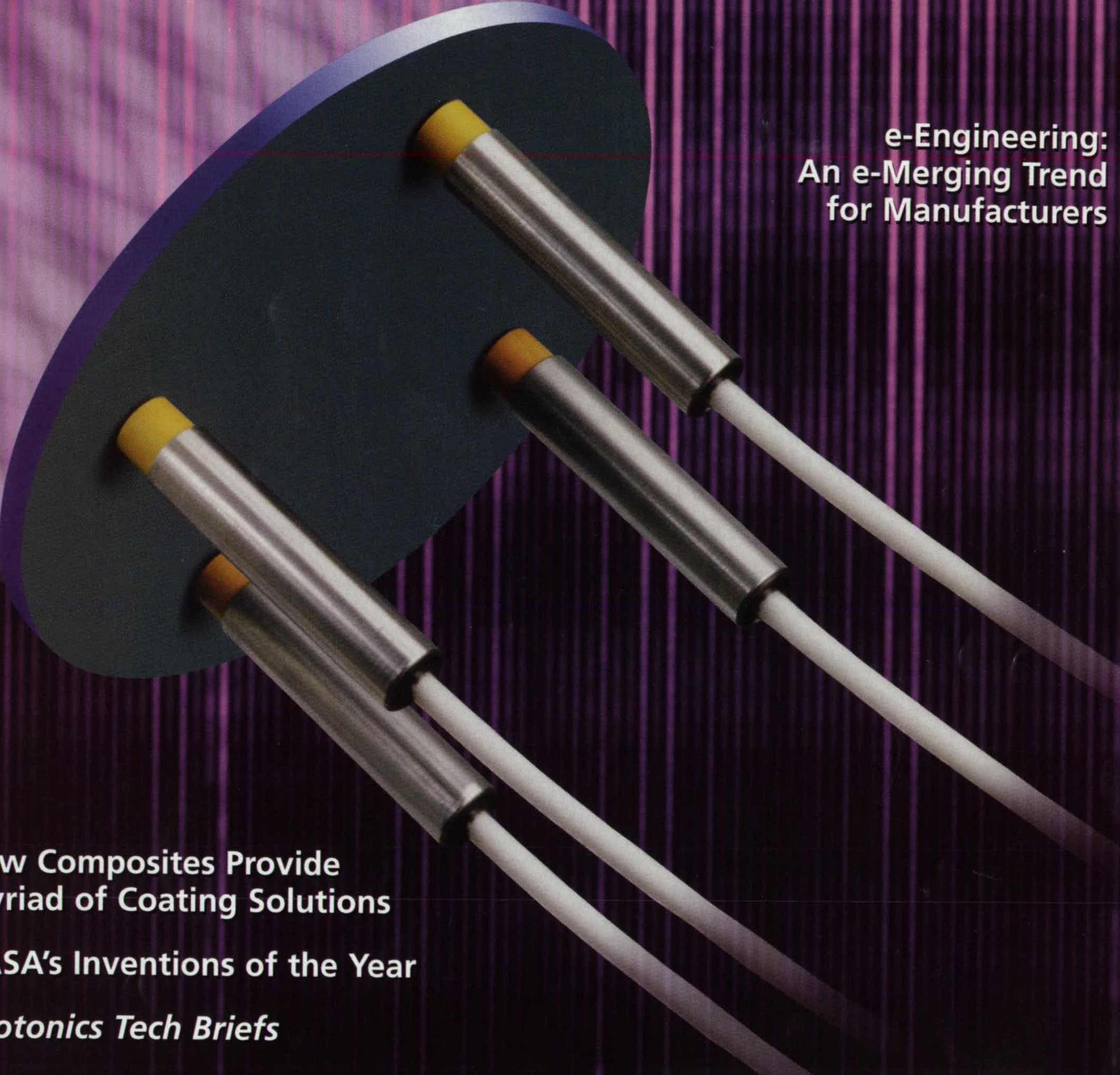
May 2001

Vol. 25 No. 5

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



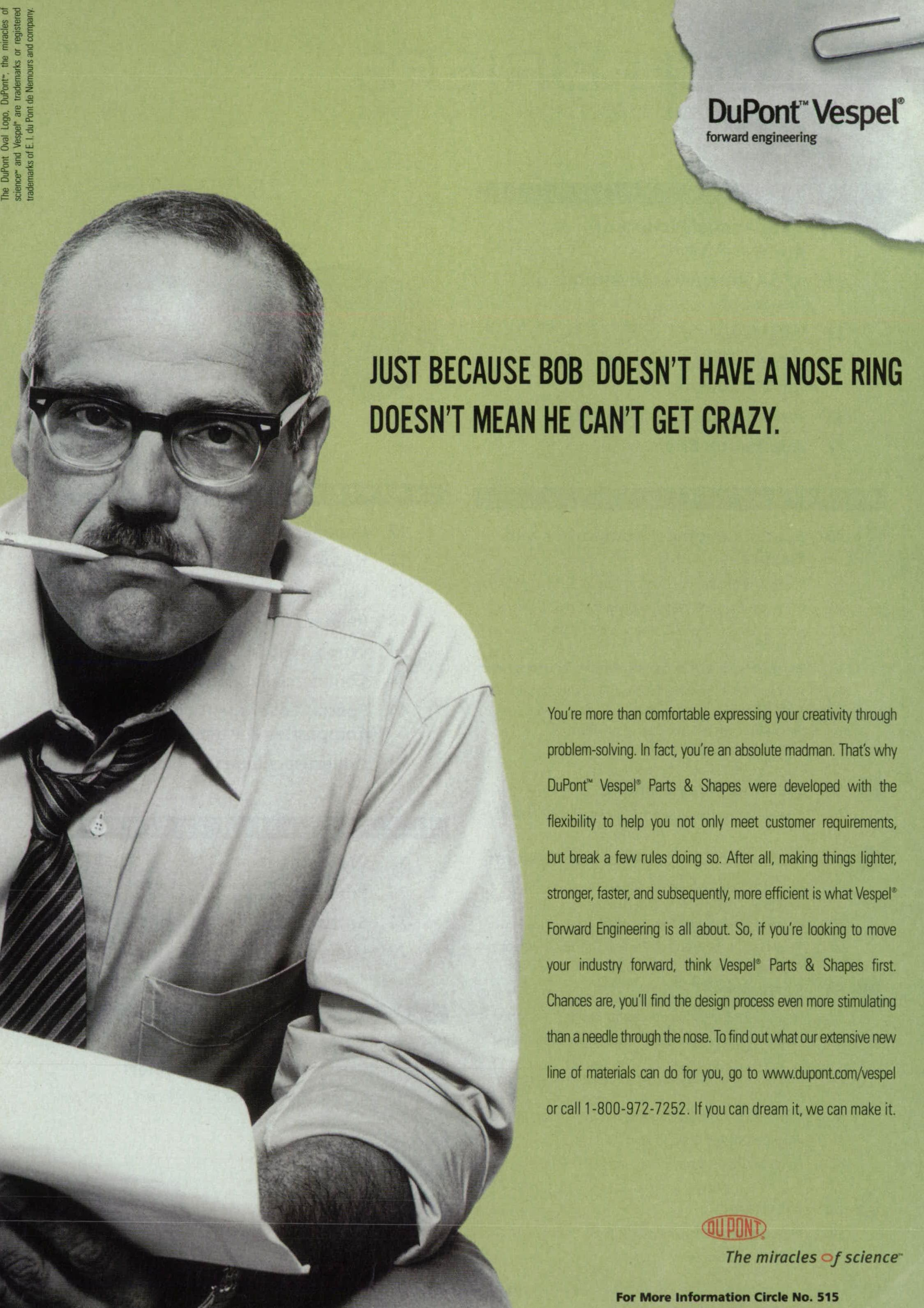
e-Engineering: An e-Merging Trend for Manufacturers

New Composites Provide Myriad of Coating Solutions

NASA's Inventions of the Year

Photonics Tech Briefs

www.nasatech.com


DuPont™ Vespel®
forward engineering
JUST BECAUSE BOB DOESN'T HAVE A NOSE RING DOESN'T MEAN HE CAN'T GET CRAZY.
You're more than comfortable expressing your creativity through problem-solving. In fact, you're an absolute madman. That's why DuPont™ Vespel® Parts & Shapes were developed with the flexibility to help you not only meet customer requirements, but break a few rules doing so. After all, making things lighter, stronger, faster, and subsequently, more efficient is what Vespel® Forward Engineering is all about. So, if you're looking to move your industry forward, think Vespel® Parts & Shapes first. Chances are, you'll find the design process even more stimulating than a needle through the nose. To find out what our extensive new line of materials can do for you, go to www.dupont.com/vespel or call 1-800-972-7252. If you can dream it, we can make it.
DUPONT
The miracles of science™
For More Information Circle No. 515
The DuPont Oval Logo, DuPont™, the miracles of science™ and Vespel® are trademarks or registered trademarks of E. I. du Pont de Nemours and company.

NASA TECH BRIEFS
ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING
May 2001 • Vol. 25 No. 5

FEATURES

26

44

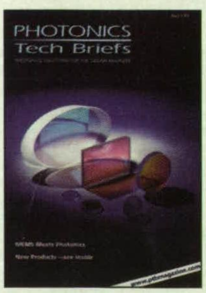
75

SOLUTIONS

DEPARTMENTS

NEW FOR DESIGN ENGINEERS

SPECIAL SUPPLEMENT

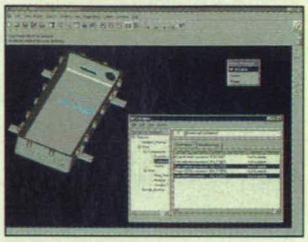


Follows page 24 in selected editions only.

Contents *continued*

PRODUCT OF THE MONTH

EnCapta™ software from Vistagy, Waltham, MA, extends the power of CAD software by capturing and communicating non-geometric design data.



16

ON THE COVER

The DIT-5200™ differential measuring system from Kaman Instrumentation Operations, Colorado Springs, CO, uses inductive technology to make precise angular measurements in pointing and tracking, forward-looking infrared, image stabilization, vibration and jitter compensation, and other applications. The DIT-5200 and other new, innovative products are featured in the New on the Market section on page 75.

(Image courtesy of Kaman Instrumentation Operations)

TECH BRIEFS
www.nasatech.com

BPA INTERNATIONAL

Published by .... **Associated Business Publications**
Publisher .... **Joseph T. Pramberger**
Editor/Associate Publisher .... **Linda L. Bell**
Associate Publisher, *Photonics Tech Briefs* .... **Linda Silver**
Editor, Market Focus Editions .... **Robert Clark**
Senior Editor/Internet Editor .... **Jason C. Flynn**
Production Manager .... **Margery Koen**
Assistant Production Manager .... **John Iwanciw**
Art Director .... **Lois Erlacher**
Production Artist .... **Christopher Coleman**
Circulation Manager .... **Hugh J. Dowling**

BRIEFS & SUPPORTING LITERATURE: Written and produced for NASA by **Advanced Testing Technologies, Inc.,** Hauppauge, NY 11788

Technical/Managing Editor .... **Ted Selinsky**
Sr. Technical Analyst .... **Dr. Larry Grunberger**
Art Manager .... **Eric Starstrom**
Staff Writers/Editors .... **Dr. Theron Cole, George Watson**
Graphics .... **Robert Simons**
Editorial & Production .... **Joan Schmiemann, Becky D. Bentley**

NASA:

NASA Tech Briefs are provided by the National Aeronautics and Space Administration, Technology Transfer Division, Washington, DC:

Administrator .... **Daniel S. Goldin**
Director, Commercial Technology .... **Dr. Robert Norwood**
Publications Director .... **Carl Ray**

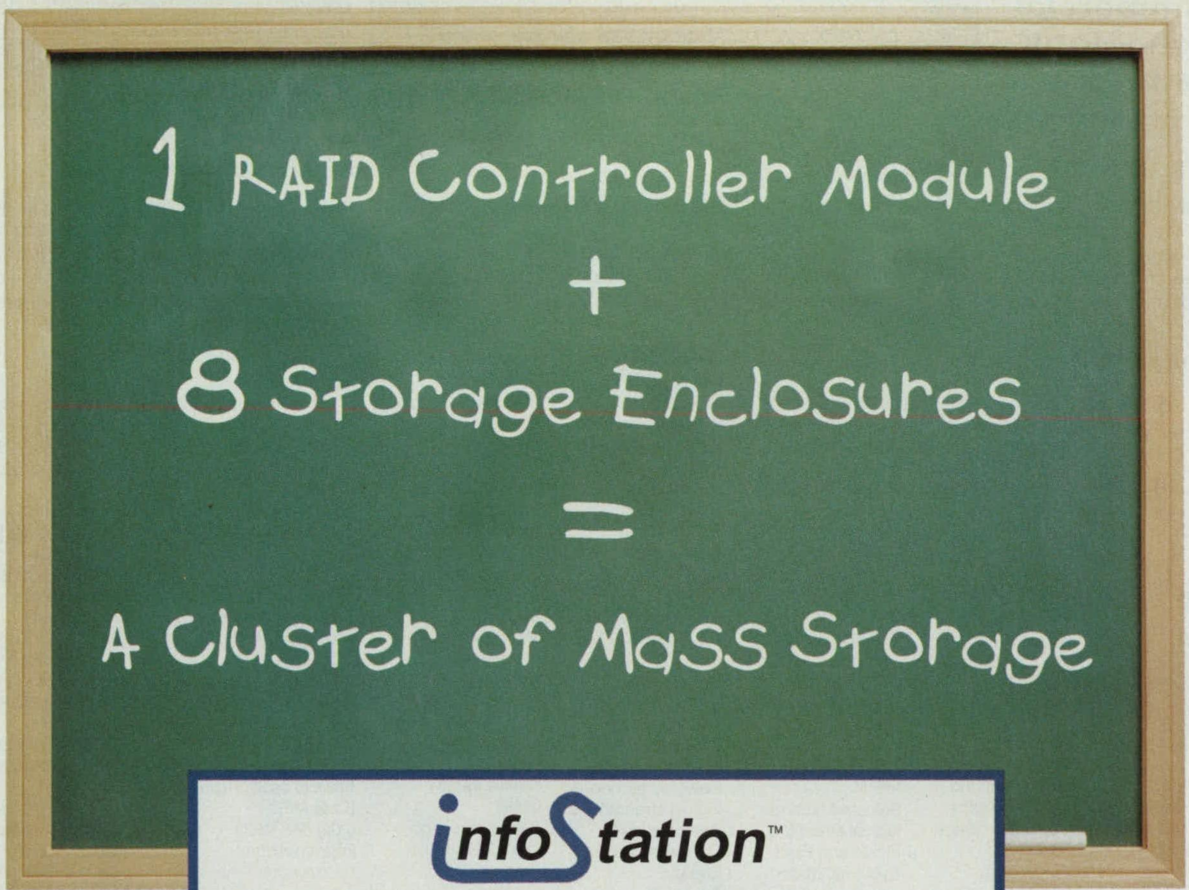
ASSOCIATED BUSINESS PUBLICATIONS INTERNATIONAL
317 Madison Avenue, New York, NY 10017-5391
(212) 490-3999 FAX (212) 986-7864

Chairman/Chief Executive Officer .... **Bill Schnirring (bill@abpi.net)**
Vice Chairman/Chief Operating Officer .... **Domenic A. Mucchetti**
MIS Manager .... **Ted Morawski**
Webmaster .... **Albert Sunseri**
eStrategy Director .... **Andrew Runk**
Credit/Collection .... **Felecia Lahey**
Human Resources Manager .... **Lourdes Del Valle**
Accounting Manager .... **Sylvia Ruiz**
Office Manager .... **Alfredo Vasquez**

NASA TECH BRIEFS **ADVERTISING ACCOUNT EXECUTIVES**

Headquarters .... (212) 490-3999
CT, MA, NH, ME, VT, RI, Eastern Canada .... **Ed Marecki** at (401) 351-0274
NJ, NY, PA, DE .... **Jim Oot** at (973) 316-9695
VA, MD, DC, NC, SC, GA, FL, AL, TN, MS, LA, AR, OK, TX .... **Bill Manning** at (770) 971-0677
MN, ND, SD, WI, IL .... **Bob Casey** at (847) 223-5225
IN, KY, MI, OH, MO, KS, IA, NE, Western PA & NY, Central Canada .... **Chris Casey** at (847) 223-5225
N. Calif., CO, WA, OR, ID, MT, WY, UT, Western Canada .... **Bill Hague** at (800) 830-4351
S. Calif., AZ, NM, NV .... **Tom Boris** at (949) 642-2785
Internet Advertising .... **Luke Schnirring** at (212) 490-3999

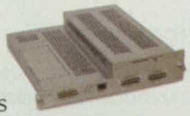
For a complete list of staff e-mail addresses, visit www.abpi.net



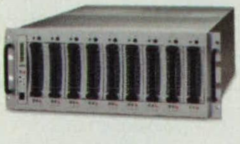
InfoStation™

THE ONLY POSSIBLE WAY

DO THE MATH AND YOU'LL REALIZE THAT INFOSTATION™ is the only mass storage enclosure available today with onboard capability that allows your customers to grow a 60 drive RAID array, *without* having to incur additional controller costs!

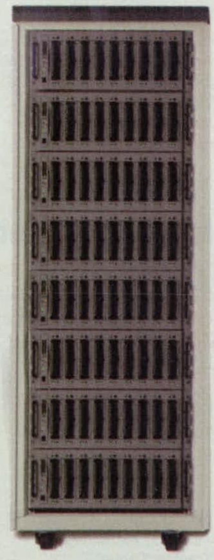


InfoStation's RAID Controller Module is capable of over 18,000 IOPS, includes 128 MB of cache memory and supports RAID levels 0 through 10. (1) feature-rich Fibre to SCSI RAID Controller Module supports up to (8) InfoStations, 60 drives. The SCSI to SCSI version supports up to (4) InfoStations, 30 drives.



InfoStation, the intelligent 9-bay RAID-ready backplane enclosure, supports up to (4) hosts. InfoStation is self-monitoring with a scrolling user interface and alarm. Also included are field-upgradable SAF-TE, NAS and SES upgrade slots. This enclosure is perfect for RAID array clustering or cascading applications.

StorCase is so confident that you and your customers will be completely happy with InfoStation that we are offering a 30-day, ***no questions asked***, money-back trial period. Call one of our well-informed consultants today at **(800) 337-8421** and find out how growing a storage RAID array with InfoStation will add up to substantial long-term savings for your customers.



TAKE THE VIRTUAL INFOSTATION TOUR | **www.storcase.com/tour**

StorCase™ TECHNOLOGY
A Kingston Technology Company

INGRAM MICRO · D&H · GATES/ARROW DISTRIBUTING · dss · Tech Data · SYNNEX · BELL MICROPRODUCTS · CONSAN A GATES/ARROW Company

ISO 9001 SGS

For More Information Circle No. 546

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: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
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.
Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; 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@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Charlene E. Gilbert
(281) 483-0474
charlene.e.gilbert1@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
Jim Aliberti
(321) 867-6224
Jim.Aliberti-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
kirk.sharp@ssc.nasa.gov

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)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mankins
Office of Space Flight (Code MP)
(202) 358-4659
jmankins@mail.hq.nasa.gov

Terry Hertz
Office of Aero-Space Technology (Code RS)
(202) 358-4636
thertz@mail.hq.nasa.gov

Glen Mucklow
Office of Space Sciences (Code SM)
(202) 358-2235
gmucklow@mail.hq.nasa.gov

Roger Crouch
Office of Microgravity Science Applications (Code U)
(202) 358-0689
rcrouch@hq.nasa.gov

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

NASA's Business Facilitators

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

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

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
Houston, TX
(713) 743-9155

John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
(410) 327-9150 x1034

Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

Joanne W. Randolph
BizTech
Huntsville, AL
(256) 704-6000

Joe Becker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

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
University of Southern California
(213) 743-2353

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

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(352) 294-7822

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

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(412) 383-2500

Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(440) 734-0094

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.

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

NASA Patents

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

Optical Path Switching Based Differential Absorption Radiometry for Substance Detection

(U.S. Patent No. 6,057,923)

Inventor: Glen W. Sachse, Langley Research Center

Gas filter correlation radiometers (GFCRs) infer the concentration of a gas species along some sample path either external or internal to the GFCR. In many of them, gas sensing is accomplished by viewing alternately through two optical cells the emission/absorption of the gas molecules along the sample path. These two cells are called the correlation and vacuum cells. However, there are instances where gas correlation cells are not practical. For example, some gases are too dangerous and/or require a construction that is too expensive for a particular application. And gas correlation cells are not useful for measuring spectral absorption characteristics of liquids or solids because these substances have broad absorption features. It is an object of the present system to detect/measure any type of substance in a nonmechanical optical fashion without the need for gas correlation cells. An optical path switch receives radiation passing along a measurement or sample path of interest. The switch divides the radiation into a time series of alternating first polarized components and second polarized components that are orthogonal to the first. Each of these groups is transmitted along a separate optical path, and each is filtered to isolate a first and second wavelength band, which are unique. Spectral absorption of a substance of interest is different at each wavelength band. A beam combiner disposed to receive the first and second filtered radiation combines same into one. A detector is disposed to monitor a portion of the combined beam alternately at the first wavelength band and the second as an indication of the concentration of the substance in the sample path.

Capacitive Extensometer Particularly Suited for Measuring In Vivo Bone Strain

(U.S. Patent No. 6,059,784)

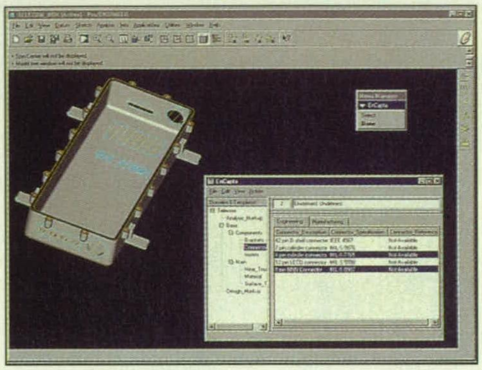
Inventor: Gail P. Perusek, Glenn Research Center

The ability of bone to form optimal structures to support loads and adapt structurally to changing loads is termed the "strain-adaptive remodeling response." It is thought that 1 to 2 Hz events during locomotion produce levels of strain on the order of 1000 to 3000 microstrain and are osteogenic. Further, it has been proposed that higher-frequency events (15 to 25 Hz) of lower magnitude (100 to 250 Hz), possibly associated with muscular contraction to maintain posture, are of importance in maintaining bone mass. Removing this stimulus in environments such as those encountered during space flight will inhibit the process of bone deposition. It is well documented that bone loss is a physiologic effect of space flight. Thus, the accurate measurement of strain within this latter range of frequencies and amplitudes is important for understanding the relationships between mechanical loading and bone remodeling. This method is directed to an extensometer, and to the operation thereof, that measures intracortial pin displacement, from which strain is calculated, and from which principal strain magnitudes and directions, maximum shear strain, and strains due to bending may be calculated via strain transformation relationships and geometric parameters of the extensometers. The extensometer comprises at least two pins adapted to be inserted into the bone, and at least two capacitive sensors mounted across the pins and providing a variable capacitance whose output is varied by the strain to which the bone is subjected. In a preferred embodiment, six sensors are arranged into three pairs, with each pair being attached to a five-sided member and oriented to each of the other pairs by an angle of 120 degrees.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. *See page 12 for a list of office contacts.*

UpFront

PRODUCT OF THE MONTH

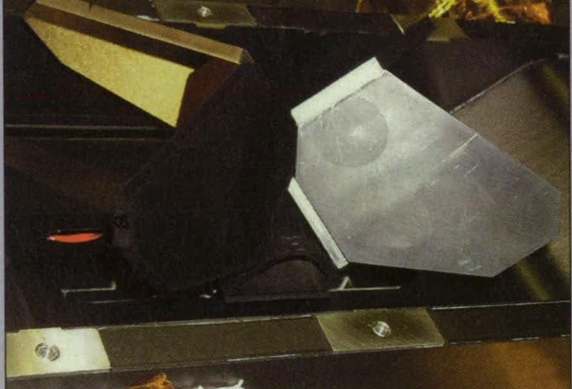


EnCapta™ software from Vistagy, Waltham, MA, augments CAD software by providing engineers with tools for capturing and communicating specialized non-geometric design data. It uses the technology behind the company's FiberSIM™ software, which provides an integrated environment in the CATIA, Pro/ENGINEER, and UGS CAD systems. Once a user captures a complete digital product definition, they can use EnCapta to distribute the information to other engineering applications and to the product development team. The software features three main components: customizable templates for defining objects, an interactive user interface, and XML tools. Data such as cost estimates, material specifications, and engineering change orders from sources such as text documents, spreadsheets, e-mail messages, and even handwritten notes can be captured and managed as objects and linked to the relevant CAD geometry. XML tools allow specific design information to be extracted from the CAD model and reported to other systems and databases.

For More Information Circle No. 735

What's New On-Line

Many of our readers have asked for electronic access to *NASA Tech Briefs* for archiving and searching purposes. Later this year, we plan to offer the option to subscribe to a .PDF version of the magazine. Right now, you can download .PDF sample issues of *NASA Tech Briefs*, *Photonics Tech Briefs*, and *Motion Control Tech Briefs*, with links from articles and ads to relevant Web pages. We're also looking at new ways to shrink file sizes and make the .PDF issues quicker to download. Go to www.nasatech.com/pdfissues to download a sample. Let me know what you think of this service at linda@abptuf.org.



Correction

In our February 2001 issue, the Application Brief on PLX's mirror assemblies used on NASA's Tropospheric Emission Spectrometer (page 22) featured an incorrect photo. The actual photo of the mirror assembly is pictured here.

