electrically conductive materials for EMI/RFI shielding, and fast-curing silicones for use in rapid assembly. **Circle No. 709**

Steel Mezzanines

Literature from Steele Solutions, Waukesha, WI, describes custom steel mezzanine systems. Applications include additional storage, support for equipment or conveyors, expanded manufacturing operations, and distribution integration. The systems meet or exceed OSHA standards and can be customized to meet BOCA, UBC, or SBCC building codes. **Circle No. 710**

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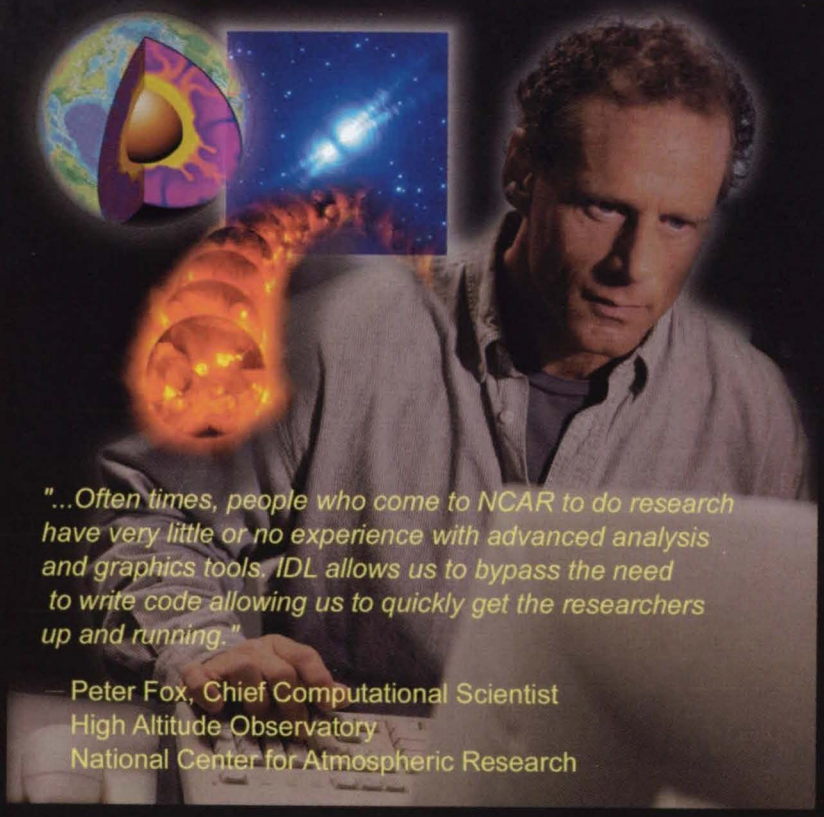

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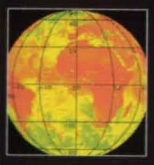

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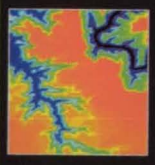

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