You Said "IT"

In the March issue, I asked for your opinions on what "IT" is. Also known by the code name "Ginger," the invention of creator Dean Kamen has been receiving attention and much speculation from other well-known inventors. For example, Bob Metcalfe, founder of 3Com and creator of the Ethernet, has seen "IT" and claims that while it's not as important a technology as cold fusion, it is a bigger innovation than the Internet. Most guess that IT stands for "Individual Transport" and is powered by hydrogen instead of gasoline. Here's what some of you thought IT is:

- "If IT is what I think IT is, IT is a powered scooter using alternate fuels like hydrogen. Not my idea of a revolutionary invention." — J. Palcher
- "While on a business trip to British Columbia, the local paper had an article on the new car plant being built there for IT. IT was described as a small car for gated communities and the college campus. It would be electric powered, with a top speed of 30 mph, and not for general public roads. The picture of the prototype looked like an electrified 60s-era VW Beetle. Projected price would be $10,000 to 14,000." — N. Campagna
- "IT stands for a marketing gimmick that's 'interesting and tantalizing.' Dean Kamen claims that everything he invents must be to help people have better lives. However, the only person who will benefit in a big way from IT is Dean Kamen. If he wanted to truly help people, he would come up with an invention that would encourage people to exercise more, not less. He uses the technology he put into his $25,000 wheelchair to make a $10,000 gyro-balanced, one-wheel scooter that 500,000 rich people can buy as a novelty item. Yeah, this really helps the human race." — J. Paris

Reader Forum

Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

I just found an interesting article on your Web site called "Inflatable Fresnel Lenses as Concentrators for Solar Power" (March 1999 issue) from NASA's John Glenn Research Center. I would like more information on the current status of renewable energy programs in the US, as well as information on any groups that are dedicated specifically to supporting and investing in such devices. Thank you.

Tim Starns
tekton@montana.com

*(**Editor's Note:** Tim, you can find out more about NASA Glenn's work in fresnel lenses and solar power by contacting Glenn Research Center's Commercial Technology Office at 216-433-3484.)*

My inquiry concerns solvent recovery. Our company has an emission stream of isopropyl alcohol (IPA) in outgoing plant air that is routed into a thermal oxidizer for almost total destruction. The thermal oxidizer runs on #2 fuel oil at 1400(F. Our aim is to cut down on fuel consumption while recovered IPA is recycled into our daily solvent extraction process. We emit 280 pounds of IPA vapor per hour in 5,000 SCFM of plant air. We want to recover as much liquid IPA from the vapor stream as possible. The thermal oxidizer will destroy whatever is unrecoverable. I would appreciate any advice on what process may work.

Paul G. Freeman
freeman@cyburban.com
800-666-6454

This is in response to a letter in the March 2001 Reader Forum from Carl Bertrand, who requested a source for shaker tables that are capable of vibrating a full-sized van. Here at General Motors' Wentzville Assembly, we use a machine built by MTS Systems that simulates various road conditions. This equipment may be what Mr. Bertrand is looking for.

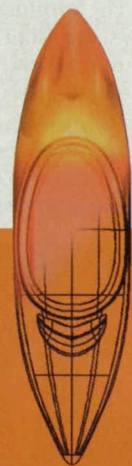
Lance Little
lance.little@gm.com

*(**Editor's Note:** Thanks for your response, Lance. MTS Systems supplies mechanical testing, simulation, and analysis equipment, and is located in Eden Prairie, MN. They can be contacted at 952-937-4000, or at www.mts.com.)*

I am researching piston loads and forces, using kinematic equations backed up by analytical software. I require a mathematical formulation on piston skirt loads. The general equations found in engineering books are only approximate and do not delve deeply enough into the explicit nature of the "rocking effect." Any assistance would be appreciated.

Stephen Golya
sg@perfectbore.com

For More Information Circle No. 409



Sixth Annual Product of the Year Awards

NASA Tech Briefs 2000 Readers' Choice Product of the Year Awards were presented at a special reception in Chicago during the recent National Manufacturing Week show. Chosen by the 200,000 readers of *NASA Tech Briefs*, the sixth annual awards recognized Gold, Silver, and Bronze winners, as well as nine Product of the Year finalists. All 12 nominees had earned Product of the Month honors during the year 2000.

Each month, the editors of *NASA Tech Briefs* choose a Product of the Month that exhibits exceptional technical merit and practical value to our readers. In December, readers are asked to vote for the one product they feel represents the most innovative product introduced during the year to the engineering community. The product receiving the most votes wins the Gold award as is named Product of the Year.

The 2000 Readers' Choice Product of the Year Gold winner was, for the first time in six years, not a software product. The Century-C/M™ series of enclosed flat-panel computers and monitors from Computer Dynamics of Greenville, SC, was the top product of last year. The award was accepted by Sue Priester, manager of marketing communications for Computer Dynamics (www.cdynamics.com).

2000 Readers' Choice Award winners and finalists gather at the John Hancock Center in Chicago (left to right): Gregory Donahue of The MathWorks, Chuck Mitchell of SGI, Gold Award Winner Sue Priester of Computer Dynamics, Silver Award Winner Magnus Ringh of COMSOL, Kimara Andreas of Network Technologies, and Geoffrey Rogers of IBM. (Photo by Michael Kardas)

The Century-C/M monitors and computers feature an analog resistive touchscreen for operator input, and are available with or without a membrane keypad. They come in four display sizes: 10.4" VGA, 12.1" SVGA, 15" XGA, and 18.1" SXGA. They feature Celeron CPUs to 500 MHz and include two RS-232 ports, two RS-232/422 ports, parallel port, mouse and keyboard/speaker connectors, a 6.4-Gb hard drive, and 10/100BaseT Ethernet. The front display unit also can be detached from the rear electronics unit.

The Silver Award was presented to COMSOL of Burlington, MA (www.comsol.com), for its FEMLAB® multiphysics modeling and analysis software that automates methods of parametric analysis and design optimization. The award was accepted by the company's vice president of sales, Magnus Ringh. The software runs on top of MATLAB® technical computing software from The MathWorks (Natick, MA), and can model virtually any physical phenomena with partial differential equations, including heat transfer, fluid flow, electromagnetics, and structural mechanics. It's available for most operating systems, and can import DXF drawing files from CAD software.

CUI Stack (www.cuistack.com) of Beaverton, OR, took the Bronze Award for the IESP and IESF Series miniature pressure sensors that use a proprietary material called Inastomer. The material provides elasticity and conductivity, allowing the sensors to continuously react to the degree of pressure applied. The Resin Molded Cover and Flexible Board sensors are used in clearance sensitivity, object contact, roll pressure, and fingertip contact pressure sensing.

The Computer Dynamics team celebrates their Gold Award. Marketing communications manager Sue Priester is flanked by (left) Andy Zuidema, regional sales manager, and Walter Kivett, senior applications engineer. (Photo by Michael Kardas)

The following companies were honored as Product of the Year Finalists for 2000:

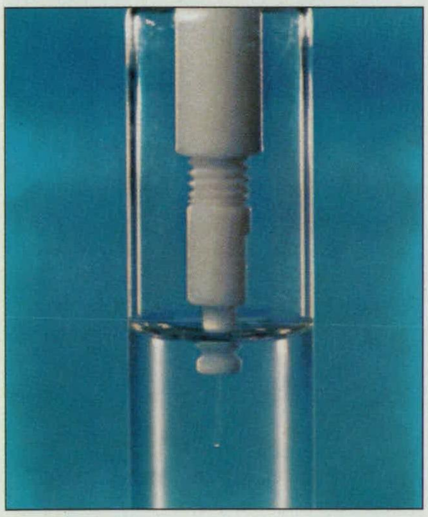
- Agilent Technologies, Colorado Springs, CO, for the 54600 series of oscilloscopes (www.agilent.com)
- Autodesk, San Rafael, CA, for Autodesk Inventor Release 2 3D solid modeling software (www.autodesk.com)
- Capital Equipment Corp., Billerica, MA, for the webDAQ/100 Web-based data acquisition device (www.cec488.com)
- IBM Engineering Solutions, Dallas, TX, for CATIA Version 5 Release 4 CAD/CAE software (www.ibm.com/catia)
- Labtec, Vancouver, WA, for the Spaceball 4000 FLX 3D motion controller/input device (www.labtec.com)
- The MathWorks, Natick, MA, for Version 6 of MATLAB technical computing software (www.mathworks.com)
- Network Technologies, Aurora, OH, for the Universal Matrix KVM keyboard-video-mouse switches (www.nti1.com)
- SGI, Huntsville, AL, for the Zx10 ViZual workstations (www.sgi.com)
- Xerox Engineering Systems, Stamford, CT, for the MAX 200 wide-format digital document system (www.xerox.com)

NASA Awards Inventions of the Year

NASA has chosen an optical fiber stripping fixture and a hazardous waste conversion process as the top inventions of 2000. Researchers from Goddard Space Flight Center have received the NASA Government Invention of the Year Award for the Optical Fiber Cable Chemical Stripping Fixture. NASA's Commercial Invention of the Year Award was given to a team from Kennedy Space Center for developing both a process and the equipment to convert hazardous waste into fertilizer. Although these products originated from NASA research centers, each has the ability to make an impact on a much wider range of industries.

Chemical Treatment of Optical Fiber Cable

In a typical fiber-optic system, one of the most difficult tasks is cutting and connecting cable so it is aligned precisely. Misalignment of even 1/10,000 of an inch can result in a 50% loss of transmission speed. But before a connector assembly can be attached to the terminated fiber, a certain portion of the coating must be removed or stripped from the glass fiber.



The delicate optical fiber cable is immersed in a solvent solution in order to remove the stripping.

Alexander Coleman and John Kolasinski of NASA's Goddard Space Flight Center in Greenbelt, MD, designed the Optical Fiber Cable Chemical Stripping Fixture — NASA's Government Invention of the Year — for stripping a fiber-optic cable chemically. The invention offers both the ability to remove a wide array of coatings, such as acrylate and polyimide coatings, and it offers precise control over the stripping length and resulting interface. This high degree of control helps eliminate damage to the fibers that can occur with other stripping methods.

Common methods of removing stripping from optical fibers proved problematic. Older methods often used electrical wire-stripping techniques or were done by hand. Mechanical removal techniques caused nicks, scratches, and other damage to the fragile fibers.

The fixture grips and perfectly aligns the fibers. It holds the jacketed glass fiber in a chemical solution for stripping of the coating layer. The fiber, with its inner and outer jackets trimmed away from its end, is threaded through the fixture's handle and body. The protruding end of the fiber is immersed in the stripping solution, which softens the coating for removal.

The process was successfully used on a number of spacecraft, and the Hubble Space Telescope (HST) Solid State Recorder. Cables treated by the process are being used in aircraft produced by both Boeing and Lockheed Martin, as well as on the International Space Station and in other harsh environment applications. *For more information on this invention, go to http://icb.nasa.gov/IOY2000/gsc13644.rtf*

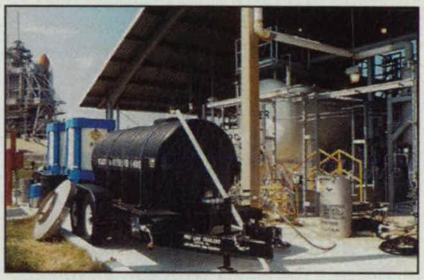
Converting Hazardous Waste to Fertilizer

NASA's Commercial Invention of the Year comes from a group of scientists and engineers from Kennedy Space Center (KSC) in Florida. Developed by Dr. Clyde Parrish, Dr. Dale Lueck, and Andrew Kelly of KSC, and Paul Gamble of Dynacs Engineering, the process converts hazardous rocket-fuel waste into a useful byproduct.

The idea came from a Navy project Dr. Parrish had worked on 25 years ago, which found that an oxidizer used in battlefield illumination flares could serve as a fertilizer. Specifically, the process was created in response to an agency request to help reduce the hazardous waste stream being captured in a scrubber when a toxic oxidizer is transferred back and forth from storage tanks into the space shuttle's Orbital Maneuvering Subsystem (OMS) and Reaction Control System (RCS) pods. Since the shuttle's OMS and RCS systems are used in a number of important orbital maneuvers, a tremendous amount of toxic nitrogen oxides were being produced.

Ongoing tests proved that the new emissions control system could eliminate the current level of scrubber liquor waste and lower the nitrogen oxide emissions by one to two orders of magnitude. The new scrubber liquor starts with 1% hydrogen peroxide at a pH of 7, and automatically adds hydrogen peroxide to maintain the 1% concentration and potassium hydroxide as required to maintain a neutral pH. The result is the formation of a solution of potassium nitrate (fertilizer), which is beneficial to the citrus crops at KSC, where the process is tested.

Researchers discovered that the new conversion technique eliminated the second largest waste stream at KSC and provided a significant cost savings. Since then, the invention has been licensed to Phoenix Systems International (McDonald, OH), an engineering firm that develops technologies used in utility and fossil fuels. The United States Air Force also has expressed interest in establishing a version of the system at Cape Canaveral Air Force Station.



A scrubber shed on the grounds of Kennedy Space Center, where the hazardous materials are converted to fertilizer. A shuttle launch pad is visible in the distance.

For more information, access the tech brief at http://www.nasatech.com/Briefs/Oct98/KSC11884.html or visit http://dynacs.ksc.nasa.gov/Scrubber/.

NASA's Government and Commercial Inventions of the Year are selected by NASA's General Counsel and supported by the agency's Inventions and Contributions Board (ICB). For a list of the winners and nominees for 2000, visit the ICB Web site at: http://icb.nasa.gov/invention.html.

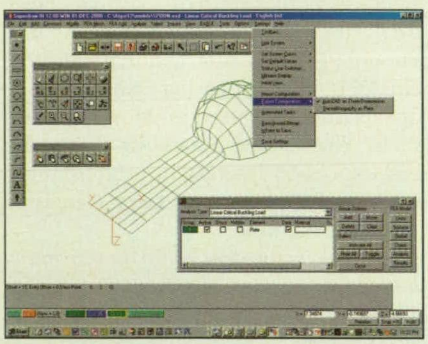
Algor 12: A New Face for Classic FEA

Steven S. Ross

There's a new face on many of Algor's Windows packages: The finite element analysis (FEA) software company introduced a new user interface across its product line this winter. You can now bring up many commands with a right-click of the mouse, allowing you to modify and remove loads and constraints on your finite element analysis, whether you are using an Algor package for piping, steel beams, or anything else.

The beauty is more than skin deep. Algor continues to make it easier to move designs into its analysis software with a minimum of fuss and a maximum of accuracy.

Algor's InCAD-Plus product family — which creates finite element meshes inside standard CAD software — has expanded (there's now a complete version for Autodesk Inventor), and its own Superdraw package (now Superdraw III) has gotten easier to use. InCAD costs $975, no matter which version you use. You add it to your own CAD or solid modeling package. Rather than simply adding a few menu commands to the CAD package's interface, InCAD pops up with its own, consistent commands. In all cases, it can grab a CAD model while the model is still in memory. Generally, the InCAD package does not even have to reside on the same computer as the CAD package that's authoring the model in the first place. Algor can open a model for viewing and analysis without the original CAD program being present.



Welcome to the functional Superdraw III screen. Preparation for analysis and multiple views can be done from this command center.

InCAD add-ons capture the original part names from the CAD model. They can model thin, solid parts such as vehicle skins or plate/shell elements by building an FEA mesh on the part's midplane, but you specify a thickness. Algor continues to be able to import "standard" CAD files such as IGES, DXF, CDL, STL, and ACIS, of course.

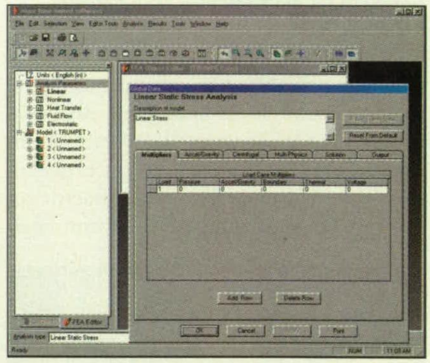
One can sense from the releases of the past year that Algor has begun to emphasize an area of FEA that it has been a leader in — mechanical event simulation (MES). In "classical" FEA, you mathematically impose a load, and see what happens to your assembly or part. If you suspect that the results will be misleading because the behavior of the assembly or part will feed back and affect the load, you break the event into small time steps. Each step is based on the load-and-deformation calculations of the step before it.

This time step approach is common among all major FEA vendors. The trick is to find the right step interval. Most engineers seem to simply select a very small interval to minimize the chance that the calculations will diverge massively from reality. Besides, the calculations are performed quickly on modern computers, so the smaller the better, unless the expected motions are very large. Where motions are large, the tendency has been to use basic kinematics calculations to handle the motion, and then slam the finite element model to do a basically static finite element analysis.

Algor's MES approach, in a sense, anticipated the needs that would be posed by the new class of design software. MES models motion, deformation, and stress (multiple stresses, actually) in a single pass. There's also a collection of "multiphysics" packages that allow modeling of, say, thermal and mechanical loads at the same time. The new interface improvements make it easier to set up an MES while minimizing input errors.

Improvements are obvious in such areas as:

- Defining load and constraint sets for various design and test (MES or plain FEA) scenarios, so you can perform multiple tests on the same part with just a few keystrokes to change a variable. The FEA loads and constraints are nicely displayed — better than ever before.
- The input screens for loads and constraints fully support Windows cut-copy-paste functions, so you can duplicate runs you've already made on another part or assembly.
- A tree view of model parts and associated data, which can be used to select individual parts and construct FEA "meshes" within them. You can also open multiple views of the same model on the screen.
- Surface-based constraint capabilities. You can apply certain loads and constraints such as boundary conditions to the entire surface instead of applying them one mesh node at a time. Also, you can select entire surfaces and parts from the tree view or by clicking on the model in any window.



The parts tree and analytical needs are all in the tree view at left.

Need to do a complex analysis? FEA and MES are still not for amateurs. But the bar continues to get lower. Need to review analyses done by others? Algor offers many tutorials on-line, and a free Webcast every Tuesday morning at 10 AM Eastern time. Contact Algor at: Tel: 412-967-2700; www.algor.com

Steve Ross is an associate professor of journalism at Columbia University, where he runs the science writing program and teaches analytical journalism. His 18 books and three commercial software packages include several on statistics and quality control. His undergraduate degree is in physics.

Who's Who at NASA

Lee Holcomb, Chief Information Officer, NASA Headquarters, Washington, DC

As the Chief Information Officer (CIO) for NASA, Lee Holcomb reports directly to the NASA Administrator and is responsible for the development of information resource management strategies, policies, and practices, including strategic planning; standards in computing, networking, and security; and establishment of system and information architectures.

***NASA Tech Briefs*: As NASA's CIO, what role do you play in both the agency's business and research areas?**

Lee Holcomb: The CIO position is a Congressionally mandated position in every agency under the Klinger-Cohn Act, which defines a set of responsibilities for the office such as setting policy, guiding capital investments in IT, developing an agency architecture, and ensuring that the workforce is adequately trained and staffed. My position includes two other important aspects. One of those is being accountable for IT security for the agency and overseeing the implementation of security aspects of all the non-classified, unclassified systems. The other important area is related to how I came into this job, which was from the Research & Development Office here at NASA Headquarters. Having worked in producing that technology, it's interesting to see the other side and try to figure out how you implement technology, and how you insert it into NASA's business.

NTB: How do you show people that NASA is more than just shuttle flights and aerospace technologies?

Holcomb: We are supporting an activity called e-NASA, which looks at how NASA does its business. We have organized the e-NASA initiative around four communities, one of which is suppliers. These are companies and universities that want to do business with NASA and we hope, through this strategy, to develop a portal that will allow them to become more knowledgeable about NASA. The second area is how we work with our partners in industry on collaborative projects. Our third portal is aimed at employees and how we support them, including benefits, financial systems, and travel. The last portal supports the general public - people who are just looking for information from NASA, technology transfer, educators and students, and people who want life-long learning. It is through this fourth portal that we try to reach out and educate the public very broadly on what NASA does.

NTB: What changes are you making to improve communication with these four target areas?

Holcomb: On the supplier side we have, through our automated system, the ability to post opportunities to compete. Any time there's a new solicitation, an announcement of opportunity, or contract opportunity, they get posted electronically. But we want to go beyond that and provide a portal through which suppliers can be put on a level playing field with others who may want to bid. We need people to understand the technical and other rationale behind a particular program or project.

We're doing a pilot with several vendors who provide electronic commerce capabilities so that we can do a procurement process or announcement of opportunity electronically. Once we actually do award a contract or a grant, we can get into supply chain management through these automated systems. And again, that depends on the infrastructure being in place so that you can not only award a contract, but you also can track the availability of certain components.

NTB: What other e-NASA initiatives are being developed?

Holcomb: We're looking at two initiatives. One is My NASA, a portal that you could come into much the way you come into Excite, and you can customize the NASA Web site for your interests. The other one is called My Space Link, which is really aimed at teachers and educators to help point them in the direction of relevant materials for coursework, and for students who want to do a project using data from NASA or NASA facilities.

A full transcript of this interview appears online at www.nasatech.com. Mr. Holcomb can be reached at lee.holcomb@hq.nasa.gov

May 2001

PHOTONICS Tech Briefs

PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER

MEMS Meets Photonics

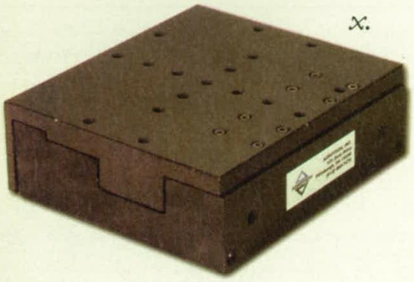
New Products—*see page 22a*

www.ptbmagazine.com

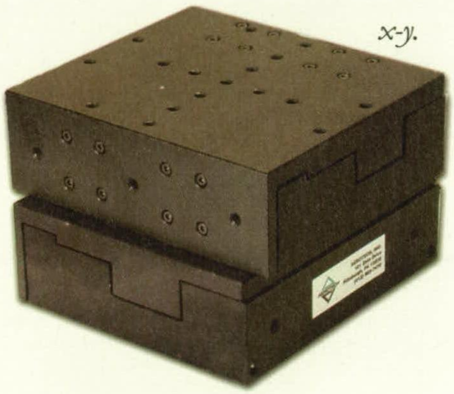
Welcome to the

ANT-25L in side-mount configuration

x.



x-y.



x-y-z.

The Aerotech Nano-Translation (ANT™) stages combine speed, accuracy, resolution, repeatability, and reliability in a very small package. No other fiber-automation tool manufacturer has successfully combined all of these features into a single product offering designed to meet the rigors of a 24/7 manufacturing environment. Our Aerotech Nano-Translation stages are ready to take your manufacturing process to the next level.

ANT-25L

Length × Width × Height: 100 × 90 × 33 mm midtravel

Travel: 25 mm

Resolution: 10 nm

Accuracy: ±2 μm standard; ±0.3 μm calibrated

Repeatability: ±50 nm

Max Load: 5 kg

Velocity: 250 mm/s

ANT-25L (x-y)

Optical Axis Height: 66 mm

Length × Width × Height: 100 × 100 × 66 mm

Travel: 25 mm × 25 mm

Resolution: 10 nm

Accuracy: ±2 μm standard; ±0.3 μm calibrated

Repeatability: ±50 nm

Max Load: 5 kg

Velocity: 250 mm/s

ANT-25L (x-y-z)

Optical Axis Height: 116.8 mm

Length × Width × Height: 100 × 100 × 116.8 mm

Travel: 25 mm × 25 mm × 5 mm

Resolution: 10 nm XY; 2 nm Z (vertical)

Accuracy: ±2 μm standard; ±0.3 μm calibrated

Repeatability: ±50 nm

Max Load: 5 kg

Velocity: 250 mm/s XY; 50 mm/s Z (vertical)

AEROTECH®

Dedicated to the Science of Motion

AF0401A

PHOTONICS Tech Briefs

Supplement to *NASA Tech Briefs'* May 2001 Issue Published by Associated Business Publications

Feature

Tech Briefs

Departments

On the cover: *Laser mirrors. Photo courtesy Linos Photonics, Göttingen, Germany*

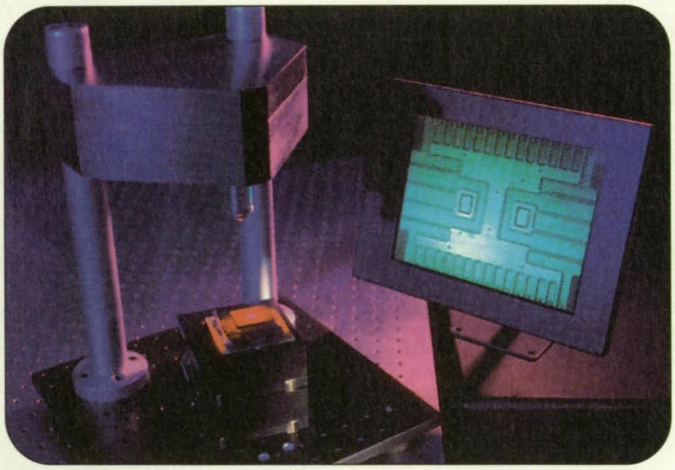
MEMS Invades the Photonics Realm

Driven by the telecommunications boom, manufacturers are marrying microtechnology to photonics more and more.

By now, any photonics professional conversant with the state of high-technology industry has encountered the acronym MEMS — and probably knows that it stands for microelectromechanical systems — particularly given the prominent presence of MEMS companies at SPIE's Photonics West, OSA's Optical Fiber Communications Conference, and other photonics trade shows in the last year or two. In fact, it is a sign of the times that, so eager are MEMS companies to identify their technology with photonics, they often expand the acronym to MOEMS, standing for micro-optoelectromechanical systems. And though it is the boom in the telecommunications field that has driven many MEMS manufacturers into the arms of the photonics industry, the fundamental methodology has been around for more than a decade, and is incorporated into such devices as accelerometers for air-bag deployment and other uses, into pressure and temperature sensors, digital cameras, medical imaging instrumentation, and a host of other familiar devices.

A MEMS device can be inclusively defined as any micro- or millimeter-sized system that has been fashioned using the standard high-volume deposition and fabrication methods of the semiconductor wafer industry and includes one or more movable parts controlled by a computer's "intelligence." The microactuator, switch, or other component can be moved by magnetism, the piezoelectric effect, the electrostatic effect, or thermal changes. An optical MEMS device can incorporate actuators, sensors, integrated circuits, and microfluidic components. It can incorporate lasers, mirrors, gratings, couplers, attenuators, crossconnects, and many another photonic device.

One prominent MEMS success story is IntelliSense Corporation of Wilmington, MA, a provider of MEMS software, design services, development, and manufacturing and now a subsidiary of Corning Inc. The company's IntelliSuite™ is a MEMS-specific CAD tool for optimizing performance, generating the fabrication process, determining static and dynamic effects, and creating manufacturable designs. The software's performance analysis capabilities include electrostatic, mechanical, thermal, fluidic, magnetic, piezoelectric, and package. IntelliSense's development capabilities include device and process layout, design for manufacturing and packaging, prototyping and transfer to manufacturing. In the latter vein, the company can do bulk and surface micromachining, and high-aspect-ratio micromachining. Process capabilities encompass lithography, wet and dry etch, deep reactive ion etching, sputtering, evaporation, electroplating, and more. Test and assembly strengths include metrology, wafer, die and wire bonding, dicing, flip-chip bonding, optical assembly and testing, and wafer, die, mechanical and electrical testing.



The Etec MEMS Motion Analyzer is a turnkey system for characterizing the complex motions of MEMS/MOEMS.

In a recent white paper titled "Building Reliable MEMS Micromirrors," the IntelliSense team of Dan Green, director of telecommunications marketing, Ajay Pareek, MEMS development engineer, and Greg Kirkos, MEMS design and development engineer, describe the intersection of MEMS and photonics in the production of silicon micromirrors. As MEMS devices have reached into more and more applications, they say, engineers in a variety of fields learned of their durability. In the aerospace industry, MEMS sensors came to be relied upon for inertial guidance in aircraft. The devices were soon finding their way into automotive fuel systems and air-bag inflators. Nozzles for household printers reliably metered ink onto pages. Tiny biosensors went into portable analytic equipment for highly accurate assays.

Finally, the telecom industry, in need of reliable and compact means of switching signals from fiber to fiber, had to be persuaded that a synchronized field of tiny silicon mirrors could be employed to reflect millions of streams of light from a bundle of fibers in optical switches. The telecom industry demanded a small-form-factor, high port-count, transparent, and very reliable switch. From IntelliSense's point of view, it was evident that silicon was up to the job. With a strength many times that of steel and a resistance to plastic deformation, silicon had proven that it was a resilient material that easily returned to its original state when twisted or bent. "When well engineered and combined with intelligent packaging and systems design," the authors say, "silicon micromirrors can meet the challenge of reliably switching signals from fiber to fiber for years."

IntelliSense has tested the fatigue characteristics of the various silicon flexure designs it knows of by running them in durability tests. In a recent accelerated life-trial test, an array's mirrors were flexed through more than a billion cycles without discernible permanent deformation or fatigue. At ordinary switch addressing rates, the company says, the installed life of a micromirror array would be more than a century.

IntelliSense's is not the only optical MEMS design platform available. Coventor of Cary, NC, is offering CoventorWare™, which is based on the company's MEMCAD. Coventor says that the new program extends the standard to include capabilities for system-level design that will save months of designs time and yield a more thoroughly analyzed design. Among the optical components the software

enables are tunable lasers and filters, variable optical attenuators and equalizers, optical add/drop multiplexers, optical switches and crossconnects, dispersion compensators, polarization controllers, planar lightwave circuits, modulators, wavelength division multiplexers and demultiplexers, and integrated optical systems.

Starting with the software's optical MEMS parametric models, CoventorWare lets the designer evaluate their behavior along with the behavior of other optical elements, electronic control circuitry, and the packaging. The company says a first-pass accurate simulation is possible in a matter of minutes. When design is complete, the user can perform selective verification — including finite element, boundary element, optical beam propagation, finite difference, and volume of fluids modeling. Then he can output a file for mask generation and fabrication.

Many of the products on display at the recent SPIE and OSA conferences were for the testing and characterization of MEMS devices. Typical of these was the new MEMS Motion Analyzer from Etec Inc. of Peabody, MA. The company describes the Motion Analyzer as combining video microscopy, stroboscopic illumination, and proprietary algorithms to analyze the motions of individual microstructures, or arrays of microstructures, simultaneously. The system measures motion in six degrees of freedom, with nanometer resolution, at frequencies from 1 Hz to 10 MHz. Etec calls the Motion Analyzer suitable for testing and characterizing the complex motions of virtually any MEMS/MOEMS device, including variable optical attenuators, optical switches, optical crossconnects, and 2D and 3D micromirror arrays. Among the parameters the system can analyze are resonant behavior, transient response, settling time, switching time, and complex motion profile, all with simple point-and-click operation.

Late last year Etec and Edmund Industrial Optics of Barrington, NJ, entered into a strategic alliance to develop and produce wafer and die test systems for optical MEMS. Edmund Industrial Optics is a designer and manufacturer of optics and optical systems for high-performance machine vision and optical analysis systems. Edmund will provide the optical metrology engine that will interface to Etec's M/SteP™ automated MEMS test system.

Cascade Microtech of Beaverton, OR, has integrated its Summit Series wafer probing system with the Polytec Micro-Scanning Laser Vibrometer (MSV), making possible automated noninvasive device characterization during MEMS optical switch manufacturing. Cascade says that the Polytec MSV does noncontact deflection measurement using a targeted laser spot at selected points on each device. In the MSV's vibration-isolated and shielded MicroChamber® switch response characteristics such as deflection amplitudes, settling times, resonant frequencies and crosstalk can be determined.

Roger Grace, president of Roger Grace Associates of Naples, FL, a leading consultancy in MEMS technology, will chair an all-day session addressing "Microelectromechanical Systems (MEMS), Microsystems Technologies (MST), and Micromachines" at the Sensors Expo Spring 2001 in Rosemont, IL, on Wednesday, June 6. Joining Grace will be more than 25 other leaders in the subject area, who will present information on technology roadmapping, market size, current research, and applications. A technical poster session is also planned for the day.

The exhibition and technical conference will be held at the Donald E. Stephens Convention Center (formerly Rosemont Center) in Rosemont, IL, near Chicago, from June 4-7. For further information, contact Kristen Blankenship or Roger Grace at Roger Grace Associates; (941) 596-8738; fax: (941) 596-8762; e-mail: rgrace@grace.com.

A recent Roger Grace/Nexus study reports that the worldwide MEMS/MST/Micromachines market will grow from approximately $14.2 billion in 2000 to a projected $30.4 billion by the year 2004.

Get connected with the companies mentioned in this article:

IntelliSense Corp.
www.intellisense.com

Coventor
www.coventor.com

Cascade Microtech
www.cascademicrotech.com

Etec Inc.
www.etec-inc.com

Edmund Industrial Optics
www.edmundoptics.com

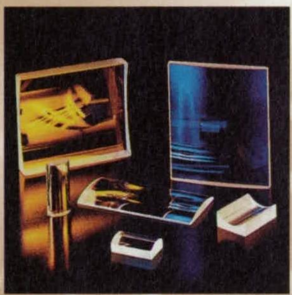
Create
Transform
Detect

See Us at CLEO Booth #241

Custom Optics and Coatings

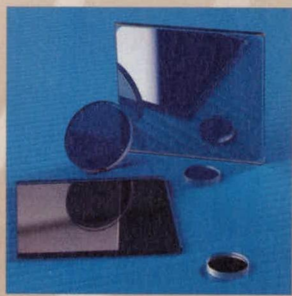
Standard Components • Custom Designs • Production Quantities • JIT Delivery

Melles Griot manufactures both standard optical components and custom optics designed to your unique material, surface, and coating requirements. Call us. Our applications engineers will work with you to develop the right optic for your application — in the production volumes you need, on time, and at a competitive price.



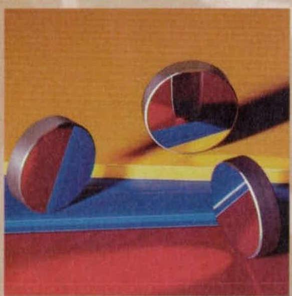
Lenses

- Achromatic
- Singlet, doublet, and triplet
- Cylindrical
- Beam expanding and collimating



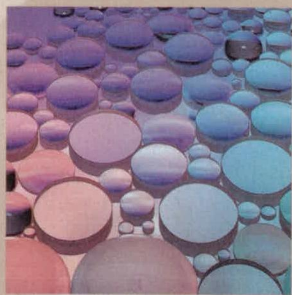
Filters

- Neutral density
- Colored glass
- Short/long pass
- Interference
- Hot/cold



Mirrors

- High energy laser
- Protected silver
- Broadband UV
- Hot/cold
- Flat, curved, parabolic



Optical Coatings

- Custom design or standard
- Ultrafast
- Antireflective
- High energy
- Hard and durable

NEW Coating Poster
Request Your FREE Poster Today!
Call 1-800-835-2626
www.mellesgriot.com/mg266.htm

BUY ONLINE!
shop.mellesgriot.com

the practical application of light

MELLES GRIOT

For More Information Circle No. 483 or Visit www.nasatech.com/483

PHOTONICS COMPONENTS
16542 Millikan Avenue • Irvine, California 92606 • 1-800-835-2626 • (949) 261-5600 • FAX (949) 261-7790 • E-mail: sales@irvine.mellesgriot.com

Asia +81 (03) 3407-3614 **Europe** +31 (0316) 333041

www.mellesgriot.com

A member of Barlow Scientific Group Ltd.

PHOTONICS *file*

Recent photonics briefs published in NASA Tech Briefs

Many photonics-related briefs from NASA's field center laboratories appear in *NASA Tech Briefs* rather than in the *Photonics Tech Briefs* supplement. Listed here are some from issues of *NASA Tech Briefs* just past, edited for brevity and indexed with reference to original publication and the availability of a Technical Support Package on *Photonics Tech Briefs'* web site.

NASA Tech Briefs *January 2001, page 46*

Humidity Interlock for Protecting a Cooled Laser Crystal (NPO-20901)

A humidity interlock has been developed at Jet Propulsion Laboratory to prevent damage that could be caused by condensation of water on a delicate and expensive laser crystal that must be maintained at a temperature below ambient during operation. The interlock is installed in conjunction with the laser's temperature controller system. Whenever the humidity inside the laser housing rises beyond a safe level, the humidity interlock turns off power to a thermoelectric cooler on which the laser crystal is mounted.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs *February 2001, page 44*

Heterodyne Interferometer with Phase-Modulated Carrier (NPO-20740)

Researchers at Jet Propulsion Laboratory say that a heterodyne optical interferometer of a type used to measure small displacements can be augmented to suppress a phenomenon, called "self-interference," that tends to limit the achievable resolution and working distance and can even render the interferometer inoperable. Self-interference is caused by optical scattering, imperfections in optical surfaces, and misalignment of optical components. An interferometer of this type includes a target and a reference optical path. Self-interference typically manifests itself as leakage, along the reference path, of part of the optical signal power intended to propagate solely along the target path. This leakage, in turn, manifests itself as a heterodyne signal with incorrect phase that competes against the heterodyne signal with the correct phase.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs February 2001, page 58

Process for Polishing Bare Aluminum to High Optical Quality (GSC-14147)

Scientists at Goddard Space Flight Center have devised a process for making precise, high-quality curved or flat mirror surfaces on bare aluminum substrates. It consists of diamond turning to establish the desired surface figure, followed by a polishing subprocess that is mostly conventional except that the polishing compound is India ink, sometimes diluted with water. This process can maintain a surface figure accurate to within a peak-to-valley error of as little as 1/8 wavelength and can produce a finish characterized by a root-mean-square roughness of less than 8 angstroms. The process creates the possibility of fabrication of precise mirrors that, because they could be made entirely of aluminum, would be lightweight, relatively inexpensive, and thermally stable over wide temperature ranges.

For further information, access the Technical Support Package (TSP) ***free online at www.ptbmagazine.com*** *under the Manufacturing/Fabrication category.*

NASA Tech Briefs April 2001, page 38

A Metric for Visual Quality of Digital Video (ARC-14236)

A research team at Ames Research Center has developed "digital video quality" (DVQ), a metric for evaluating the visual quality of digitized video images. It was developed in an effort to incorporate mathematical models of human visual processing while maintaining computational efficiency so that accurate metrics can be computed in real time by use of modest computational resources. DVQ incorporates aspects of early visual processing, including dynamic adaptation to changing brightness, luminance, and chromatic channels, dynamic contrast masking, and summation of probabilities.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Information Sciences category.*

Determining Particle Sizes From Scattered-Photon Statistics

A relatively simple, compact apparatus quickly yields approximate results.

John H. Glenn Research Center, Cleveland, Ohio

A method of determining sizes of particles suspended in liquids and engaging in Brownian motion involves statistical analysis of counts of photons of laser light scattered by the particles. The method can be implemented by a compact, portable apparatus that can be used, for example, in monitoring of colloidal suspensions, characterization of suspended protein molecules, and the like.

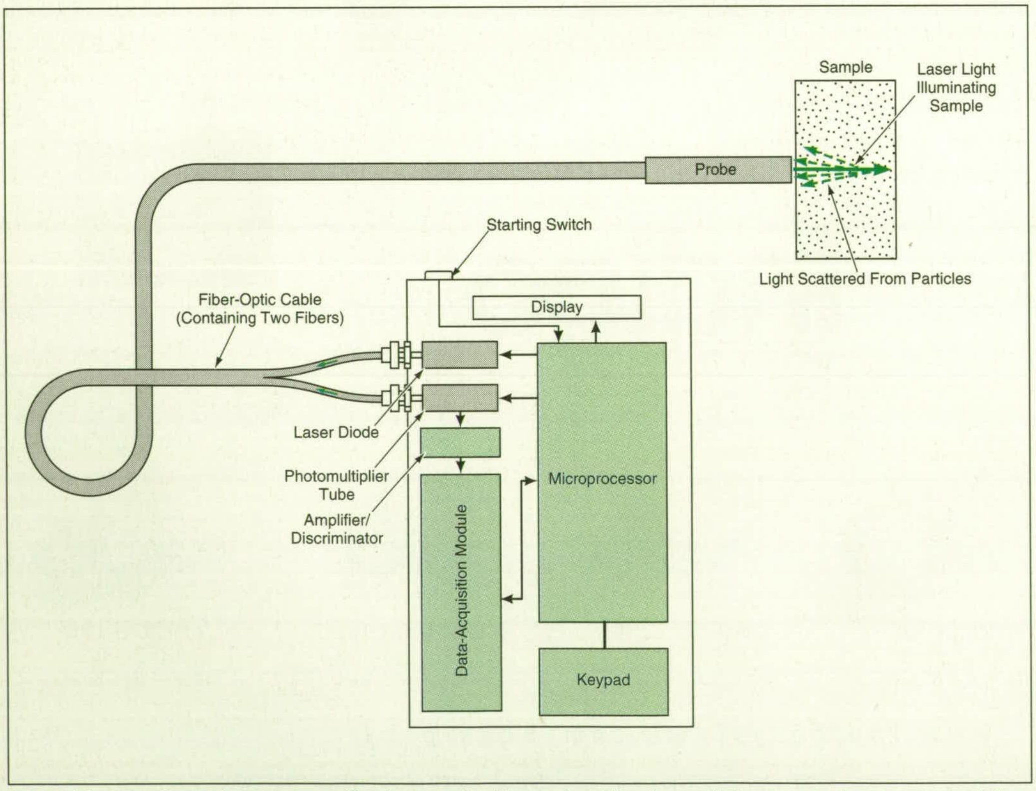
In the prior state-of-the-art light-scattering method for determining particle sizes, one performs a digital correlation followed by an ill-conditioned inversion to obtain a particle-size distribution. The disadvantage of the prior method is that the equipment (especially the computer needed to perform the correlation) is expensive and usually too large and complex to be portable, and the measurements and computations take a few minutes. In the present method, one does not obtain a particle-size distribution; on the other hand, one can estimate the average size of light-scattering particles in a sample after a measurement and computation time of a few seconds.

This method is an instance of photon-correlation spectroscopy (PCS). As such, it is closely related to dynamic-light-scattering (DLS) methods, which are based on 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. The differences between DLS and PCS arise from the fact that in DLS, one operates photodetectors and associated signal-processing circuits in a photocurrent-measuring regime, whereas in PCS, one operates in a photon-counting regime.

The theoretical basis of the present method is not simple; the mathematical derivation would greatly exceed the space available for this article. However, the underlying theory yields an important benefit: In comparison with other light-scattering methods for measuring particle sizes, this method is relatively simple in practice and involves much less computation.

A typical apparatus used in the present method (see figure) includes a laser diode as the source of light. A monomode optical fiber delivers the light to a probe that is placed in contact with, or proximity to, a sample. A short length of multimode optical fiber with a gradient in the index of refraction is fusion-spliced to the end of the monomode fiber to provide focussing of the light delivered by the probe to the sample. The light emerging from the probe illuminates a small volume in the sample. A portion of the light back-scattered from particles in the sample is collected by the probe, and a second optical fiber couples this collected light to a photomultiplier tube. Under control by a microprocessor, the photomultiplier output is processed by an amplifier/discriminator to obtain equal-amplitude voltage pulses at times that correspond to the times of arrival of the collected scattered photons and then processed by a data-acquisition module.

The aforementioned lengthy mathematical derivation elucidates the relationships among temporal coherence of scattered light, photon-counting statistics, and average particle size. One of the results of the derivation is that the temporal coherence of the scattered light depends on both the integration time and the particle diameter. Consequently, it is possible to estimate the average particle size from the degrees of coherence of the photon counts accumulated during two different integration times — T and KT. The values of T and K are chosen to cover a reasonable range of particle sizes by use of the fastest available electronic circuitry. For example, the choice of T = 200 ns and K = 25 makes it possible to estimate diameters from 5 to 3,000 nm.



A **Portable Optoelectronic Instrument** illuminates a liquid sample with coherent light, counts photons scattered from particles suspended in the liquid, and computes the average size of the particles from photon-counting statistics.

This work was done by Harbans S. Dhadwal and Kwang I. Suh of the State University of New York 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. Refer to LEW-16706.

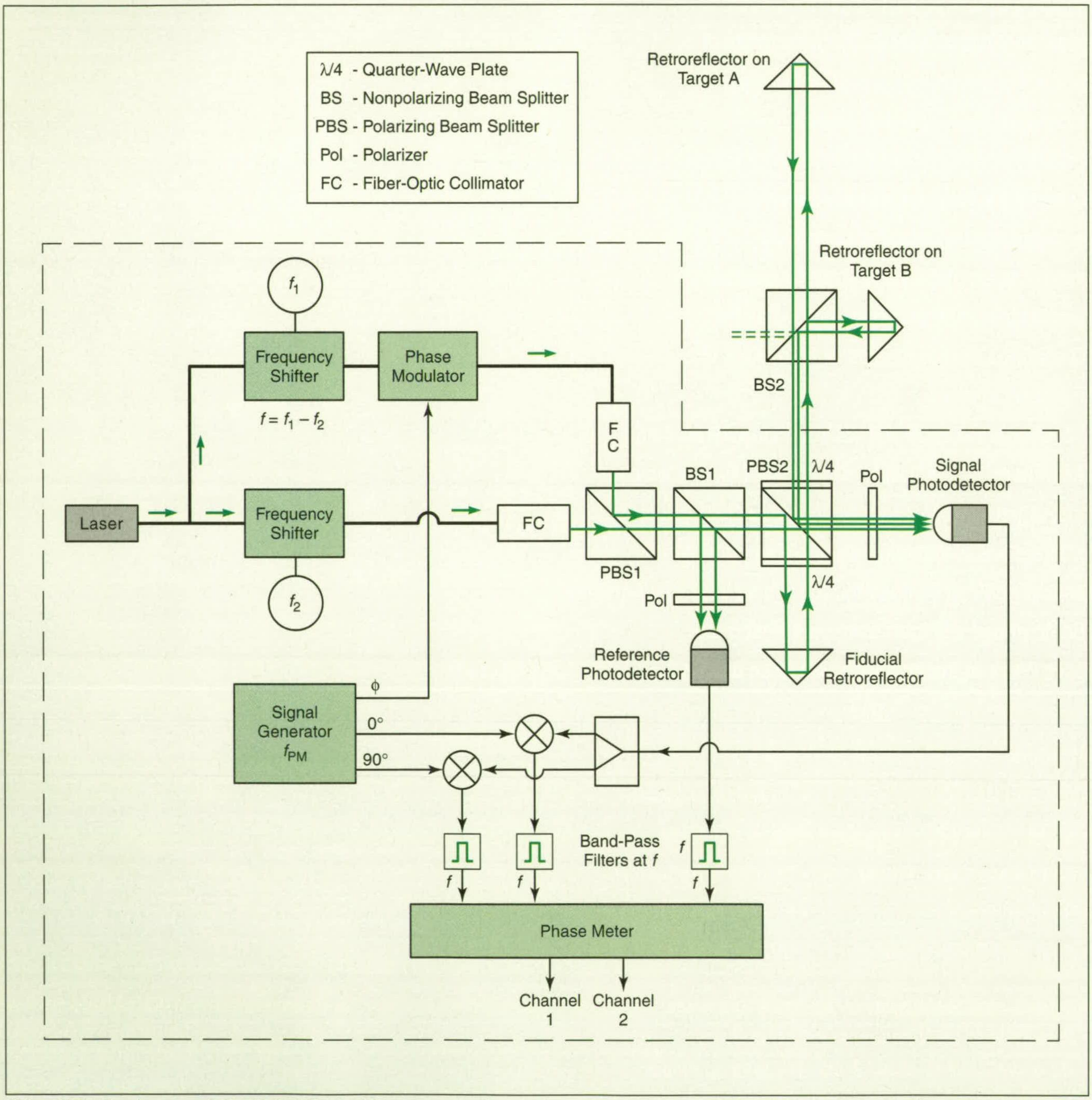
Dual-Target, Single-Laser Metrological System

It is not necessary to use two lasers with separate sets of components.

NASA's Jet Propulsion Laboratory, Pasadena, California

A single-laser-based, heterodyne optoelectronic system that measures the displacements of two targets along the same lines of sight has been developed. Heretofore, it would have been necessary to construct a two-target laser metrological system as two partly or wholly independent subsystems, each containing a set of optoelectronic components (including, possibly, its own laser) that must be aligned separately. The present system contains only one laser, and with the exception of the targets themselves, all optical and electronic components function together as a single system that generates a separate measurement of the displacement of each target.

More precisely, the system (see figure) measures the displacement of a retroreflector on target A and a retroreflector on target B along an optical path between each target and a fiducial retroreflector. (The portion of the optical path below beam splitter 2 in the figure is common to both targets.) Light from the single laser is launched along a single-mode optical fiber, which is split into two arms. The beams in the arms are shifted in frequency by f_1 and f_2, respec-



Using Only One Laser and One Set of Optical Components, the apparatus depicted schematically within the dashed outline generates separate indications of the displacements of targets A and B.

tively, such that the difference frequency ($f = f_1 - f_2$) is a convenient heterodyne radio frequency. Phase modulation at radio frequency f_{PM} is applied to the f_1 arm only. The outputs of the two arms are arranged to be orthogonally polarized and collimated, and the resulting beams are combined in polarizing beam splitter 1.

The subsequent propagation of the light is very similar to that in a standard heterodyne interferometer of prior design. A small fraction of each beam is reflected by a nonpolarizing beam splitter 1, and the radio-frequency signals of the two beam fractions are mixed in the reference photodetector. The component of the reference-photodetector output at heterodyne frequency f serves as a phase reference, against which the phases of other signal components are measured as described below.

The light transmitted by nonpolarizing beam splitter 1 enters polarizing beam splitter 2. The p-polarized light (with frequency shift f_2) is transmitted directly to the signal photodetector. The s-polarized light (with frequency shift f_1 and phase modulation at frequency f_{PM}) is reflected toward the fiducial retroreflector, from whence it is reflected back toward polarizing beam splitter 2. On its way to and from the fiducial retroreflector, this portion of the light makes a double pass through a quarter-wave plate and is thereby converted to p polarization. Now p-polarized, this portion of the light passes through polarizing beam splitter 2 and propagates to the target retroreflectors. [Although the target-B optics are shown as a combination of nonpolarizing beam splitter 2 and the target-B retroreflector, the target-B optics can also be realized as a retroreflector (only) that intercepts a fraction of the same light beam that propagates toward target A.] Like the light that goes to and from the fiducial retroreflector, the light that goes to and from the targets makes a double pass through a quarter-wave plate; thus, the returns from the targets are converted back to s polarization, so that upon arrival at polarizing beam splitter 2, they are reflected toward the signal photodetector.

For each target, the output voltage of the signal photodetector includes a component

$$V_{PD,i} \propto \sin[2\pi ft + 2\pi\Delta x_i/\lambda]$$
$$\sin[2\pi f_{PM}(t - \tau_i) + \phi],$$

where i represents either A or B, Δx_i is the difference between the length of the optical path from the laser straight through polarizing beam splitter 2 to the signal photodetector and the length of the optical path from the laser to target i to the signal photodetector, λ is the laser wavelength, t is the present time, τ_i is time of propagation between the phase modulator and the signal photodetector via target i, and ϕ is an adjustable constant component of the phase of the f_{PM} signal.

The output of the signal photodetector is demodulated in two channels by mixing with two differently phase-sifted versions of a signal of frequency f_{PM}, then filtering. The i component of the resulting waveform in the jth channel is given by

$$V_{demod,i} \propto \sin[2\pi f t + 2\pi \Delta x_i/\lambda] \cos[2\pi f_{PM}\tau_i - \phi - \alpha j],$$

where α_j is a constant component of the phase of the demodulating signal of frequency f_{PM} in the jth channel ($\alpha_1 = \pi/2$, $\alpha_2 = 0$). The sine factor term is the heterodyne beat-frequency factor, the phase of which depends directly on the optical-path difference. The cosine factor establishes the amplitude of the heterodyne signal.

The waveforms in the two channels are fed to a phase meter that separately compares their phases with the phase of the output of the reference photodetector. This is the same phase-comparison process as that in a standard heterodyne laser metrological system of prior design. By choosing $\phi = 2\pi f_{PM}\tau_B$, one can make channel 1 of the phase meter generate a null response to the return signal from target B. By also choosing $f_{PM} = [4(\tau_A - \tau_B)]^{-1}$, one can make channel 1 of the phase meter generate a maximum response to return signal from target A. These choices further cause channel 2 to generate a null response to target A and a maximum response to target B. Thus, the responses to the two targets are separated, making it possible to monitor their displacements separately.

This work was done by Oliver Lay and Serge Dubovitsky 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

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-21032, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Performance Micromachined Linear Arrays of Thermopiles

These uncooled infrared detectors can be useful in dispersive spectrometers, thermal imagers, and horizon sensors.

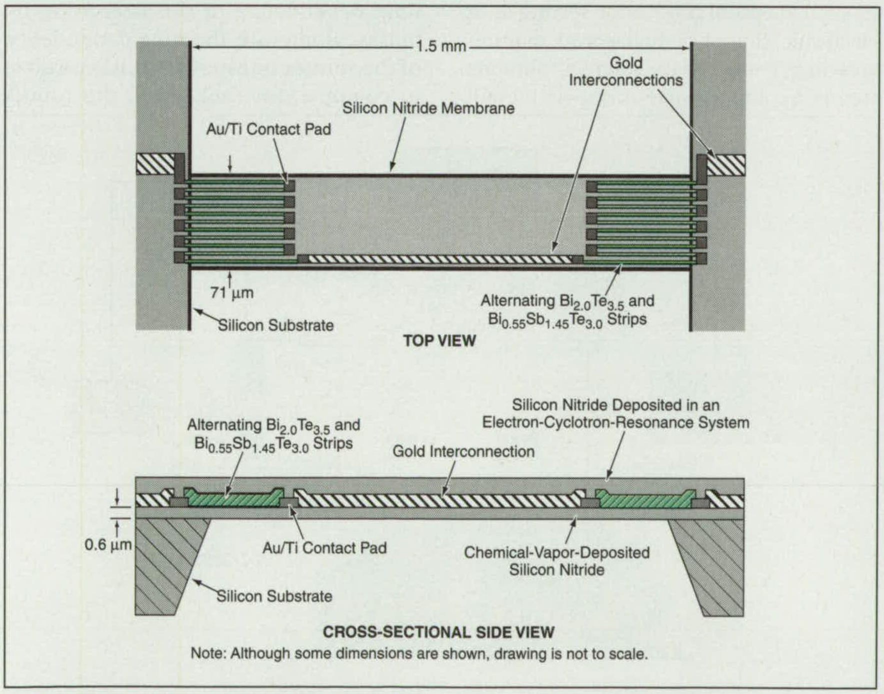
NASA's Jet Propulsion Laboratory, Pasadena, California

Linear arrays of thermopile infrared detectors made of high-performance thermoelectric materials have been fabricated on silicon substrates by micromachining processes. Such detector arrays can be useful in dispersive spectrometers for chemical analyses, including exhaust and environmental monitoring, in inexpensive thermal imaging systems for predictive and preventative maintenance, such as looking for hot spots on train wheels or power generating equipment, and in horizon sensors for satellite attitude control.

For some applications, thermopiles offer advantages over other uncooled infrared detectors. Thermopiles can operate over a broad temperature range without temperature stabilization. They are passive devices, generating a voltage proportional to the incident infrared power without electrical bias. They require no chopper. Thus, for some applications, thermopiles can be supported by simpler, lower-power, more-reliable ancillary components than are needed for the operation of such infrared devices as bolometers, pyroelectric or ferroelectric detectors. Another advantage is that if thermopiles are read out with high-input-impedance amplifiers, they exhibit negligible excess low-frequency ($1/f$) noise. Thermopile response is typically highly linear over many orders of magnitude in incident infrared power.

Prior to the development of the present high-performance devices, arrays of thermopiles had been fabricated by micromachining of silicon, but those arrays contained metal or silicon-based thermoelectric materials, which are characterized by low thermoelectric figures of merit. [A material's thermoelectric figure of merit is defined by $Z = \alpha^2/\rho\lambda$, where α is the Seebeck coefficient, ρ is the electrical resistivity, and λ is the thermal conductivity.] The signal-to noise ratio of an infrared detector can be described by the specific detectivity, (D^*). The D^* of a thermopile is approximately proportional to $Z^{1/2}$.

The present devices are 63-element linear arrays, with each element containing 11 Bi-Te/Bi-Sb-Te thin-film thermocouples, which are supported on a silicon nitride membrane over a hole in the silicon substrate to maximize the thermal isolation of the thermocouple junctions from the substrate (see figure). The thermocouple films were deposited



$Bi_{2.0}Te_{3.5}/Bi_{0.55}Sb_{1.45}Te_{3.0}$ Thin-Film Thermocouples electrically connected in series were fabricated on a silicon nitride film over a hole in a silicon substrate by standard deposition and micromachining techniques.

by sputtering from targets of $Bi_{2.0}Te_{3.5}$ and $Bi_{0.55}Sb_{1.45}Te_{3.0}$. The Bi-Sb-Te-Se family of compounds has the highest known thermoelectric figure of merit at room temperature. The thin-film thermoelectric wires are electrically connected to each other and gold interconnect wiring with contact pads made of gold film deposited over titanium film.

When exposed to radiation from a 1,000 K black-body source, the detectors exhibited zero frequency responsivity values of 1,100 V/W and specific detectivities of $D^* = 1.4 \times 10^9$ cm·Hz$^{1/2}$/W, with a response time of 99 ms. The only measurable noise at frequencies above 20 mHz was Johnson noise from the detector resistance. These performance figures are the best reported to date for an array of thermopile detectors.

This work was done by Marc Foote, Eric Jones, and Thierry Caillat of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL; 818-354-2240. Refer to NPO-20402.

Imaging Lidar System Would Map Surface Heights

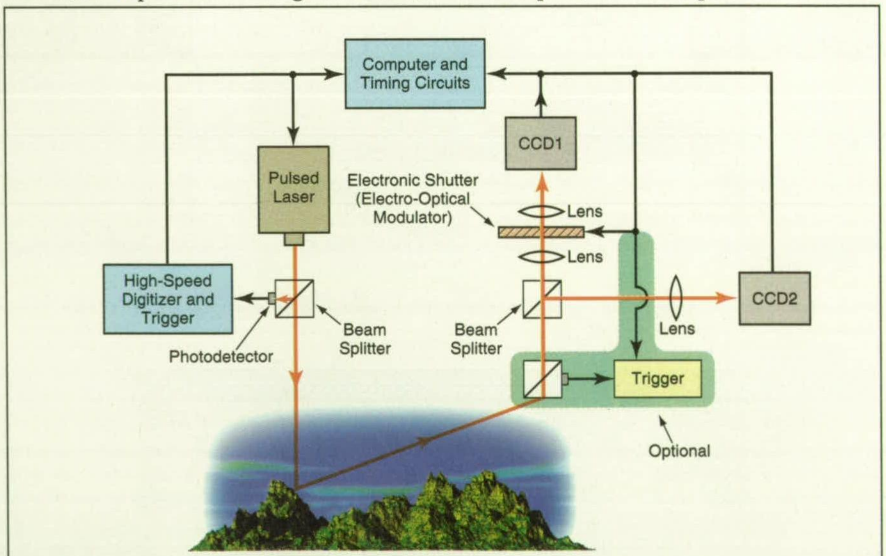
Potential uses include high-resolution topographical mapping.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed optoelectronic system based on imaging-lidar and differential-altimetry techniques would generate data equivalent to a height map of a surface area. Originally conceived for use in determining spatial-frequency characteristics of ocean waves with high temporal resolution, the system could also be used to generate high-resolution topographical maps of terrain or to study the roughness properties of land areas of geological interest.

The system would include a pulsed laser, an electro-optical modulator serving as an electronic shutter, a high-speed digitizer-and-trigger unit, beam splitters, photodetectors, a computer-and-timing-circuit unit, and two charge-coupled-device (CCD) array detectors. The two CCDs must be radiometrically calibrated and co-registered so that corresponding pixels receive light from the same points in the scene.

In operation, the system would illuminate the target surface with a short laser pulse, and both CCDs would image laser light reflected from the target surface. However, the electronic shutter would be activated to truncate the optical return to CCD1 at a time, T_0, after the initial laser-triggering pulse. With knowledge of the time dependence of the laser-pulse intensity, along with the time dependence of the shutter transmittance, it is possible to compute, for each pixel, the round-



By **Suitable Timing of The Electronic Shutter** with respect to the laser-trigger pulse, this system would generate different images of the same scene in the two CCDs. One could compute round-trip light-travel times from ratios between light signals integrated by the two CCDs.

trip light travel time (T) corresponding to the local surface height.

For this purpose, T_0 is set to some value $\approx T$, such that the shutter would be in the process of closing just as the optical return pulse reached CCD1. It can be seen that nominally T_0 corresponds to the mean height of the target surface.

The mathematical model for computing T (and thus the surface height) would utilize the output signals proportional to the received radiant flux integrated over time. For a given surface point and the corresponding pixel on CCD1, this signal would depend on the round-trip and shutter times and is therefore denoted $S_1(T,T_0)$. On the other hand, CCD2 would integrate the entire return optical pulse, so that the signal from the corresponding pixel of CCD2 would be denoted by $S_2(T,\infty)$.

Both $S_1(T,T_0)$ and $S_2(T,\infty)$ would be influenced by the reflection coefficient of the surface and laser-speckle characteristics. The effect of these unknown factors is eliminated by applying a ratiometric approach:

$$E(T,T_0)=\frac{2S_1(T,T_0)-S_2(T,\infty)}{S_2(T,\infty)}$$

This function increases monotonically with $T_0 - T$, and can be inverted to compute $T[E(S_1,S_2)]$ for each pixel, thus yielding a relief map of the scene with high temporal resolution.

This work was done by Ernesto Rodriguez, Robert T. Menzies, David M. Tratt, and Carlos Esproles of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-18812

Optics for Compact, High-Performance Imaging Spectrometers

An off-axis, telecentric telescope/camera is combined with convex diffraction grating spectrometers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Several high-fidelity imaging spectrometers have been designed with convex diffraction gratings for wavelengths ranging from the ultraviolet to the thermal infrared. All the designs are telecentric and can be combined with a flat-field, three-mirror anastigmatic telescope that also functions as a panchromatic camera.

The spectrometers are derivatives of an elegant relay disclosed by Offner in the early 1970's. The original "Offner relay" was a mask aligner consisting of two concentric spherical mirrors for projecting a telecentric image of a mask onto a semiconductor wafer. A few years later Thevenon suggested replacing the convex secondary mirror of the relay with a diffraction grating to form an imaging spectrometer.

In 1992, an Italian firm decided to act on Thevenon's suggestion and developed the first compact Offner imaging spectrometer for the Cassini mission to Saturn. Dubbed the "VIMS-V", the prototype was delivered to the Jet Propulsion Laboratory (JPL) for integration into the "Visible Infrared Mapping Spectrometer." The grating for the VIMS-V was manufactured by a German company using holographic recording and ion-beam milling. The gratings can also be fabricated using electron-beam lithography.

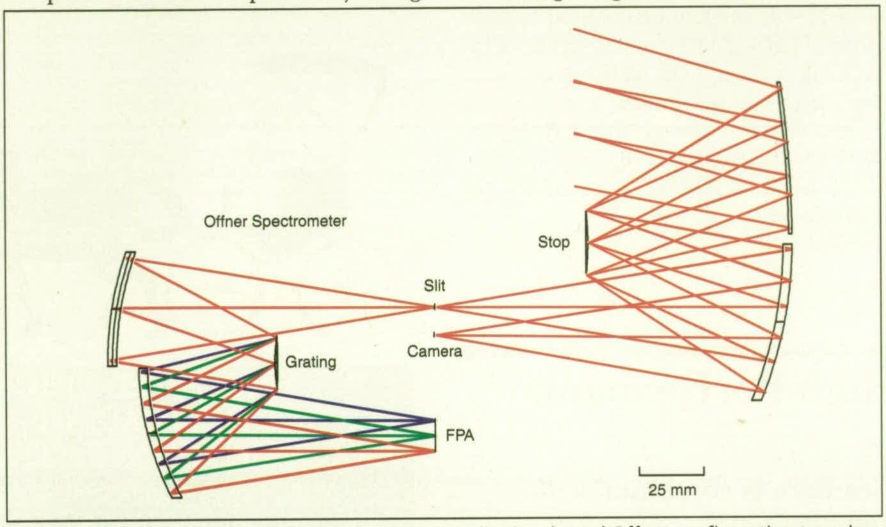
The Offner spectrometer was initially developed to overcome the inherent limitations of another popular concentric spectrometer invented by Dyson in the late 1950's. The Dyson uses a concave grating and controls optical aberrations with a thick plano-convex lens placed immediately in front of the slit-detector plane. Unfortunately a lens in this position back-scatters the input white light directly onto the focal plane array (FPA), and it does not leave space for a cold stop. Without a cold stop the entire spectrometer must be cooled to the FPA temperature, thereby increasing the low temperature cooling load by a factor of 10 or more.

A cold Dyson spectrometer would also be sensitive to misalignment because its grating reflects the chief rays at large angles to the optical axis before they can be made telecentric by the lens. Hence, a small shift in the position of the lens distorts the image and the spectrum. For example, a shift within a typical position tolerance of 10 µm generates 8 percent distortion at the edge of a spectrum only 5 mm long.

An acceptable uncalibrated distortion limit is 1 percent of a pixel, which is easily controlled in the Offner when the spectrum is confined to a narrow, annular zone less than a few millimeters wide. Two examples of miniature Offner designs with less than 10 nm distortion (0.1 percent of a pixel along a 16 mm image) are listed at *http://focus.software.com/file-exchange/index.html*.

Distortion increases as the cube of the spectral length, so it becomes increasingly difficult to maintain performance across large-area FPAs. The new designs use several variations of Offner configurations to maintain high performance across large areas. In the design shown in the figure, the image is 16 mm long and the spectrum is 12 mm long, yet the spectral distortion is less than 1 percent of a pixel. This is accomplished by tilting the two relay mirrors of a lateral Offner configuration (the grating and FPA are displaced laterally from the slit line).

In another design the image is 12 mm long and the spectrum is 16 mm long, so the Offner is put into a vertical configuration (the grating and FPA are displaced vertically above the slit line). A single, aspheric relay mirror helps control optical aberrations. The vertical configuration enables the grating to be divided into two sections that are blazed for positive and negative diffraction orders. Each section is optimized for its own FPA spectral passband and resolution. This technique is used in an imaging spectrometer being developed for the comet rendezvous mission *Rosetta*. The spectrometer can cover the 0.25 – 5 μm spectral band without the need for a dichroic beam splitter. Dichroic beam splitters limit the spectral passband considerably, especially when the passband extends from the ultraviolet to the infrared.



This **Imaging Spectrometer/Camera** uses a convex grating in a lateral Offner configuration to reduce distortion to less than 1 percent across a 12-mm spectrum with a 16-mm image.

This work was done by Francis Reininger 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.*

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

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20239, volume and number of this NASA Tech Briefs *issue, and the page number.*

Snapshot SEM Imaging of Moving MEMS Structures

The principle of stroboscopy would be extended to scanning electron microscopy.

NASA's Jet Propulsion Laboratory, Pasadena, California

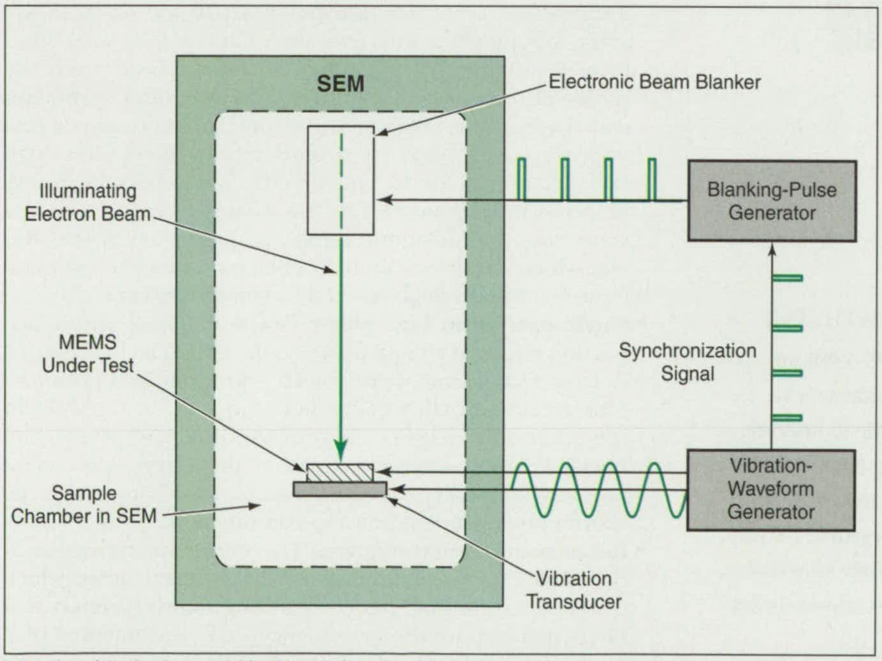
A stroboscopic scanning electron microscope (SEM) has been proposed as a means of generating still or slow-motion pictures of moving structures in microelectromechanical systems (MEMS). Such imaging is used in characterizing the dynamics of MEMS; characterization of the dynamics is a critical component of the MEMS development cycle.

Conventional strobed-illumination microscopy with visible or infrared light provides adequate temporal resolution but insufficient spatial resolution for measuring subwavelength motions in the main plane of a typical MEMS. A conventional SEM provides adequate spatial resolution, but is inadequate for resolving motions at frequencies greater than several tens of hertz because the illuminating electron beam is continuous. The proposed stroboscopic SEM would offer both the spatial resolution of a conventional SEM and the temporal resolution of conventional optical stroboscopy, making it possible to form crisp images of moving (e.g., vibrating) MEMS structures.

According to the proposal, a conventional SEM would be augmented with an electronic beam blanker that would be operated in coordination with a signal generator. The output of the signal generator would control the vibrational excitation of a MEMS device mounted in the SEM (see figure).

In one mode of operation, the blanking-pulse-repetition frequency would be set equal to the frequency of vibration, so that the resulting SEM image would "freeze" the motion at some phase in the vibration cycle. The phase could be varied by adjusting the phase offset between the vibration-waveform and blanking-pulse generators. In another mode of operation, the blanking-pulse-repetition frequency would be made to differ slightly (no more than a few hertz) from the vibration frequency, yielding a sequence of images at slightly different phases (in other words, a slow-motion picture). Freeze-motion images taken at different phases could be used to quantify the shape of a vibrational mode at the frequency of excitation, while slow-motion pictures could be used to obtain qualitative understanding of the motion.

This work was done by Kirill Shcheglov and Russell Lawton 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-21056



Vibrational Excitation and Blanking Pulses would be synchronized or nearly synchronized to obtain snapshots or slow-motion pictures, respectively, of the vibrating MEMS.

Spatially Modulated Prism Interferometer

Advantages include high efficiency over a very broad spectral bandwidth, compactness, mechanical stability, spectral radiometric purity.

NASA's Jet Propulsion Laboratory, Pasadena, California

A spatially modulated prism interferometer (SMPI) has been developed that overcomes the complexities of traditional interferometers and the inherent limitations of diffraction gratings, dispersion prisms, and spectral selection filters. Applications include atmospheric sounding, geologic mapping, *in-situ* mineralogy, oceanography, pollution monitoring, poisonous gas detection, medical spectroscopic imaging, and industrial inspection.

At the heart of the SMPI is the prism triplet shown in Figure 1. Its function is to shear the input beam into two mutually coherent output beams with chief rays that are parallel to the optical axis. A Fourier optical system, shown in Figure 2, collimates the two beams, tilts them, and then recombines them at a pupil plane. The tilted wavefronts generate a spatially modulated interference pattern that is recorded as an interferogram by a detector array. If the Fourier optical system is made anamorphic, then a line image is formed in a direction orthogonal to the series of interferograms. Interferometers with a 25° image field have been designed.

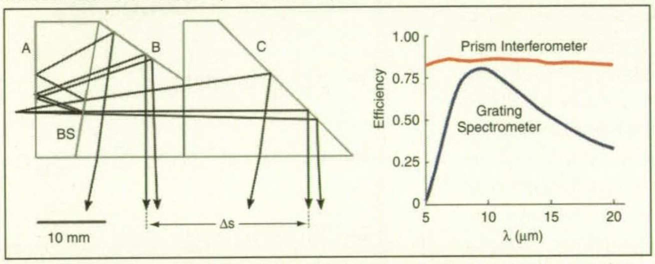


Figure 1. **The Beam-Shearing Prism Triplet** is made from a single-crystal material to maintain the same optical path length for both beams. Its unique design enables the spatially modulated prism interferometer to have double the efficiency of conventional interferometers and a much broader spectral pass-band than grating spectrometers.

Because the SMPI generates instantaneous interferograms at a pupil plane, it benefits from the following attributes:

- **Field-Widened:** The entrance slit can be widened to any width to increase the signal flux without affecting the spectral resolution. This gives it a significant advantage over grating and prism spectrometers, which must trade throughput for spectral resolution. Image plane interferometers suffer a similar fate because their modulation efficiency degrades in proportion to the slit width and fringe frequency, a phenomenon known as self-apodization.
- **Broadband Efficiency:** As shown in Figure 1, the SMPI efficiency is nearly constant with wavelength. In contradistinction, the efficiency of a grating spectrometer is high only at the blaze wavelength, and then it diminishes rapidly. The SMPI has double the efficiency of the Michelson, Sagnac, and Wollaston prism interferometers because it utilizes all (instead of half) the incident light.
- **No Stray Light Induced Spectral Errors:** Stray light in the SMPI increases the noise floor but does not necessarily contribute to an erroneous spectral signal. In filter, prism, and grating spectrometers, stray light is indistinguishable from spectral signals and introduces large radiometric errors. Gratings are particularly troublesome because they behave like badly scratched mirrors. The edge of each groove, even when perfectly fabricated, scatters the incident white light directly across the spectrum.
- **Radiometric Purity:** When the detector array is at a pupil plane the radiance contributions from the various objects in the field are uniformly distributed across the pixels in the array. A pupil plane interferometer has the additional benefit of distributing all the colors of the spectrum uniformly across all the pixels of the array. This simplifies calibration and eliminates the radiometric errors that are routinely generated in image-plane spectrometers and filters when high radiance objects are lost in the dead zones between pixels. Responsivity variations across the active regions of pixels also contribute to radiometric errors in image-plane spectrometers, which is why they should not be used in science applications that require high spectral radiometric accuracy.
- **Single Instrument Line Shape Function:** There are no diffraction effects at a pupil plane, so the SMPI can be designed to have a single line shape for all colors and field positions. This greatly simplifies calibration and spectral retrievals in comparison to image-plane gratings, dispersive prisms, and filters. The line shape generated by these devices broadens with wavelength-dependent diffraction and changes with the aberration-dependent point-spread function.
- **Instantaneous Interferogram:** The entire interferogram is recorded instantaneously across the detector array, which eliminates recording errors. Scanning interferometers and filters that require the movement of the observational platform or an optical component are prone to irrecoverable spectral errors when the platform motion is not perfectly rec-

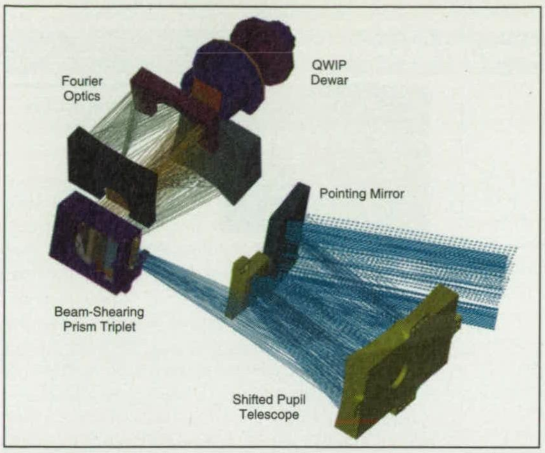


Figure 2. This **Spatially Modulate Prism** Interferometer design has a spectral resolution of 1.2 cm^{-1}. It uses a shifted pupil telescope to double the spectral resolution and toroidal mirrors in the Fourier optics to maximize the spatial resolution.

tilinear or the scene changes during the scan period.

- **Mechanical Stability:** Unlike Michelson interferometers, the SMPI is relatively insensitive to mechanical shock, focal plane jitter, and misalignment because there are no moving parts, and because the two beams converging on the detector array are collimated. The collimation attribute relaxes the focal plane axial position tolerance: a 1-mm axial shift generates less than 0.5-percent change in the spectral line width at 5 cm^{-1} resolution, and no change in the spectral line position. Since a typical axial position tolerance is 10 μm and the typical axial vibration amplitude of an active cooler is 1 μm, the detector array can be mounted directly onto the cold finger without concern for vibration-induced spectral errors. This significantly reduces the cooling power requirements and the complexity of the thermal-mechanical focal-plane mount.

The SMPI incorporates several important optical design characteristics that enable it to achieve high spectral resolution and high efficiency in a compact form. The telescope is designed with a shifted pupil so that the chief ray strikes the edge rather than the middle of the detector array. This shifts the zero path difference point to one side of the array and effectively doubles the maximum possible optical-path difference and spectral resolution without requiring a doubling of the pupil width.

The beam-shearing prism is designed so that the beam splitter (BS) coating on prism A is tilted less than 10° to the input beam. This prevents total internal reflection at the airgap between prisms A and B, and it eliminates the need for an oil or adhesive to fill the gap. Adhesives have strong absorption features in the thermal infrared, so their omission is desirable.

The prism configuration is governed by a requirement to maintain the same optical path length for two light beams whose chief rays must emerge parallel to each other and perpendicular to a flat output surface. When the entrance and exit surfaces are perpendicular to the chief rays, then astigmatism and dispersion are eliminated. Astigmatism reduces the spectral resolution of the interferometer, and dispersion changes the instrument line shape as a function of wavelength.

The prism is designed for minimum volume and maximum beam shear. The beam shear distance, ΔS, is proportional to the spectral resolution. A thumb-sized beam-shearing prism with a 60-mm focal length Fourier lens can achieve a spectral resolution of 1 cm^{-1}. This is a factor of 40 reduction in volume with respect to an equivalent Sagnac interferometer. Likewise, a 0.5 cm^{-1} prism interferometer can improve by a factor of two the NEΔT of the Atmospheric InfraRed Sounder (AIRS) and reduce its volume by a factor of 25. AIRS is a pupil plane grating spectrometer.

The high-resolution performance of the SMPI is due in no small part to the recent advances in large format, GaAs based Quantum Well Infrared Photoconductor (QWIP) detector arrays. The SMPI requires a large array of pixels with high pixel operability and uniform responsivity, which are two unique characteristics of the QWIP arrays being developed at JPL (see *Tech Briefs*, Vol. 24, No. 5, p. 26a-30a). The QWIP arrays also have low 1/f noise, which increases the calibration stability of the detector array and of the interferometer.

This work was done by Francis Reininger 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.*

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

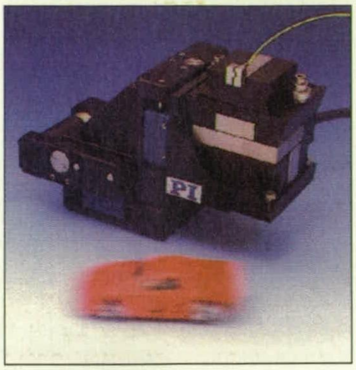
Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20647, volume and number of this NASA Tech Briefs *issue, and the page number.*

New Products

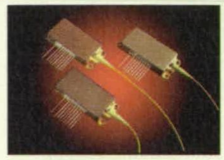
For more information on the products below, go to www.ptbmagazine.com/products.

Product of the Month



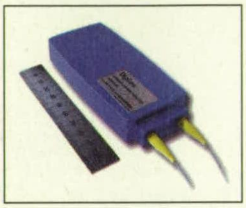
Nanoalignment System for Packaging

Polytec PI, Auburn, MA offers the F-130 nanopositioning system, designed for fiber positioning and photonics packaging applications. It combines 15-×-15-×-15 motor-driven travel range for "first-light" alignment with 100-×-100-×-100-µm high-speed piezoelectric travel range for fine alignment. Resolution of the motor is 0.1 µm and piezoelectric resolution is 1 nm. A two-dimensional transverse profile of a single-mode fiber coupling can be acquired in less than 4 seconds. Polytec suggests the F-130 for microscopy, electrophysiology, micromachining, semiconductor technology, mass storage, optical instrumentation, and metrology.



High-Power EDFA Pump Laser

Coherent Inc., Santa Clara, CA, introduces the OPSL™-980-500, a 980-nm optically pumped vertical-cavity surface-emitting (VCSEL) laser that the company says is the first pump laser on the market to provide more than 500 mW of output power from a single-mode fiber pigtail. The laser is intended for pumping erbium-doped fiber amplifiers (EDFAs) in high-channel-count dense wavelength division multiplexing (DWDM) applications. Coherent says that the OPSL™-980-500 can replace several multiplexed conventional fiber Bragg grating stabilized devices with a single compact footprint. The company says the unit is spectrally stable over wide drive-current and temperature ranges.

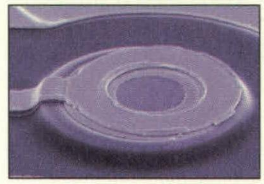


Dynamic Channel Equalizer

The dynamic channel equalizer (DCE) from DigiLens Inc., Sunnyvale, CA, incorporates the company's solid-state free-space attenuators, and comes complete with all drive, control, and electronics inside its small housing. The DCE provides eight discrete channels of up to 20-dB attenuation, and is tailored to either 200- or 100-GHz spacing, conforming to ITU standards. DigiLens says that full C- and L-band coverage may be achieved by using multiple modules in parallel with bandpass filters, thereby maintaining low insertion loss. It is designed to comply with Telcordia GR-1209 and GR-1221 defined tests.

High-Power Tunable Laser

Iolon Inc., San Jose, CA, offers the Apollo, a MEMS-based tunable external-cavity laser (ECL) for optical networking systems. Delivering 20 mW output power, the Apollo is continuously tunable over the entire C-band. Iolon says that its narrow linewidth (<2 MHz), high side-mode suppression ratio (>50 dB), and low relative intensity noise (less than -145 dB/Hz) give it the spectral purity necessary for long-haul, high-bit-rate applications. Channel spacing is 50 GHz. Iolon says the Apollo has excellent wavelength accuracy (±2.5 GHz) and power stability (±0.25 dB), eliminating the need for additional equipment to maintain a clear, consistent signal.

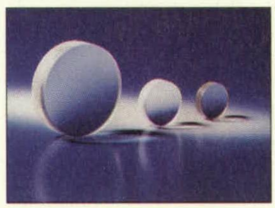


10-Gb/s Oxide VCSEL

EMCORE Corp., Somerset, NJ, introduces the 850-nm 10-Gb/s oxide vertical-cavity surface-emitting laser (VCSEL) intended to meet emerging speed and performance requirements in data communication networks. The company calls it the first 10-Gb/s VCSEL on the market. It is designed to work in existing optical components and is optimized for high-speed data communications over multimode fiber in interconnect applications of less than 300 meters. It has 3 dB bandwidth in excess of 10 GHz, enabling transceiver vendors to develop devices that meet 10-Gb/s short-haul multimode standards. Its optical output power is 1 mW typical.

Color Submersible IR Camera

The Sub-Cam-CL from Polaris Industries, Atlanta, GA, is described as an ultracompact color digital signal processing (DSP) submersible camera that measures just 48.92 mm in diameter and 60.04 in depth. The camera has a quarter-inch CCD chip that yields more than 350 TV lines in resolution, and a Lux rating of 0 with IR on. Accessories include a 3.6-mm lens supplying a 92-degree angle of view, and 65 feet of cable. Internal IR IEDs supply autoillumination for the camera in murky water to a maximum of 25 feet. The case is machined from a solid billet of aluminum.

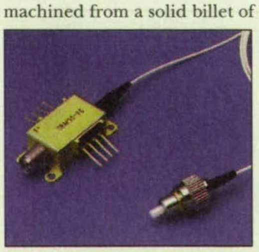


Achromats for the Near-IR

Linos Photonics, Milford, MA, has added five new near-infrared achromats to its existing line. The company says that the series' broadband antireflection coating for the 700-1100-nm wavelength region makes the lenses suitable for use with diode lasers that are sensitive to back-reflection. The doublets are available in focal lengths of 40, 80, 140, and 250 mm. They can be supplied either mounted or unmounted for direct use on microbenches.

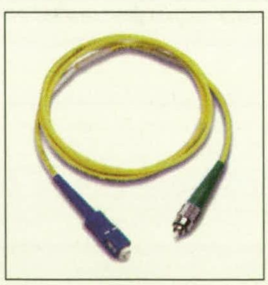
Laser Diode Assembly Cell

Palomar Technologies, Vista, CA, automates laser diode attachment in optoelectronic packages with its Laser Diode Attach (LDA) system. Its void-free eutectic solder interface manages thermal and electrical connections that are needed to generate a stable transmission of laser light. Palomar says that the programmable closed-loop system gives tightly coupled control and repeatability of the eutectic reflow process while maintaining a final placement accuracy of 5 microns. The assembly cells accommodate a variety of presentation tooling, including expanded wafer and 2-in. and 4-in. waffle or gel packs in trays or stacked, allowing for more than 4 hours of continuous unattended operation.



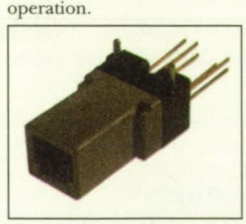
Fiber Optic Receiver Modules

The SRAA10 and SRAP10 10-Gb/s fiber optic receivers from PerkinElmer Optoelectronics, Santa Clara, CA, incorporate a high-speed InGaAs photodiode with a low-noise GaAs transimpedance amplifier. They come in an 8-pin butterfly package with K-connector output for digital communications applications. The 10 Gb/s series conforms to Synchronous Optical Network (SONET) requirements for OC-192 receivers used in long-range, intermediate-range, and short-range applications. They are available in hermetically sealed fibered housings with a single-mode pigtail.



Test and Reference Cables

Storm Products, Westmont, IL, offers test and reference cables designed to test and verify single-mode fiber optic components. The assemblies are available in three grades: test, reference, and master level. All NIST traceable, they feature connectors finished with a precision polishing process to exceed Telcordia end-face geometry standards. With master-level cables, insertion loss is as low as 0.01 dB and return loss as low as -60 dB (PC) and -75 dB (APC). Test data is supplied with each cable.



Data Communications VCSELs

The HFE4181-521 from Honeywell, Richardson, TX, is a small-form-factor 850-nm vertical-cavity surface-emitting laser (VCSEL) packaged for high-speed (≥1 GHz) data communications. The company says it combines the performance advantages of the VCSEL with a custom-designed power monitor diode, which can be used with appropriate feedback control circuitry to set a maximum power level. According to Honeywell, the low drive current (5-15 mA) requirement makes direct drive from positive-emitter-coupled logic or emitter-coupled logic gates possible, easing driver design.

TECH BRIEFS
ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

R345-0

FREE SUBSCRIPTION REQUEST FORM

STAY ON THE CUTTING EDGE

Renew or get your own copy of *NASA Tech Briefs*. You can qualify at our website: **www.nasatech.com/subscribe** or Fax this form to **856-786-0861**

Please print

Reader ID Number 000 ______________

Name ______________

Title ______________

Company ______________

Address ______________

____

City/St/Zip ______________

Phone ______________

Fax ______________

e-mail ______________

Home delivery (possible only if all items above are completed.)

Street ______________

City/St/Zip ______________

Signature ______________ Date ______________

Check one of the following:

❑ New Subscription

❑ Renewal

❑ Change of address

For Change of Address and/or Renewal you must provide the 11-digit Reader ID Number from your mailing label.

You can also mail this form to:

NASA Tech Briefs
P.O. Box 10523
Riverton, NJ 08076-9023

1 **Do you wish to receive (continue to receive) *NASA Tech Briefs*?**

❑ Yes ❑ No

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

E ❑ Electronics
S ❑ Computers
X ❑ Communications
O ❑ Automotive
T ❑ Transportation
M ❑ Materials/Chemicals
P ❑ Power/Energy
B ❑ Bio/Medical
J ❑ Consumer Product Manufacturing
Q ❑ Industrial Machinery & Equip.
A ❑ Aerospace
G ❑ Government
D ❑ Defense
R ❑ Research Lab
U ❑ University
Z ❑ Other *(specify)*: ______________

3 **Your engineering responsibility is:** *(check one)*

A ❑ Manage Engineering Department
B ❑ Manage a Project Team
C ❑ Manage a Project
D ❑ Member of a Project Team
E ❑ Other *(specify)* ______________

4 **Your job functions are:** *(please check all that apply)*

10 ❑ Design & Development Engineering (Inc. applied R&D)
12 ❑ Testing & Quality Control
13 ❑ Manufacturing & Production
14 ❑ Engineering Management
16 ❑ General & Corporate Management
17 ❑ Basic R&D
15 ❑ Other (specify)

Write in the number of your principal job function ______________

5 a. **In which of the following categories do you recommend, specify, or authorize the purchase of products?** *(check all that apply)*

01 ❑ Electronics
02 ❑ Photonics
03 ❑ Computers/Peripherals
04 ❑ Software
05 ❑ Mechanical Components
06 ❑ Materials
07 ❑ None of the above

5 b. **Products you recommend, specify, or authorize for purchase:** *(check all that apply)*

32 ❑ ICs & semiconductors
33 ❑ Connectors/interconnections/ packaging/ enclosures
02 ❑ Board-level products
18 ❑ Sensors/transducers/detectors
16 ❑ Data acquisition
19 ❑ Test & measurement instruments
34 ❑ Power supplies & batteries
35 ❑ PCs & laptops
06 ❑ Workstations
36 ❑ EDA/CAE software
37 ❑ CAD/CAM software
17 ❑ Imaging/video/cameras
38 ❑ Lasers & laser systems
39 ❑ Optics/optical components
40 ❑ Fiber optics
41 ❑ Optical design software
20 ❑ Motion control/positioning equipment
30 ❑ Fluid power and fluid handling devices
31 ❑ Power transmission/motors & drives
42 ❑ Rapid prototyping and tooling
13 ❑ Metals
28 ❑ Plastics & ceramics
27 ❑ Composites
43 ❑ Coatings
80 ❑ None of the above

6 **How many engineers and scientists work at this address?** *(check one)*

A ❑ 1
B ❑ 2-5
C ❑ 6-19
D ❑ 20-49
E ❑ 50-99
F ❑ 100-249
G ❑ 250-499
H ❑ 500-999
J ❑ over 1000

7 **To which of the following publications do you subscribe?** *(check all that apply)*

01 ❑ Cadalyst
02 ❑ Cadence
03 ❑ Computer-Aided Engineering
05 ❑ Designfax
06 ❑ Design News
07 ❑ Desktop Engineering
08 ❑ EDN
09 ❑ Electronic Design
10 ❑ Machine Design
11 ❑ Mechanical Engineering
12 ❑ Product Design & Development
13 ❑ Sensors
14 ❑ Test & Measurement World
15 ❑ Laser Focus World
16 ❑ Photonics Spectra
17 ❑ None of the above

8 **Would you like to receive a free e-mail newsletter from *NASA Tech Briefs*?**

❑ Yes ❑ No

____
Your e-mail address

You may receive renewal reminders via e-mail.
Do you want to receive other business-to-business third party e-mail offers from *NASA Tech Briefs*?

❑ Yes ❑ No

e-Engineering: An e-Merging Trend for Manufacturers

Manufacturers, engineers, and suppliers need to change the way they perceive themselves in order to survive in the competitive Internet world.

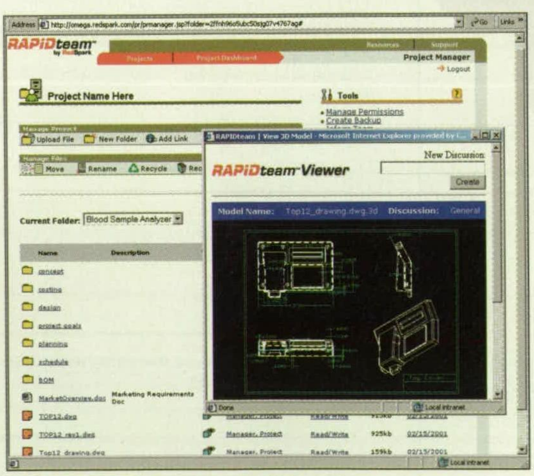
Competition, reducing costs, market leadership, and making money are all driving forces behind the move towards collaborative manufacturing and e-engineering. Put simply, e-engineering involves leveraging the Internet and its related technologies to electronically join manufacturers with engineers, suppliers, designers, and ultimately, customers. While working with suppliers isn't a new concept, emerging online technologies create a supercharged environment for working with partners, according to Forrester Research's recent study on supplier collaboration.

Manufacturers, engineers, and suppliers need to change the way they perceive themselves in order to survive in the competitive Internet world. No longer can any of these groups be single entities — they all must be players on the same team. It's a community, according to Peter Ostrow, president and CEO of Test-Mart, a leading information and commerce marketplace for the test and measurement industry.

"Community is the sense of collaborative workflow. It's a big word that means sharing ideas, in real-time, using the Internet. The Internet for engineers, in particular, provides access to significant content that in the past they had much more limited access to," Ostrow said.

That content comes in many forms from many different places on the Internet. "There's a hierarchy of needs in terms of what engineers are using the Internet for," said Ostrow. "And what almost every engineer at this point is using it for is research, whether it's product specifications or research on specific applications and concerns." The next level in the hierarchy is price comparison, and at the highest level of use, full-blown e-commerce on-line, according to Ostrow.

Engineers are using the Internet as a read-only application, according to Chuck Grindstaff, vice president of products and operations for UGS (formerly Unigraphics Solutions). "I don't really think engineers will get the full value of the Internet until they use it effectively as a design-oriented, multipoint conference call that's got mechanical definitions moving across the connection." UGS's e-vis connect private business-to-business exchange service provides manufacturers and their suppliers with what Grindstaff calls "back-office connectivity projected out across the Internet," taking advantage not only of the basic collaboration advantages of the Internet, but also the visual tools, linked viewing and markup, analysis, and data management opportunities it can provide to a supply chain.



RedSpark's RAPIDteam is a collaborative product development (CPD) platform for project managers, engineers, supply chain managers, and purchasing personnel to work together.

"We started with the realization that engineers spend an average of 23 hours per week in their desktop design application, and a lot of the rest of the time is spent sourcing the supply chain," said Dominic Gallello, president and CEO of RedSpark, a spinoff of Autodesk that provides manufacturers with a common, inter-enterprise platform (called RAPIDteam) for project mangers, engineers, supply chain managers, purchasers, and direct materials suppliers to work together via the Web.

"The process of integrating suppliers is paper-based," Gallello added. "We're trying to help manufacturers manage their suppliers' suppliers and their customers' customers. One level deep may not be enough. Integrating your suppliers is great, but they have suppliers, too."

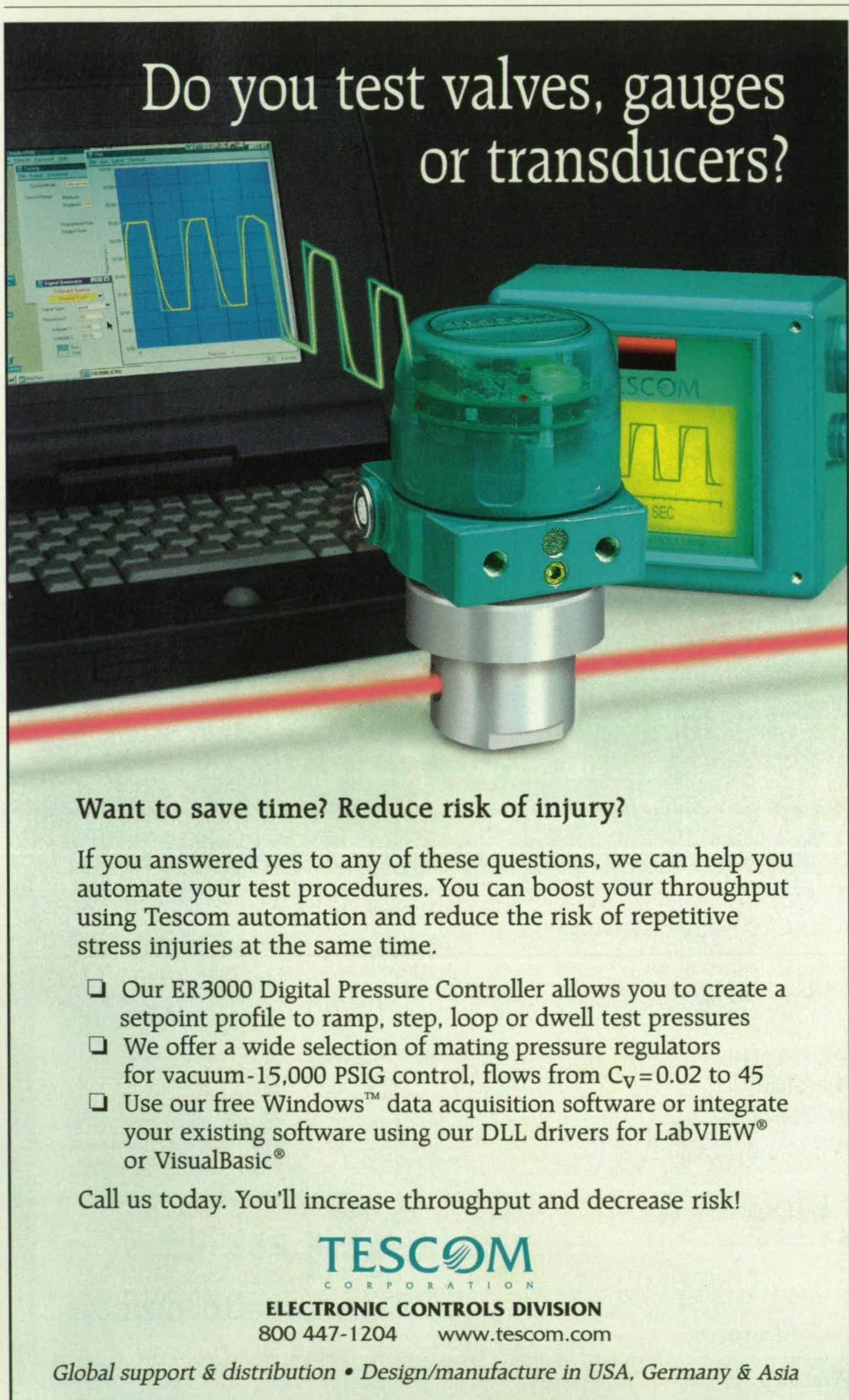
Manufacturers are eager to shorten their time to market and expand the roles of their suppliers by using a variety of Internet tools, according to Forrester Research. But what types of tools are they using? How are they connecting everyone who needs to be connected, and how quickly is all of this really happening?

"It's shocking how many companies are just now starting to think of collaborative Web sourcing with their suppliers," said Gallello. "How do you make an engineer's life a lot easier with useful, configurable, specified, searchable, and downloadable product information? There is tons of activity on the manufacturer's side." That activity, he explained, won't take place overnight. In the next two years, Gallello estimated, "The manufacturers' Web sites that you're interacting with today are going to change dramatically."

Companies like Tecnomatix and Workgroup Technology Corp. (WTC) are trying to change the way manufacturers use the Internet. Tecnomatix offers eM-

Power, which provides electronics manufacturers with a collaborative environment that allows the planning departments, plants, and contractors to collaboratively create and operate their facilities. They also provide for the capture and aggregation of process information in something called an eBOP, or e-Bill of Processes, which describes all of the parts, resources, operations, and relationships among all of the elements required to produce a part. WTC's offering, called ProductCenter, is a product data management software package that gives manufacturing teams secure access to product data via the Web. It also puts up-to-date product information right on the factory floor.

Andrew Rodger, executive vice president of SmarTeam, already can see the effects of what happens when manufacturers use the Web to reduce the cost of doing business. SmarTeam offers Web-based collaborative product commerce solutions — such as SmartBriefcase — that allow users to exchange product design data with supply chain partners through e-mail or over the Web using a data exchange concept similar to the "zip" file.



"I can see people moving and swapping data over the Web," Rodger said. "I see supply chain management beginning to be managed over the Web, including the bill of materials, sharing and passing of information to suppliers, and CAD collaboration. It's really moving very quickly," he said.

His company, he explained, is a "recession-advantaged solution." According to Rodger, SmarTeam was made possible because of the Internet. "We've enabled a data management solution for medium and smaller sized companies, and guess what? That's about 98 percent of American industry. If medium and smaller sized companies don't invest in the data management arena, they will be out of business in five years because the rest of the world won't tolerate being unable to work electronically with them."

Watch That Data

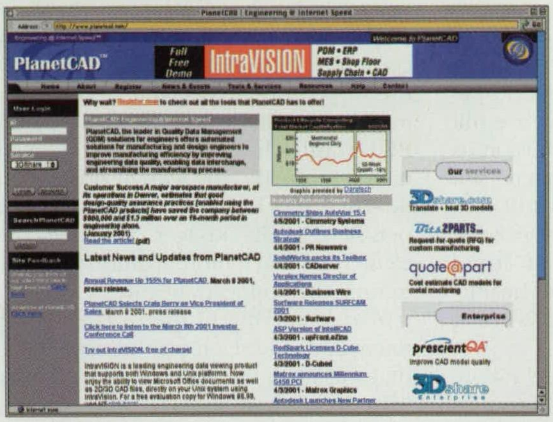
Despite the fact that manufacturers are eager to become "electronic," there are a number of weighty obstacles that stand in their way, including Internet security. For instance, many manufacturers are looking to outsource more of their engineering work, and the Internet would appear to be the perfect vehicle for distributing procurement and quoting requests. Or is it?

"If you look at the kinds of transactions that happen between the manufacturer and the supply base, clearly one of them is describing what it is you want built, and getting back a response that, 'yes, I can build that, and here's the cost and the lead time.' I think there's more to it than that," said Grindstaff.

Manufacturers are interested in using the Web to put out requests for quotes (RFQs), but according to Rachael Dalton Taggart, vice president of marketing for PlanetCAD, what they don't do is close the deal on the Web. "They'll use the Web as a tool to send it out and get RFQs back pretty quickly, but when they select the company they're going to use as a supplier, they pick up the phone and talk to them."

Gallello agrees that manufacturers are nervous about putting RFQs on the Internet that may include proprietary specifications on a company's product. "I'm not going to throw my RFQ onto the Web and hope someone bites at it. I want to know someone before I release any confidential information to them." The bottom line, according to Gallello, is security. "Protecting your intellectual property still has to figure into the process of when you use the Internet."

MSC.Software is hoping that manufacturers will use the Internet as a quick, easy, PlanetCAD's data management site includes 3Dshare.com, which translates and heals 3D models, and prescientQA™ for improving engineering data quality.



and secure process to retain qualified engineering consultants. The company's Engineering Exchange links customers to a virtual engineering environment that captures the information necessary to define a problem. Templates define the work statement, organize the specifics of a product, supply industry and government standards, and supplier limitations and cost restraints. To identify the best-qualified resources, client companies sort through a database of engineering consultants by discipline and industry experience. On-line Pre-Bid Sessions occur between client companies and the prospective providers. Security concerns are addressed through the use of passwords to ensure that project definitions and bids are solicited only by invitation.

Companies realize that in order to truly work collaboratively with their supply chain, they will have to share significant amounts of proprietary data. Most Web-based engineering and data management services already know the security drill. "You really wouldn't put any kind of engineering details out on the Internet if you couldn't restrict who can see it," said UGS's Grindstaff. "I don't know of one of our customers who would even consider moving information across the Internet if they didn't feel the tools they were using provided a high degree of security."

Internet data security is a larger issue for manufacturers than it is for other industries, according to PlanetCAD's Dalton Taggart. "With 3Dshare.com [the company's Internet site for translating and healing 3D design models], we find that manufacturers love it, but they may not be authorized to send their proprietary design data over the Internet. They are very paranoid about losing their data or getting it pirated."

TestMart's Ostrow, on the other hand, believes that manufacturers are, for the most part, comfortable putting their data on-line. TestMart — which provides information for customers looking to buy, lease, or sell new, used, or refurbished test equipment — updates price and availability information in real time using secure and controlled remote access. Users can find the product information they need and make a secure purchase transaction without leaving the site.

SmarTeam's Rodger agrees that security is an issue, but that the Web really is a very secure environment. "The concern is there, but the solutions are there, too. There are ranges of software from cheap to very expensive that address the security issue in a good way," said Rodger. "There's definitely a learning curve for people to learn how to work better over the Web."

Bandwidth and More

As more and more manufacturers change their business to incorporate the Web, the Internet itself faces changes of its own. Many companies agree that the Internet must evolve in a number of ways in order to provide engineers with an even better set of tools and opportunities than it currently offers. That evolution includes improved bandwidth, ease of use, and accessibility.

"Two years ago, many manufacturers had one Internet system in their design office on a separate desk, and it wasn't automatically on everyone's desktop," explained Dalton Taggart. "That's changing. Many engineers have immediate access to T1 lines straight from their desks."

Accessibility continues to improve, according to Ostrow. "More and more engineers are getting faster and faster access to the Internet. That's a very positive sign for the evolution of e-engineering." But, he added, manufacturers still aren't convinced that engineers are going to move to a full on-line environment. "If you ask manufacturers, they have a real challenge at this point. Job number one is manufacturing and marketing the equipment. Job number two is finding alternative distribution for it. All of a sudden, it's become a lot more realistic, and a lot more expensive."

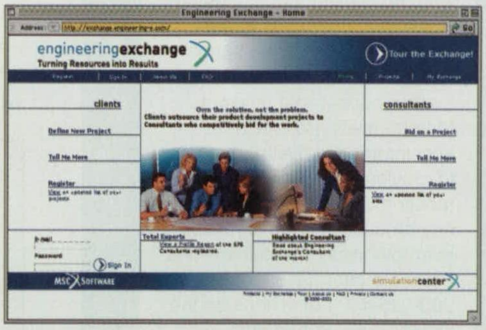
Gallello agrees that bandwidth is only the tip of the Internet iceberg. "Companies will have to re-architect their internal and external productivity networks, because they're going to be putting a lot more of their business out there. I'm not so worried about the bandwidth issue at all. The problems are re-thinking the strategy of firewalls, and pushing suppliers on how to do it."

More bandwidth is always nice, but the bigger issue is interoperability, according to Grindstaff. Industry-accepted standards that enable various applications to interact with each other will help manufacturers and their supply chains use the Internet more, and with better results. "As our partner applications take advantage of new XML standards, that interoperability will allow information to smoothly move between applications. That will be the biggest change. We can always use more bandwidth, but our applications have ways around it."

Here Today, Where Tomorrow?

Let's face it — empty office spaces pop up every day where there used to be a ".com" on the door. The Internet can become companies' best friend, or it can be their downfall. But for all of the dot-com failures, there are successes, and many of them are e-engineering ventures. What's the recipe for survival? TestMart's Ostrow sees his company's success as a simple matter of a sound business model.

"What we focused on was that you could take the 'dot.com' out of the name

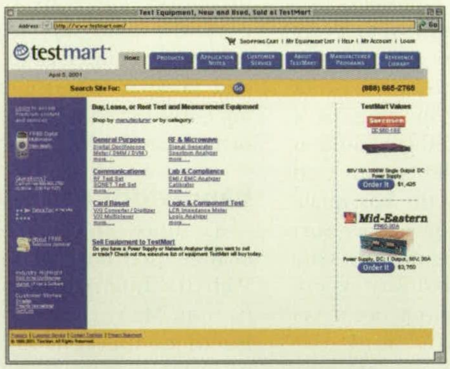


MSC.Engineering-e.com (a division of MSC.Software) provides separate areas on its Engineering Exchange site for clients and consultants. All communications are logged into a Message Board for clarity.

of the company and almost any company that's in business, especially newer businesses, would focus on the same things: customer acquisition, relationships with manufacturers and suppliers, repeat business, revenue, and increasing margin growth. Those are all things you would hear with or without a 'dot.com' after it."

The Internet companies that fail, Ostrow explained, thought primarily about cool technology or a tricky infrastructure. Those firms, he continued, were the pretenders to the throne. "Only those companies that provide tangible value to the customers and to their investors are still standing." TestMart, he believes, is on its way to being one of those that is still standing. But it's not over yet. "Until TestMart is a profitable, significantly growing business, I don't think we're out of the woods, either. But I think that's a healthy dose of realism that, if anything, is going to get us over the hill."

Having a basic, sound business rationale that addresses traditional business needs is also how Grindstaff sees UGS succeeding in the Internet arena. "What we did was take a relatively conservative view of the Internet. We didn't put the whole company at risk to put up our e-vis.com. The Internet piece of your business may speed the technology evolution, and may actually change priorities of what is most important to implement in our whole product suite. We've certainly adopted many of the Internet technologies, but we haven't thrown the baby out with the bath water."



TestMart offers a one-stop shop for renting, buying, and selling new and used test equipment, in addition to news, applications support, and databases of information on more than 10,000 products from 500 manufacturers.

SmarTeam's Rodger sees a huge difference between consumer-oriented Internet ventures and business-to-business (B2B) sites. Dot-com companies at the consumer level fail, he said, because of over-hype, over-expectation, and over-marketing. That's not the same as the B2B world, where economic fundamentals are stressed. "The kind of crash of the dot-com types is not what's going to happen here at all," Rodger predicted, "because it's a much more mature approach to what the opportunities are."

What's working in the Internet realm today, added Rodger, are the same things that will work 20 or 30 years from now. "The Web is here to stay. What's working today is the data management piece of this business because it's like the nervous system that's reaching out to all different clients and drawing together the data."

Fundamentals are working, Rodger said, and that's what manufacturers are focusing on. "Companies need to save money, they need to reduce costs, they need to reuse their data, they need to share data efficiently, and they face the enormous problem of getting to market first and faster. If they don't accomplish that, they end up selling black bananas, and who wants to buy black bananas? When we talk technology, the bottom line is the bottom line."

Visit www.nasatech.com/features for more comments from industry leaders on engineering and the Internet.

Get Connected to the Companies Featured in this Article:

Forrester Research
www.forrester.com

MSC.Software/
MSC.Engineering-e.com
http://exchange.engineering-e.com

PlanetCAD
www.planetcad.com

RedSpark
www.redspark.com

SmarTeam
www.smarteam.com

Tecnomatix Technologies
www.tecnomatix.com

TestMart
www.testmart.com

UGS
www.ugs.com
www.e-vis.com

Workgroup Technology Corp.
www.workgroup.com

Technologies of the Month

Sponsored by yet2.com

For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

Optical Technology Enables Wireless Monitoring of Shallow Exploration Drilling

Sandia Laboratories

A new optical transmission system monitors drilling activities in real time, without wires or cables to get tangled or cut. Utilizing infrared beams to transmit data, Sandia Laboratories has developed an optical telemetry system that uses inexpensive light emitting diodes (LEDs) or laser diodes to send data to the surface from sensors mounted near the drill bit. A large number of drilling parameters and soil conditions can be monitored instantly.

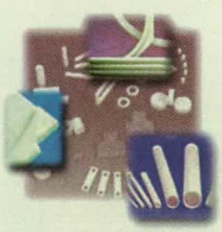
Individual sensors can be deployed in a floating housing within the drill pipe with no direct electrical contact with the drill or drill barrel. All sensor data is transmitted from the bit to the floating telemetry system by electromagnetic signals. From the floating telemetry system the data is transmitted via infrared. A voltage converter converts the transmission back to a digital signal for display purposes.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/sandia.html

New Technology Strengthens Advanced Ceramics

Dr. Jack Solomon, Director, Technology Planning, Praxair

Typically, ceramic products are created by combining ceramic particles or powders, such as alumina, with an organic binder to form a malleable mixture that can be shaped by tape-casting, injection-molding, or extrusion. Once the ceramic has been shaped, the "green body," as the unfired ceramic is called, is heated, or "sintered" in a furnace, removing the organic binder (debinding) and hardening the ceramic. As the ceramic is heated, the gases generated by the oxidation or decomposition of the organic binder can cause damage to the part, including cracking, bloating, and warping.



Praxair has developed a method to slow the rapid outgassing by introducing an inert gas into the binder removal zone, significantly reducing the oxygen concentration in the air and controlling the rate of binder removal. The result is a substantial reduction in rejects and the ability to produce stronger, more consistent ceramic parts.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/praxair.html

Maximizing Profits From Intellectual Properties: GE's New IP Asset Management System

Gerard Devine, IP Counsel, GE Industrial Systems

GE Industrial Systems (GEIS) has developed an electronic system for managing intellectual property assets and agreements, now available for license to third parties from GEIS.

The software application runs on common computer hardware, and provides comprehensive cataloging and monitoring of GEIS's licensing agreements. The IP management system uses a platform built around Microsoft's Internet Information Server 4.0 and Microsoft Access 97, enabling GE to electronically capture key elements of each licensing agreement for future tracking, collections, and general management. The entire system is web-based, enabling GEIS personnel to get up-to-date information via the company's intranet on licensing by product line, licensee, territory, and agreement type.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/ge.html

New Plastic Laminate Provides Same Quality Paint Surface as Metal

John Markey, Avery Dennison

Engineered by Avery Dennison, a new technology enables thermo-formable plastic to accept a uniform painted finish, including a Class A automotive finish that previously was attainable only on metal parts. Avery Dennison has created a laminate that features an electrically conductive layer. This first layer is the key to the new process and acts as a primer to attract and hold electrostatically sprayed paint.

Cast onto a temporary flexible casting sheet, the primer layer starts as a liquid polymeric film that includes a highly conductive particulate such as carbon black for a uniform finish, and fumed silica to aid drying and produce a smooth surface. The primer layer is transferred by heat lamination from the temporary casting sheet onto a thin, semi-flexible, thermo-formable plastic face sheet, which then can be thermo-formed into a 3D part. The primer layer also can be formulated as a resistive layer, making it suitable for electromagnetic interference (EMI) and radio frequency (RF) shielding in data and telecommunication components.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/avery.html

Commercialization Opportunities

Polyorganosiloxane Waterproofing for Porous Ceramics

Whereas the previously developed silane-based waterproofing materials are toxic and volatile, the present formulations are nontoxic and nonvolatile and can be applied by ordinary coating procedures.
(See page 38.)

Attachment of Small SiC Hoops to SiC-Based Ceramics and Composites

This technique prevents the detachment of lead wires from thin-film sensor systems surface mounted on ceramic substrates for high-temperature tests.
(See page 39.)

A Mass-Spectrometer System for Detecting Gas Leaks

This system was originally designed to perform leak detection and measurement of cryogenic propellants from a remote location during a shuttle launch. This versatile, expandable system can be adapted to other applications that require monitoring from remote locations.
(See page 46.)

Simplified Construction of Conical Log-Spiral Antenna

This design provides for mating parts, the faying surfaces of which enforce alignment initially during construction and maintain alignment subsequently during use.
(See page 52.)

Micromachined Double Resonator

This design was inspired by the realization that solid mounting is not necessarily desirable and that if the substrate of a resonator is suspended on thin springs, what is formed is a double-mass resonator that can have a *Q* greater than that of the original resonator.
(See page 58.)

Molten-Carbonate Oxidation of Solid Waste

This process completely oxidizes wastes as diverse as polytetrafluroethylene, polyvinyl chloride, polyethylene terephthalate, polyethylene, wheat straw, and other materials. The process can operate at atmospheric pressure without flames and without direct feed of fuel into the oxidation chamber.
(See page 62.)

Hermetic Wafer Bonding by Use of Microwave Heating

The technique has the potential to become a standard one for bonding in the fabrication of microelectromechanical systems.
(See page 66.)

Macroextraction for Purification of Nucleic Acids

Nucleic acids can be quickly extracted from relatively large volumes of starting materials. This technique can facilitate diagnoses and studies of infectious and genetic diseases.
(See page 69.)

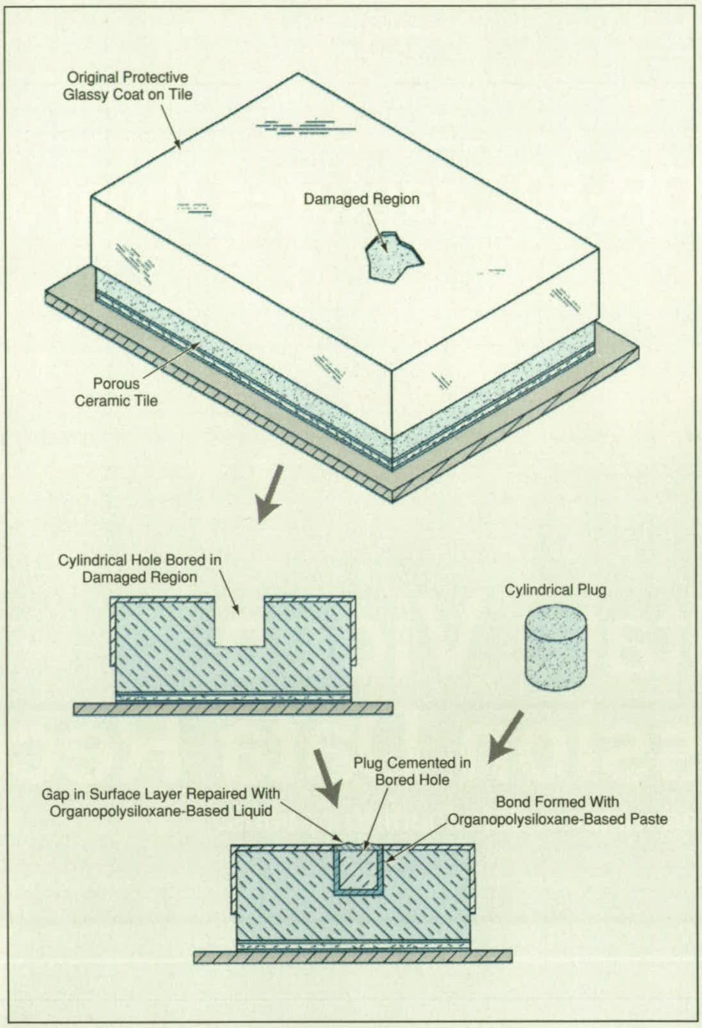
Polyorganosiloxanes for Coating Porous Ceramic Insulation

Protective coating and repairs can be performed relatively easily.

Ames Research Center, Moffett Field, California

Liquid and paste polyorganosiloxane formulations (which become high-temperature- and oxidation-resistant organosilicone-based ceramics upon curing) have been invented for use in (1) protecting porous, lightweight ceramic thermal insulation materials against aeroconvective thermal degradation and (2) repairing and bonding such materials. These formulations were originally intended especially for application to the fibrous refractory composite insulation (FRCI) tiles that protect parts of the space shuttles during re-entry into the terrestrial atmosphere; they may also be suitable for application to similar insulating tiles in laboratory and industrial furnaces.

A formulation of this type starts out as a mixture of (1) one or more liquid di- and tri-functional organosilanes; (2) one or more suitable fillers to enhance chemical, mechanical, and/or thermal properties of the uncured mixture and/or the organosilicone end product; and (3) water. The functionality of the organosilanes resides in alkoxy groups attached to the silicon atoms. Before application to a ceramic thermal-insulation surface that one seeks to protect or bond, the mixture is allowed to cure partially at room temperature by the hydrolysis and partial condensation of the organosilanes with the water, yielding liquid polyorganosiloxanes (incompletely polymerized organosilicones) with unreacted silanol groups. Also formed in the condensation reaction are alcohols, which become dissolved in the remaining water. The resulting mixture can be applied to the surface of the ceramic insulation by spraying, brushing, rolling, flowing, or other conventional technique.



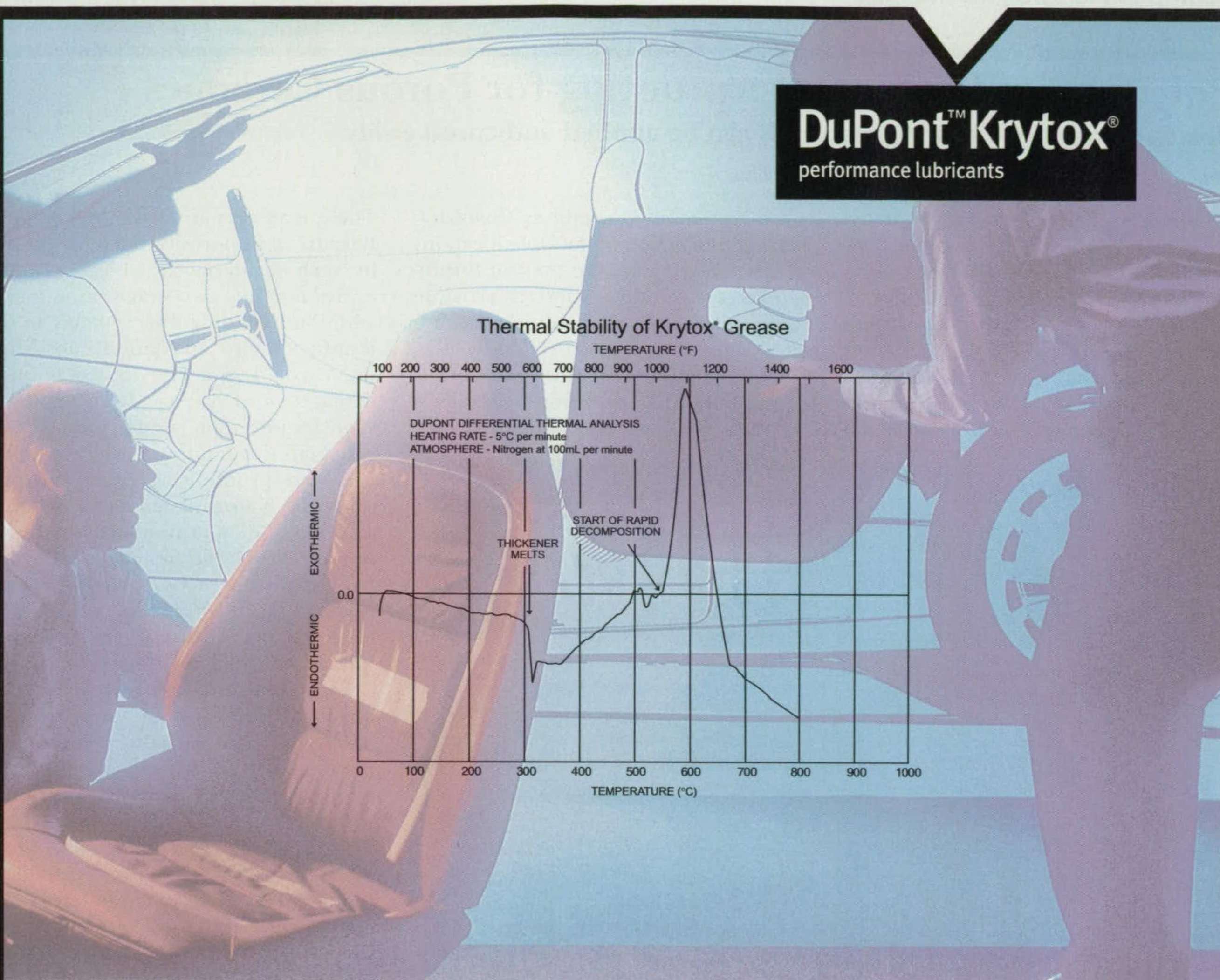
A Damaged Region of a Thermal-Insulation Tile is bored out to a cylindrical shape to receive a cylindrical repair plug. Prior to insertion of the plug in the hole, the side and bottom of the plug and/or the hole are coated with a viscous polyorganosiloxane-based adhesive. After insertion, the outer surface of the plug is coated with a dilute organopolysiloxane formulation to close the opening in the original glassy protective coat.

After application, the mixture is allowed to cure at room temperature to become a soft solid coat. The mixture continues to cure at room temperature, eventually becoming a hard polyorganosiloxane coat. The continued curing occurs by condensation of the unreacted silanol groups. If desired, curing can be accelerated by heating. When exposed to still higher temperature (especially in an extreme oxidative and aeroconvective environment like that experienced by a spacecraft during re-entry), the coat becomes an oxidation-resistant and thermally stable protective ceramic on the underlying ceramic insulation.

A low-viscosity, watery formulation of this type, with or without one or more fillers, would ordinarily be applied to a porous ceramic tile and allowed to soak into a surface layer of pores so that, upon curing, it could form a protective surface layer within and on the ceramic substrate to prevent the entry of hot gases. A viscous liquid formulation containing larger amounts of fillers could be applied to the surface of the ceramic tile to form a hard, impermeable layer on the external surface of the ceramic. A highly viscous formulation in the form of a paste could be suitable as an adhesive and/or filler for fabrication or repair. For example, the paste could be used to fill small holes caused by chipping or to cement plugs in place to fill larger holes (see figure).

This work was done by Daniel B. Leiser, Ming-ta S. Hsu, and Timothy S. Chen of **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

This invention has been patented by NASA (U.S. Patent No. 5,985,433). 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-14077.



WITH DUPONT™ KRYTOX® BUILT INTO THE EQUATION, YOU'LL FIND THE PERFECT SOLUTION.

bearings and bushings

universal joints

Designing critical parts that have to last? One formula fits any equation—Krytox®. The most advanced lubricant formulated from space-age fluoropolymer technology, Krytox® is nonflammable, chemically inert, and compatible with metals, elastomers and engineering plastics. It also stands up to harsh solvents. And it won't migrate. At temperatures ranging from -70°F to 650°F (where most lubricants degrade), Krytox® excels—extending the life of critical components. No matter what you're designing, the logical conclusion for durability is Krytox®. For more information on Krytox® and other DuPont performance lubricants, call 1-800-424-7502. Or visit our new, redesigned website at www.krytox.com.

alternator bearings

DUPONT
The miracles of science™

Polyorganosiloxane Waterproofing for Porous Ceramics

Relatively nontoxic coating materials can be applied and cured easily.

Ames Research Center, Moffett Field, California

Liquid waterproofing agents based on polyorganosiloxanes have been invented for use in treating porous, lightweight, fibrous ceramic thermal-insulation materials in both tile (rigid) and blanket (flexible) forms. Whereas silane-based waterproofing materials developed previously for this purpose are toxic and volatile and must be applied in tedious procedures (involving repeated injection at multiple locations by use of syringes), the present formulations are nontoxic and nonvolatile and can be applied by ordinary coating procedures.

Waterproofing of lightweight, fibrous ceramic thermal-insulation materials is needed for the following reasons: These materials are often hygroscopic. Because of its porosity and hygroscopicity, such a material can absorb as much as five times its own weight in water. In addition to adding unacceptably to the weight of the insulation, absorbed water could give rise to freeze/thaw damage or to damage from explosive vaporization upon sudden exposure to very high temperature.

A waterproofing agent of the present type is formulated as an aqueous solution of di- and tri-alkoxyfunctional organosilanes, the molecules of which contain hydrocarbyl groups of between 1 and 10 carbon atoms. The functionality resides in alkoxide groups attached to the silicon atoms. Before application to a ceramic thermal-insulation material, the solution is allowed to cure partially at room temperature by the hydrolysis and partial condensation of the organosilanes with the water, yielding low-molecular-weight polyorganosiloxanes with unreacted silanol groups. Also formed in the condensation reaction are small amounts of alcohols, which become dissolved in the water. If desired, alcohol can be added to the solution to facilitate drying; however, it has been found that the addition of water alone yields satisfactory results. Thus, unlike previously developed waterproofing materials, which generally contain such toxic, volatile solvents as toluene, xylene, naphtha, and/or lacquer thinner, this waterproofing agent is relatively nontoxic and nonvolatile.

The resulting solution can be applied to the ceramic insulation that one seeks to render waterproof by any suitable conventional coating technique — for example, spraying, brushing, rolling, or flowing. The solution penetrates the ceramic substrate to some depth by capillary action in the pores. Thus, what is formed is not a continuous coat on the exterior surface that would seal against penetration of all liquids and gases; instead, the interior surfaces of the pores become coated with a thin layer of waterproofing material that adds little to the overall weight of the ceramic. The waterproofing treatment is completed by mild heating (typically to no more than about 100 °C) to drive the condensation reaction to completion and to dry the coated ceramic substrate. Heating can be effected by use of a heat gun, heat lamp or any other convenient means.

This work was done by Daniel B. Leiser, Domenick E. Cagliostro, Ming-ta S. Hsu, and Timothy S. Chen of **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

This invention has been patented by NASA (U.S. Patent No. 5,766,322). 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-14068.

Attachment of Small SiC Hoops to SiC-Based Ceramics and Composites

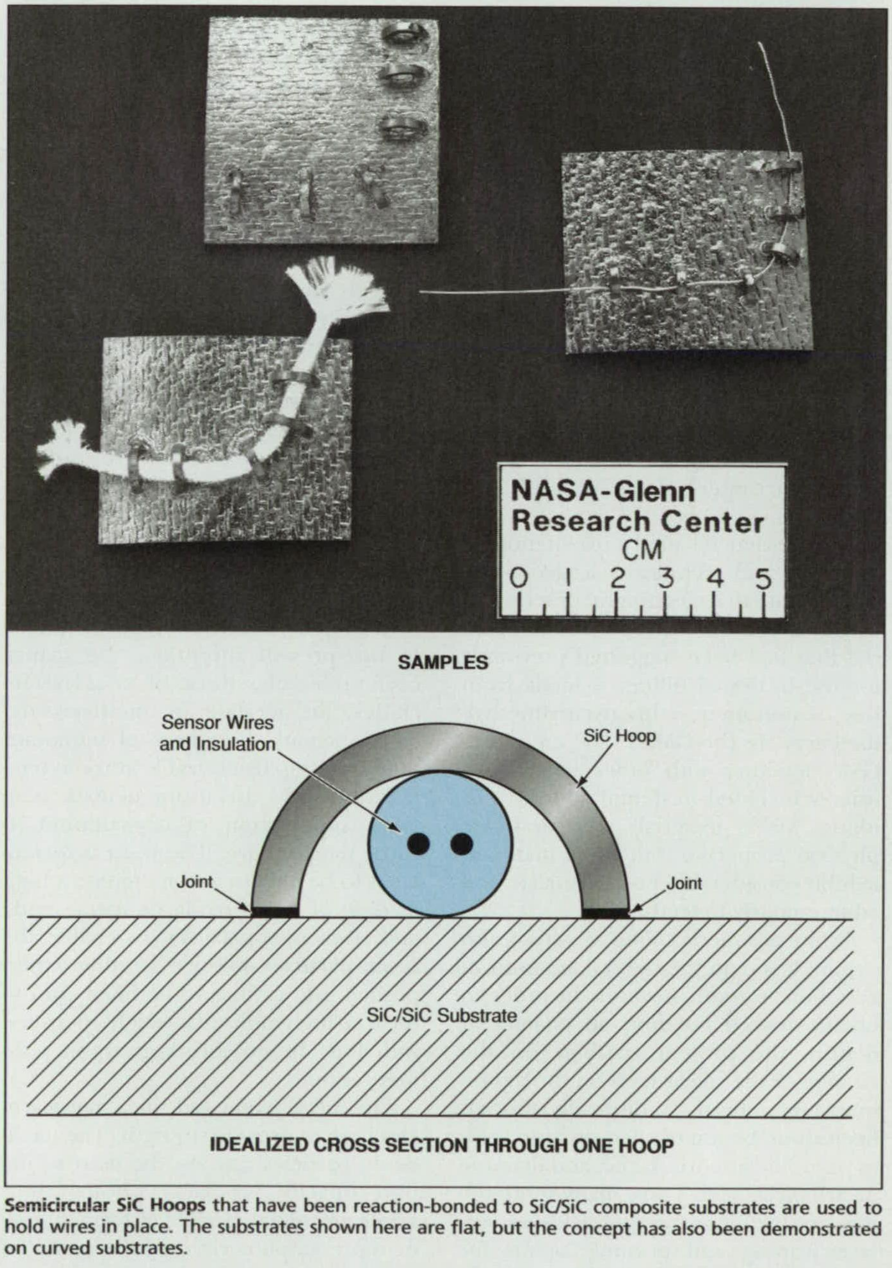
These hoops can be used to hold sensor lead wires in place.

John H. Glenn Research Center, Cleveland, Ohio

A technique for holding sensor lead wires in place on substrates made of SiC-based monolithic ceramic or SiC/SiC fiber-reinforced ceramic-matrix composite materials involves routing the wires through semicircular hoops that have been reaction-bonded to the substrates. These hoops are made of SiC-based materials similar or identical to the substrate materials. This technique was devised to prevent the detachment of lead wires from surface-mounted thin-film sensor systems (e.g., thermocouples and strain gauges) during testing of the substrates (panels, subcomponents, etc.) at temperatures >1,000 °C in the presence of high-speed gas flows.

The reaction-bonding process used to join the hoops to the substrates is called "ARCJoinT" (which signifies "Affordable, Robust Ceramic Joining Technology"). This process was described in several previous *NASA Tech Briefs* articles, including "Joining of SiC-Based Ceramic and Fiber-Reinforced Composite Parts" (LEW-16405), Vol. 22, No. 5 (May 1998), page 54; "Reaction-Forming Method for Joining SiC-Based Ceramic Parts" (LEW-16661), Vol. 23, No. 3 (March 1999), page 50; and "Reaction-Forming Method for Joining SiC-Based Parts" (LEW-16827), Vol. 24, No. 4 (April 2000), page 59. To recapitulate: A carbonaceous mixture is applied between the parts to be joined. The parts are heated to a temperature of 115±5 °C for 10 to 20 minutes. This action cures the mixture, bonding the parts with moderate strength. Next, silicon or a silicon alloy in tape, paste, or slurry form is applied to the joint regions. The parts are heated to a temperature between 1,250 and 1,425 °C for 5 to 10 minutes, causing the silicon to melt, infiltrate the joints, and react with carbon. The finished, full-strength joints contain silicon carbide with minor amounts of silicon and other phases. The joints are expected to retain mechanical strength and integrity at temperatures up to 1,350 °C in air.

Once hoops have been joined to a substrate via this approach, the sensor lead wires can be slipped through the hoops (see figure) and connected to the sensors. Any excess space between the lead-wire insulation and the hoop



Semicircular SiC Hoops that have been reaction-bonded to SiC/SiC composite substrates are used to hold wires in place. The substrates shown here are flat, but the concept has also been demonstrated on curved substrates.

can be filled with a refractory cement or another nonreactive material, if necessary, to prevent the wires from moving.

As an alternative to SiC as a starting material, hoops could be made initially of carbon — more specifically, graphite. If carbon hoops are used, then additional silicon is applied to the joints and the carbon is converted to silicon carbide during the bonding process. The advantage of this approach is the relative ease of machining graphite (vs. machining SiC).

This work was done by J. Douglas Kiser, Jih-Fen Li, and Lisa C. Martin of **Glenn Research Center** *and Mrityunjay Singh of Dynacs Engineering Co. 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-17009.

Improved Polymeric Composite Materials for Dental Fillings

In comparison with prior formulations, these materials shrink less.

Lyndon B. Johnson Space Center, Houston, Texas

Composite materials that include combinations of metal oxide and silica nanoparticles in polymeric matrices have been invented for primary use as dental fillings, dental and bone adhesives, and the like. There have been previous efforts to develop polymeric replacements for the amalgam used traditionally as dental filling material, but those efforts involved polymers that exhibited unfavorable characteristics, including shrinkage and poor adhesion to bone. Strong adhesion is desirable and zero shrinkage is essential for a dental filling material because accumulated stresses from shrinkage can cause debonding with consequent leakage and attack by microbes. The present materials are formulated to obtain stronger adhesion and less shrinkage.

A somewhat detailed presentation of historical and technical background is prerequisite to a meaningful description of the invention. One polymeric material that had been suggested previously for use in dental fillings is made from the monomer bis-glycidylmethylmethacrylate (bis-GMA). The use of bis-GMA together with other ingredients usually included in dental adhesives or fillings yields materials with desirable physical properties, but these materials exhibit considerable post-shrinkage and adhere poorly to teeth.

Other polymeric filling materials also exhibit less than the desired amounts of adhesion to tooth surfaces. In order to obtain desired bonding on enamel or dentin, the protein coatings on the enamel or the smear level on the dentin must be removed. Traditionally, this has been done by use of such organic acids as phosphoric, citric, lactic, and diamine dicarboxylic acid. Thus, many tooth-filling products contain polyacids as surface-cleaning and priming agents for enamel and dentin. Because bis-GMA is not inherently adhesive to tooth surfaces, similar provisions for etching by acids would have to be made if bis-GMA were to be used.

Another class of candidate dental adhesive and filling materials includes some nematic liquid crystals that can be photopolymerized within seconds, at temperatures in the vicinity of 90 °C. These materials form densely cross-linked networks of reaction extent greater than 95 percent and exhibit very little polymerization shrinkage because of the high packing efficiency that already obtains in the nematic state. However, polymerization at lower temperatures (including room temperature) results in undesirable intervening smectic and crystalline phases that make the materials unsuitable as medical and dental restoratives. This completes the background information.

In a representative composite material of the present invention, the matrix resin preferably consists of, or at least includes, an acrylate or methacrylate-based nematic liquid-crystal monomer that is photopolymerizable at room temperature and exists in the nematic state (with suppression of crystallinity) at room temperature. The resin is formulated to be able to accommodate a high loading of metal oxide or metal oxide and silica nanoparticles, to enable the resin/particle mixture to flow when pushed into cavities to be filled, and to form a high-molecular-weight polymer, with little or no shrinkage upon polymerization.

The metal oxide and silica nanoparticles help to provide strength. The metal oxide particles can also be used to impart opacity for x-ray photography. While any metal capable of forming one or more amphoteric oxide(s) could be used, tantalum is particularly advantageous for imparting x-ray opacity to the composite.

For compatibility with teeth, the metal oxide particles must not exhibit high surface acidity. The surface acidity of tantalum oxide nanoparticles is neutralized by mixing, with the particles, a polymerizable, biocompatible, heterocyclic base (e.g., an alkene-terminated imidazole or phosphate) that can form complexes with the acid sites on the surfaces of the particles.

In many cases, it is desirable to formulate resin/nanoparticle filling mixtures to be translucent or transparent. In a typical dental restorative procedure, a liquid or pasty filling material is placed on a tooth and ultraviolet light used to effect the polymerization (cure) into a high-strength, hard, x-ray-opaque coating or filling, with essentially zero shrinkage. The transparency or translucency makes it possible to effect photopolymerization of a thicker layer of filler than would otherwise be possible, thus making it unnecessary to apply and photocure multiple thinner layers.

This work was done by Stephen T. Wellinghoff of Southwest Research Institute 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

Stephen T. Wellinghoff
Southwest Research Institute
6220 Culebra Road
Drawer 28510
San Antonio, TX 78228

Refer to MSC-22842, volume and number of this NASA Tech Briefs *issue, and the page number.*

For More Information Circle No. 592

Polymer/Metal Laminate for Heat-Pipe and Radiator Envelopes

This material is durable, flexible, hermetic, and heat-sealable.

Lyndon B. Johnson Space Center, Houston, Texas

A thin polymer/metal laminate has been developed for use as an envelope material for lightweight heat pipes and heat-pipe radiators that operate at temperatures up to 360 K. The material is flexible enough to make it possible to roll or fold heat pipes compactly for transport and to unfurl them for use. The material is durable enough to withstand folding or rolling without incurring leaks. In addition, it is heat-sealable and thus an attractive alternative to metal heat-pipe envelope materials, which must be welded or brazed at temperatures much greater than those needed for heat sealing.

Material	Thickness of Layer, mm	Notable Characteristics of Layer Material
Polyvinyl Fluoride (Tedlar TWH15BL3 or Equivalent)	0.0380	Ultraviolet Diffuse Reflector, Emissivity = 0.826, Absorptivity = 0.393
Copper	0.0340	Roll-Annealed, Surface Treated With Electroplated Copper
Polyvinyl Fluoride (Tedlar TWH10BS3 or Equivalent)	0.0254	High Yield Elongation, Low Moisture Transmission
Copper	0.0340	Roll-Annealed, Impermeable, Strong
Polyvinyl Fluoride (Tedlar TWH10BS3 or Equivalent)	0.0254	High Yield Elongation, Low Moisture Transmission
Polypropylene	0.0952	Very High Yield Elongation, Negligible Moisture Transmission, Heat-Sealability

This **Six-Ply Polymer/Metal Laminate** offers a combination of flexibility, strength, and thermal stability not available from any of the laminate materials taken by itself. The laminate has an overall thickness of 0.252 mm and an areal mass density of 40 g/ft^2 (0.43 kg/m^2).

A polymer/metal laminate was selected for development because neither a metal nor a polymer foil exhibits the required properties, whereas the combination of materials could be expected to exhibit those properties. A metal foil can serve as a leak-proof pressure boundary for containing a heat-transfer fluid, but it fatigues easily and fails through growth of cracks and/or pinholes at the highly stressed tips of wrinkles that form during flexing. A polymer film has the required flexibility and does not develop cracks or pin holes when flexed; however, air and the vapor of the heat-transfer fluid can diffuse through a polymer film. When the two materials are bonded together in a laminate, the metal foil serves as the fluid-containment and pressure boundary, while the polymer film supports the metal foil, preventing large localized stresses and thus increasing the flex-fatigue resistance of the metal foil. With the proper selection of laminate layers, a laminate can be designed to exhibit such desired characteristics as flex-fatigue resistance, high emissivity, and resistance to ultraviolet radiation.

The present laminate contains six plies. It is an improved derivative of four-ply polymer/metal laminates that are used commercially to package foods and medicines and that do not have the strength or the high-temperature stability required for the heat-pipe application.

The table describes the six layers. The two copper layers provide the hermetic seal; in contrast, all commercial laminates use only single metal layers. The use of two metal layers in this laminate affords redundancy for protection in the event that a leak arises in one metal layer. The innermost layer is made of a heat-sealable polymer to ease fabrication. The outer polyvinyl fluoride layer provides the optical properties needed for efficient radiation of heat.

This work was done by John D. Cornwell of **Johnson Space Center** *and John E. Fale and Nelson J. Gernert of Thermacore, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
MSC-22856

Hybrid Composite Structures Made From Polybenzoxazole Fibers

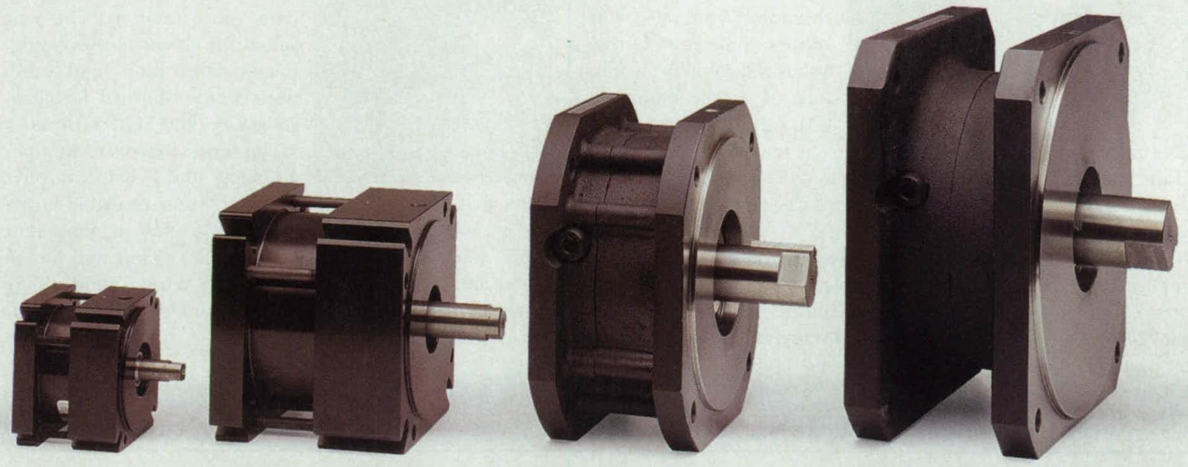
Strength-to-thickness ratios would be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

Hybrid composite-material (fiber/matrix) structures of a proposed type would incorporate recently developed polybenzoxazole (PBO) fibers that feature high strengths and high moduli of elasticity and which can be made in much thinner sections than are possible with graphite fibers. The PBO fibers could be used, for example, in skins, face sheets, or panels, any or all of which could be made as multiple-angle-ply layups.

In comparison with similar structures made from graphite fibers to satisfy a given set of strength and stiffness requirements, those made from PBO fibers to satisfy the same set of requirements could be thinner. In a typical application, PBO-fiber laminated face sheets or skins would be bonded to graphite stiffeners or honeycomb cores to make hybrid composite stiffened sandwich structures thinner and less massive than the corresponding structures made with graphite (only) fibers, due to the thinner sections possible with PBO fibers.

This work was done by Joseph Lewis 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 Materials category.*
NPO-20774

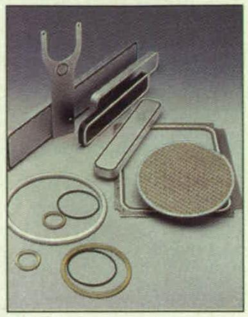


Special Coverage: Composites and Plastics

ND Industries, Clawson, MI, offers ND Microspheres® water-based microencapsulated **acrylic thread adhesives** that are applied to threaded fasteners. The room-temperature-curing adhesives combine a mixture of acrylic emulsions with capsules of activators. The material remains inert until the shearing action of engagement to a mating part causes the capsules to break, allowing the adhesive to cure. They can be applied by most types of coaters.

The AA0695 general-purpose adhesives are yellow and feature a 72-hour cure time; the AA0895 are adjustable, green in color, and have 72-hour cure; and the AA0795 high-temperature adhesives are yellow with a 72-hour cure. Application of the adhesive generates no heat to affect platings. Applied assembled nuts and bolts can be removed and re-used up to three times.

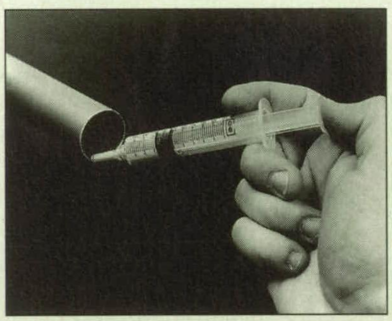
For More Information Circle No. 724



Parofluor ULTRA™ **perfluorinated elastomer materials** from Parker Hannifin Seal Group, Irvine, CA, are designed for extreme sealing applications and are formulated to reduce contamination in harsh environments. The materials are suited for chemical processing, semiconductor fabrication, and other applications where thermal stability, chemical resistance, and high purity are required.

The series consists of new perfluorinated compounds, each with physical properties that offer a choice of sealing levels. Available in black, white, and translucent, the materials can be used in temperatures up to 608°F. They are resistant to chemicals, organic and inorganic acids, bases, amines, steam and hot water, ketones, and aldehydes. The materials can be formed into O-rings, molded shapes, and metal/rubber composite seals.

For More Information Circle No. 726



Master Bond, Hackensack, NJ, offers the Polymer System Supreme 3AOHT **electrically insulating epoxy**, a one-component thermally conductive epoxy resin formulation for high-speed production operations. It adheres to both metallic and nonmetallic substrates such as ceramics, printed circuit boards, and most plastics. The epoxy's shelf life is six months at 75°F.

The resin system is a thermal conductor and maintains electrical insulation properties. Its high strength is maintained after curing at 5-10 minutes at 300°F, or 20-30 minutes at 250°F. It is best suited for advanced electronic circuitry, where miniaturization increases the need for effective heat dissipation. The epoxy is available in pints, quarts, gallons, pails, and drums.

For More Information Circle No. 722

A line of thermoset **cast polyurethane thin films** is available from Mearthane Products Corp., Cranston, RI. The films are available in a variety of dimensions and may be custom formulated for chemical, physical, and electrical conductivity requirements, including abrasion-resistant coatings, self-adhesive tapes, gaskets, and static control.

The films can be laminated to other materials such as PTFE, or can be coated with adhesives to create composite film structures with multiple performance and manufacturing capabilities. They are available in colors, opaque, translucent, and near clear, with or without static dissipation properties. Available hardness ranges from 90 Shore A to 75 Shore D. The films are temperature-stable to 250°F.

For More Information Circle No. 723

Tra-Con, Bedford, MA, offers TRA-BOND 2153 **thermally conductive epoxy** for bonding transistors, diodes, resistors, integrated circuits, and other heat-sensitive components to circuit boards. The two-part electrically insulating compound develops high-impact bonds at room temperature, improving heat transfer while maintaining electrical insulation.

The epoxy bonds to itself and to metals, silica, steatite, alumina, sapphire, and other ceramics, as well as glass, plastics, and other materials. It features a wide temperature range and compatible coefficient of thermal expansion. It also is resistant to many solvents.

For More Information Circle No. 727

NYPLAS™ and NYSEAL® **sealing elements** from Nylok Fastener Corp., Macomb, MI, are applied to threaded and unthreaded fasteners to create gasket-type seals. The NYPLAS process applies a Plastisol material under the heads of fasteners, pop-style rivets, and double-ended flanged screws to seal out water, dust, and air. The black-colored sealant also provides noise-dampening anti-rattle.

NYSEAL is a pre-applied, permanently fused sealing element that prevents leakage of fluids under pressures up to 500 psi. The pliable, green-colored coating also is used for preventing galvanic reactions between aluminum and stainless steel parts, and covers 360° of the bearing surface of the fastener's head, and 2 to 3 thread pitches down the shank. As the fastener is seated, the material compresses and fills the void between the bearing surface of the head and the countersink or counterbore.

For More Information Circle No. 725

A Mass-Spectrometer System for Detecting Gas Leaks

This versatile, expandable system can be controlled from a safe remote location.

John F. Kennedy Space Center, Florida

The Hydrogen Umbilical Mass Spectrometer (HUMS) consists of an integrated sample delivery system, a commercial mass-spectrometer-based gas analyzer, and a set of calibration gas mixtures traceable to NIST (National Institute for Standards and Technology). The system, except for the calibration gas mixtures and the remote operator display, fits into a standard 24-in. wide, 6-ft high, 36-in. deep (0.61 by 1.83 by 0.91 m, respectively) equipment rack and is powered by 120-Vac, 30-A, 60-Hz source. It was designed to perform leak detection and measurement of cryogenic propellants (oxygen and hydrogen) from a remote location during shuttle-launch countdown. It is used specifically to sample the background gas surrounding the 17-in. (0.43-m) Orbiter-ET disconnect, looking for leakage of gaseous hydrogen. The capability to monitor shuttle purge gases and cryogenic hydrogen fill and drain line T-0 disconnect helium purge gas is incorporated into the shuttle installation on each Mobile Launch Platform (MLP).

HUMS was designed to switch rapidly between background gases (helium, nitrogen, or air) during normal operation. The operator has the ability to remotely select one of eight sample lines and between any of six calibration gas mixtures. It can measure from 0 to 100 percent hydrogen, helium, or nitrogen; 0 to 25 percent oxygen; and 0 to 1 percent argon, in any combination in either a helium, nitrogen, or air background. It has an internal cycle mode, added after installation, to cycle between various pre-set sample and calibration gas lines on a continuous basis, if desired.

Operational features include the ability to update the reading for background of each gas in the mixture, thereby avoiding performance of a complete recalibration during operation. This saves a considerable amount of time. The zero gas for the background of interest must be monitored for a couple of minutes to allow the system to stabilize and a reading taken. Only the zero coefficient in the calibration equation for the background of interest is updated. Switching between backgrounds requires only changing to the new background and updating the zero reading for each species. This flexibility is critical when testing in an environment where samples are taken from helium, nitrogen, and air during the test. After testing is complete, a sequence of readings in each background, consisting of zero, test, and span gas mixtures, in that order, provides post-test verification that the system performance remained unchanged since the initial calibration was performed, pre-test.

Selection of calibration gas mixture concentrations was critical to remote verification of performance. Three concentrations of each gas are included, each in backgrounds of helium and nitrogen. This calibration/verification technique was developed after installation of the Hazardous Gas Detection System (HGDS) in 1979 and is based on experience gained during operation of that system. The performance of the COTS multigas, multicollector magnetic sector analyzer is slightly dependent on background gas, whether helium or nitrogen dominates the mixture. Independent calibration curves are used, depending whether the unknown sample is drawn from either a helium or nitrogen/air background.

During the calibration process, linear calibration curves are generated for each gas in the mixture (hydrogen, helium, nitrogen, oxygen, argon), based on pure background (helium or nitrogen) and a span gas (1 to 10 percent of each gas, in each background). An independent test gas, containing mixtures approximating red-line levels (where action is to be taken, based on readings of the sample) is used to both verify a good calibration (test gas reading lies on the line generated by zero and span, for each species) and to compare directly with the unknown sample, if necessary, to remove uncertainty in reading the unknown mixture. The choice of calibration gases allows differentiation of leak sources of cryogenic oxygen from oxygen contained in air. The operator has the ability to measure the ratio of oxygen to argon (~20), indicative of air intruding into the purge gas. Cryogenic oxygen contains no argon.

The design of HUMS achieved two goals. The first was to provide a permanently installed replacement for the Interim-HUMS (I-HUMS), a system designed and built over a weekend (in part to support nearly simultaneous STS-35, STS-38 launch attempts) to be portable between shuttle MLPs. I-HUMS replaced the one-time installation of the Turbo Mass Spectrometer (TMS) developed for launch of STS-26R (first shuttle launch after 51-L). TMS was designed to verify the performance of the 17-in. (0.43-m) Hydrogen Orbiter-ET Disconnect during hydrogen fill and drain operations, prior to shuttle launch. TMS demonstrated the ability of a high-vacuum turbo-molecular pump to operate and survive in a high vibration environment.

Use of a turbo-molecular pump replaced the need for ion pumps to achieve high vacuum for the mass-spectrometer-based gas analyzer. Ion pumps are unable to pump high concentrations of helium, restricting earlier versions of mass spectrometers to sampling in backgrounds of either nitrogen or air. The HUMS data acquisition and control system was designed to match the standard CORE interface planned to replace the Shuttle Launch Processing System (LPS), but retrofitted to interface with a standard LPS "XCard" when the CORE concept was abandoned during HUMS.

This work was done by Greg Breznik, Barry Davis, and Frederick Adams of **Kennedy Space Center***; Guy Naylor, Francisco Lorenzo-Luaces, Charles H. Curley, Richard J. Hritz, Terry D. Greenfield, David P. Floyd, Curtis M. Lampkin, Donald Young, Gary N. McKinney, and Don Greene of Lockheed-Martin; and David R. Wedekind, Larry Lingvay, and Andrew P. Schwalb formerly of I-NET. For further information, access the Technical Support Package (TSP),* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*
KSC-12109/06


The Pinnacle of Telemetry Recording
EVEREST™
Telemetry Recorder-Workstation
EVEREST
Astro-Med
Large color display for real-time data viewing
Intuitive touch-screen interface simplifies setup and operation
Look-back while recording in real time
Up to 32 analog or digital input channels
Virtual Chart™ efficiently stores data while saving paper
Ethernet interface for command and control
High-resolution chart printing for clear, crisp traces
www.astro-med.com/ev 15
For More Information Circle No. 518
Call, E-mail, Fax, or write to us today for all the details.
®Astro-Med,®Inc.
TEST & MEASUREMENT SYSTEMS
Astro-Med is System Certified to ISO-9001
Astro-Med Industrial Park, West Warwick, Rhode Island 02893
Phone: (401) 828-4000 • Toll Free: 1-877-867-9783 • Fax: (401) 822-2430
In Canada Telephone 1-800-565-2216
E-mail: MTGroup@astro-med.com

Oscillator-Stability Analyzer Based on a Time-Tag Counter

This system would combine the best characteristics of prior single- and dual-mixer systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed system for simultaneous characterization of the instability of several precise, low-noise oscillators of nominally equal frequency would be built around a commercially available time-tag counter. One of the oscillators would be deemed to be a reference oscillator, and each of the other oscillators would be compared with it by operation of a combination of hardware and software. In addition, without further modification of the hardware, any two nonreference oscillators could be compared with each other via software.

The design of the proposed stability analyzer is of a type called "dual mixer" in the precise-time-and-frequency-measurement art because the comparison of any two nonreference oscillators would involve the outputs of two mixers. There are also single-mixer stability analyzers. Single-mixer analyzers exhibit low measurement noise, but an offset-frequency reference oscillator is needed for each pair of nonreference oscillators to be compared. A prior dual-mixer analyzer contains only one offset-frequency reference oscillator, but exhibits noise greater than that of a single-mixer analyzer. The proposed system would offer both the convenience and low cost of a dual-mixer analyzer and measurement noise about as low as that of the best single-mixer analyzer.

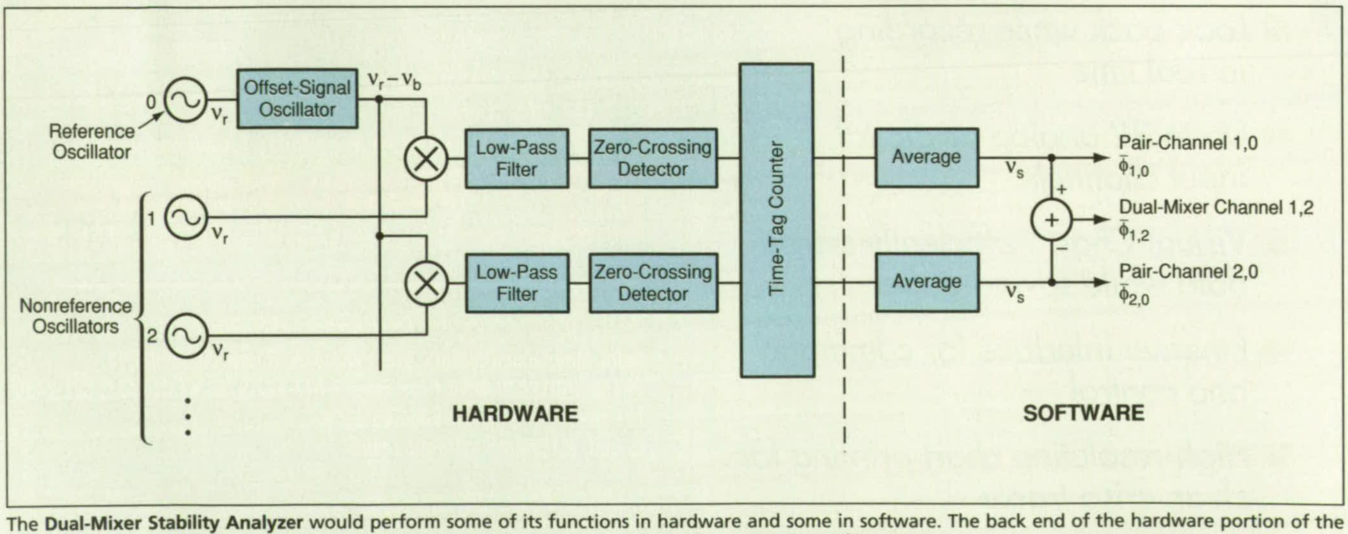
A typical prior dual-mixer stability analyzer utilizes interpolation or extrapolation to convert several incoherent channels of beat-note zero crossings into phase residuals at a predetermined grid of times, so that the residuals of any two channels i and j can be subtracted to give an i-vs.-j comparison. This measurement is contaminated by uncanceled noise from the offset-frequency reference oscillator. The proposed system would take advantage of a modern high-rate time-tag counter to collect zero-crossing times of beat notes, the nominal frequency of which must be much greater than the desired data rate. Then the system would effect a combination of interpolation and averaging to process the time tags into low-rate phase residuals at the desired grid times. The advantage over prior art would be greater cancellation of the reference noise.

The figure schematically depicts the system. The oscillators to be compared would be of nominal frequency ν_r. The frequency of the reference oscillator would be offset by an amount ν_b. The offset reference signal would be mixed with the signal from each of the nonreference oscillators, and the mixer outputs would be low-pass filtered, thereby generating beat notes of nominal frequency ν_b. By use of zero-crossing detectors, the beat notes would be converted to square-wave signals. The time-tag counter would capture the zero-crossing time tags of all the beat notes on a common time axis.

In software, the time tags would be converted to phase residuals that would be averaged over sequential intervals of duration τ_s. These intervals would be the same for all channels. The averages thus computed would constitute one of the sets of output data of the system. An essential feature of the design is that τ_s must be much greater than the beat period $\tau_b = 1/\nu_b$.

Each beat note would yield phase residuals for one pair-channel [e.g., the ith channel, defined with respect to the ith oscillator (a nonreference oscillator) vs. the zeroth oscillator (the reference oscillator)]. Because the averaging intervals would be the same for all pair-channels, the data for two pair channels could be differenced to give a synthesized dual-mixer (i-vs.-j) channel. The ability of this system to suppress the noise of the reference oscillator would depend on the relation $\tau_s >> \tau_b$.

This work was done by Charles Greenhall 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.*
NPO-20749



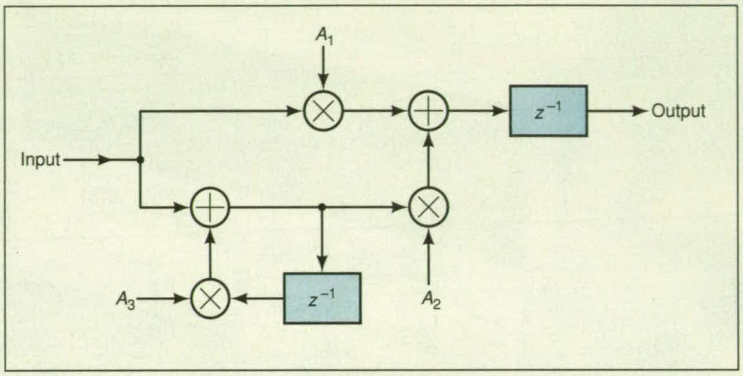
The **Dual-Mixer Stability Analyzer** would perform some of its functions in hardware and some in software. The back end of the hardware portion of the system would be a high-rate time-tag counter that would measure the times of zero crossings of beat notes.

Flexible Carrier-Signal-Tracking Loop for a Transponder

This loop could be programmed for perfect or imperfect integration.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed digital carrier-signal-tracking loop in a radio transponder could be programmed to operate in either a perfect-integration or an imperfect-integration mode. Although originally intended for use in a transponder aboard a spacecraft at a great distance from the Earth, the proposed loop might also be advantageously incorporated into terrestrial communication systems in which it is necessary to track the phases of received carrier signals.



A **Loop Filter** of this configuration can be made to behave as a perfect or imperfect integrator, depending on the choice of A_1 and A_2 and of a third parameter A_3.

Either imperfect or perfect integration can be advantageous or disadvantageous, depending on state of signal reception. Among specialists in the design of carrier-signal-tracking loops, it is well known that as long as a carrier signal is present, the tracking performance of a loop that contains a perfect integrator is better than that of a loop that contains an imperfect integrator. For example, when the frequency of the received carrier signal is offset from the best-lock frequency by an amount δf, a loop that contains a perfect integrator exhibits zero phase error, whereas a loop that contains an imperfect integrator exhibits a phase error equal to $2\pi\delta f/\alpha K$, where αK is the loop gain. On the other hand, when a loop idles (that is, when the input to the loop consists solely of noise), then for a given loop bandwidth, the best-lock frequency of the loop drifts less if the integration is imperfect than it does if the integration is perfect.

The proposed loop design would make it possible to choose whichever integration mode — perfect or imperfect — is currently more advantageous. The figure is a block diagram of a loop filter that can implement either mode. The transfer function of the loop can be given by $A_1z^{-1} + A_2/(z - A_3)$, where A_1, A_2, and A_3 are arbitrary parameters and z is the argument of the z transform ($z = e^{Ts}$, where T is the sample period of the digital circuitry and s is the complex-frequency variable of the Laplace transform). The transfer function is that of a perfect or imperfect integrator, depending on the choice of A_1, A_2, and A_3.

To obtain a perfect integrator, one must choose

$A_1 = K_1$,

$A_2 = K_2T_U$, and

$A_3 = 1$,

where K_1 and K_2 are parameters that determine the loop performance and TU is the sample period at the output of the loop error accumulator.

To obtain an imperfect integrator, one must choose

$A_1 = K(T_U - \tau_2)/(T_U - \tau_1)$,

$A_2 = K[(\tau_2/\tau_1) - [(T_U - \tau_2)/(T_U - \tau_1)]]$,

and

$A_3 = 1 - (T_U/\tau_1)$,

where K is the strong-signal loop gain and τ_1 and τ_2 are the loop time-constant parameters.

It is not necessary to select the parameters A_1 and A_2 with high precision: it suffices to set these parameters within about 1 percent of the values given in the equations above. However, the performance of the loop is quite sensitive to the value of A_3: For an imperfect integrator, A_3 must be set at a value that is less than 1 by a small, precise amount.

This work was done by Jeff Berner, James M. Layland, and Peter Kinman 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.*

NPO-20845

Simplified Construction of Conical Log-Spiral Antenna

Mating parts align themselves during assembly.

Lyndon B. Johnson Space Center, Houston, Texas

An improved design for a conical log-spiral antenna (see Figure 1) simplifies construction and improves alignment. The radiating-element substructure of such an antenna must be properly aligned with the signal-feed substructure to obtain the correct impedance match for efficient coupling of the signal into or out of the antenna. This design provides for mating parts, the faying surfaces of which enforce alignment initially during construction and maintain alignment subsequently during use.

Heretofore, the fabrication of a conical log-spiral antenna typically involved either (1) etching a sheet of metal to form the required spiral strip, then wrapping the strip around a mold or (2) manually aligning a thin, injection-molded part with a feed wire. In either case, initial alignment depends on the subjective judgement and skill of the technician, and the parts can become misaligned subsequently.

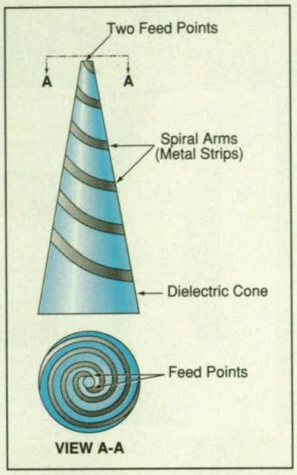


Figure 1. A **Typical Conical Log-Spiral Antenna** includes two spiral arms that must be kept in alignment.

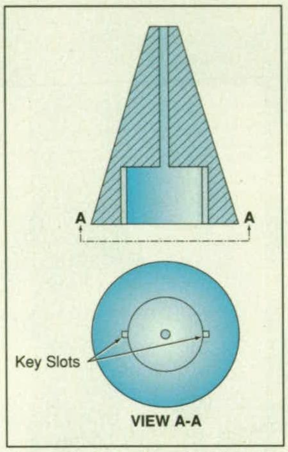


Figure 2. A **Machined Polytetrafluoroethylene Body** defines the spatial relationships among the spiral arms and feed wires, thereby enforcing alignment.

In the present improved design, the outer conical surface is a machined surface on a single-piece polytetrafluoroethylene body (see Figure 2). The use of a machined solid piece guarantees consistency of the cone angle. The inside of the body is machined to provide space for a board that holds the feed circuit, plus key slots that accept opposite edges of the board, thus aligning the feed wires with the log-spiral pattern. Instead of wrapping an etched metal spiral onto the cone, the log-spiral metal pattern is etched onto the cone before final machining.

This work was done by Roland W. Shaw of Shason Microwave Corp. for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
MSC-22334

Program for Evaluating Spacecraft Designs and Missions

Design for X (DFX) is a computer program that assists, at the preliminary stage of planning, in the evaluation of alternative spacecraft designs and mission scenarios. The input required by DFX includes a set of operations goals (scientific and engineering goals and constraints), a mathematical model of the spacecraft, and a set of scoring functions for quantifying the engineering utility and/or scientific value of various operations. DFX uses the operations-goals and model information, along with artificial-intelligence-based planning and scheduling techniques, to generate a high-level activity plan that is then scored by the provided functions. The benefits of using DFX to automate the evaluation of spacecraft designs include (1) improved scientific spacecraft design, leading to improved science return; (2) greater accuracy in analysis of margins and interactions, leading to improved operability of the spacecraft; and (3) decreased project risk (e.g., budget and schedule risk) from rapid prototyping and analysis of designs.

This program was written by Robert Sherwood, Gregg Rabideau, Steve Chien, and Tobias Mann 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20492.

Programming Language for Automated Scheduling and Planning

The ASPEN Modeling Language (AML) has been developed for use in the Automated Scheduling and Planning Environment (ASPEN) software system. As described in prior NASA Tech Briefs articles, ASPEN is an object-oriented system that contains a modular, reconfigurable, reusable set of components that implement the elements commonly found in complex automated-scheduling application programs. AML has a simple syntax that makes it easy for a user who lacks expertise in computer science and artificial intelligence to rapidly create a model of a spacecraft-operations domain for an ASPEN automated-scheduling application program. AML enables a user to construct a model, expressed as a plain-text file, that defines activities, resources, and states. A user can also modify a model without need to recompile ASPEN. AML encodes spacecraft operability constraints, flight rules, spacecraft hardware models, goals of scientific experiments, and operational procedures to enable the generation, by the automated-scheduling program, of low-level sequences of spacecraft operations.

This program was written by Robert L. Sherwood, Alex Fukunaga, David Yan, Quoc Vu, Gregg Rabideau, Steve Chien, and Anita Govindjee 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20281.

Communication Software for Distributed Application Programs

The Task Remote Asynchronous Message Exchange Layer (Tramel) software reduces the costs of distributing application programs across computer networks, including the Internet. Tramel implements robust, reliable, simple, highly portable interprocess communication, such that distributed application programs can tolerate extreme deterioration of communication links and elements of such a program can be stopped, moved to other computers (including computers with different operating systems), and restarted, all while the program is running and without alteration of any source code or configuration file. Because Tramel is based on asynchronous message passing, it can tolerate extremely low link performance without sacrificing transaction concurrency or relying on a multithreading system. Tramel manages network connections for an application program, shielding the program from such details as processor architectures, operating systems, and communication protocols. At the same time, Tramel affords monitoring capabilities that can keep application-program elements informed of the current configuration of the program. Tramel can be executed on any of a variety of computers running the UNIX, VxWorks, or Windows NT operating system.

This program was written by Scott Burleigh 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-19889.

Software for Coordinating Multiple Exploratory Robots

A computer program coordinates the activities of multiple instrumented robotic vehicles of the "rover" type intended for use in scientific exploration. The program is a master/slave, distributed version of the ASPEN planning software, other versions of which have been reported in several prior *NASA Tech Briefs* articles. On the basis of an input set of goals and the initial conditions of each rover, the program generates a sequence of activities that satisfy the goals while obeying the resource constraints and rules of operation of each rover. The program includes a central planning subprogram that assigns goals to individual rovers in such a way as to minimize the total traversal time of all the rovers while maximizing the scientific return. The remainder of planning is distributed among the individual rovers: each rover runs a subprogram that plans its activities to attain the goal(s) assigned to it.

This program was written by Tara Estlin, Darren Mutz, Steve Chien, Anthony Barrett, and Gregg Rabideau 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21031.

Program Creates Code to Parse Text

Saxj is a computer program that facilitates the development of programs that parse textual input in the Java programming language. Saxj is a parser generator that creates static Java parsers in the same sense in which YACC, Bison, and YACC++ are static parser generators that create static C-language parsers. Saxj creates Java object-oriented parsers on the basis of grammar specifications. Saxj uses an algorithm of the "look-ahead 1 token, look right" [LALR(1)] type to convert a grammar specification into a parser. Saxj is built upon implementation of this algorithm by use of a library of Java classes. Grammar specifications in Saxj are intentionally similar to those in YACC, Bison, and YACC++, so that the documentation of Saxj can be nearly the same as that of YACC++. The various instantiations of the class of parsers contain a single definition of the parse table; it is in this sense that the parsers are characterized as static. All of the parsers generated by the YACC family are similarly static. A dynamic parser is feasible in the case of machine learning. Saxj can be used, for example, for writing compiler software, for interpreting sequences of computer-generated commands, and for general language parsing.

This program was written by Richard Weidner 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21055.

Program Creates Java Lexical Analyzers

Luthorj is a computer program that creates static lexical analyzers in the Java programming language, in the same sense in which Flex and Lex create lexical analyzers in the C programming language. The majority of users of Luthorj are expected to be familiar with Lex, and Luthorj parses input files that are largely the same as Lex files. However, Luthorj is not merely a look-alike, Java version of Lex. The functionality of Luthorj is partly compatible with that of Flex, but Luthorj and Flex use different methods to provide similar functionality. The lexical analyzers created by Luthorj convert textual strings into tokens that, in turn, can be fed to parsers created by the Saxj program described in the preceding article. Luthorj converts input string specifications to lexical-analysis data structures by use of an algorithm that converts regular expressions to nondeterministic finite automata (NFA). The NFA are then mapped to deterministic finite automata (DFA). The combination of all DFA are represented as a transition table, which is stored in a file. The outputs of Luthorj are the transition table and the code to use it.

This program was written by Richard Weidner 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 Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21054.

Still puzzled about how to cut or mark your product?

Steel, labels, acrylic, foam, cork, leather, fabric, lace, gaskets, sail cloth, nylon, sandpaper, vinyl, specialty paper, wood, and plastic. Every day over 30,000 Synrad CO_2 lasers cut, drill and mark these and many other materials. Applications are practically boundless - the more you learn about our lasers, the more uses you will find for them.

Simple to use with the reliability demanded by the toughest industrial applications. No gas bottles to replace, tools to resharpen or nozzles to clean - our lasers offer maintenance-free operation 24 hours a day for over four years. That's why Synrad lasers cost less to buy and run than other technologies.

Integrating our lasers into your existing application is easy. We design our CO_2 lasers to be components - think of them as light bulbs - to mate with XY tables, gantry systems, or robot arms. No major redesigns are necessary to obtain the benefits of laser processing.

Our all-sealed technology means no adjustments or alignment problems - ever.

Eliminate die cutters, blades, scribers or ink. The small focused laser beam produces sharp, clean edges and, as the process is non-contact, intricate patterns can be cut in thin, delicate materials with no drag - even at high speeds. CO_2 lasers can offer increased precision, higher processing speeds and less waste.

Never used a laser before? Neither had most of our customers before talking to us. To learn how sealed CO_2 lasers can help improve your process quality and reduce your manufacturing time and costs, call 1.800.SYNRAD1 today.

www.synrad.com

Send us your samples for a FREE Process Evaluation

Can you benefit from laser technology? Find out by sending us samples (remember to include a description of your current process and, if possible, an example of a "finished" product). You'll receive a Synrad SamplePak containing your samples (suitably marked, drilled or cut by our Applications Facility), a written Materials Evaluation and more information on implementing laser technology.

SYNRAD®
An Excel Technology Company

6500 Harbour Heights Parkway Mukilteo, Washington 98275 USA *tel* 1.425.349.3500 *fax* 1.425.485.4882 *e-mail* synrad@synrad.com

For More Information Circle No. 561

Micromachined Double Resonator

The design affords both vibration isolation and low-loss suspension.

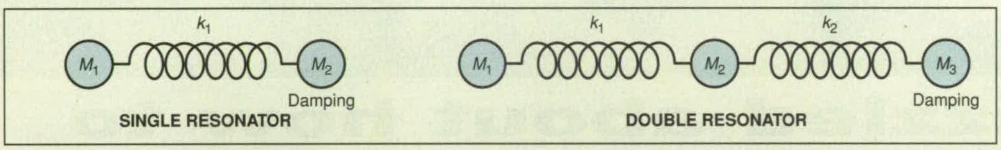
NASA's Jet Propulsion Laboratory, Pasadena, California

A double-resonator design has been devised for a cloverleaf-shaped silicon microelectromechanical resonator. The double-resonator design provides for an inner, higher-frequency resonator suspended on an outer, lower-frequency resonator. This design concept affords several advantages, as described below.

A typical prior design of a microelectromechanical resonator calls for a solidly mounted substrate. Solid mounting entails (1) poor vibration isolation and (2) high energy losses in the substrate, with consequent decrease of the resonance quality factor (Q). The double-resonator design was inspired by the realization that solid mounting is not necessarily desirable and that if the substrate of a resonator is suspended on thin springs, what is formed is a double-mass resonator that can have a Q greater than that of the original resonator. In addition, the outer resonator helps to isolate the inner resonator from packaging stresses and from vibrations of external origin.

The figure schematically depicts mathematical models of the previous single-resonator design and the present double-resonator design. The schematic diagrams reflect the observation that it is more accurate to model the substrate as a finite mass with damping than to assume that the substrate is so rigidly mounted that it represents an infinite mass. In the single-resonator design, resonator mass M_1 is coupled, via a spring of stiffness k_1, to a damped substrate mass M_2. This model yields close agreement between predicted and measured Q factors.

In the double-resonator design, inner resonator mass



Simple Mass/Spring/Damper Models are used to compute the resonance frequencies and Q values of the single- and double-resonator designs.

The Power of Digital Broadband makes possible a new approach to the test and measurement of wireless components and systems. Using this dynamic new capability, Celerity has created a series of "virtual" instruments that provide the power, speed and flexibility to test in ways you never before imagined.

More Data Test analog and digital signals with multiple coherent or independent input and output channels quickly, conveniently and cost-effectively. Bandwidths up to 160 MHz and 50 times more memory (4,000 MB).

More Speed Utilizing the fastest embedded Pentium platforms, these instruments zip through signal measurements. Ultralinear 8, 10, 12 and 14 bit ADCs and DACs provide 5x better resolution and 9 dB improvement in dynamic range for 3G, EDGE, CDMA and other broadband wireless testing. Signal acquisition and waveform generation functions cover the spectrum from RF to 40 GHz with high performance frequency converters.

More Flexibility Utilizing a unique architecture, a completely open test environment is created with a selection of functions (spectrum analysis, oscilloscope, digital pattern generation/analysis), along with a series of digital and RF multi-carrier waveform generation capabilities. Now stand-alone test instruments can be replaced with one box that does everything you need, faster and better. At a price that keeps you market-competitive.

At every level - product evolution, pre-standard release verification, prototyping, field testing, or production test and implementation, you need test capability that matches your technology. Celerity test instruments will take you there.

AVAILABLE CS2010W SERIES PRODUCTS	
CS2010 VSG	Vector Signal Generator
CS2010 WWS	Wireless Workstation (Generator/Analyzer)
CS2010 D	Digital/Digital (Generator/Analyzer Test Set)
CS2010 BT	Bluetooth Wireless Simulator

Download details at www.csidaq.com or call us at (888) 274-5604 for more information.

CELERITY
DIGITAL BROADBAND TEST
L3 communications

10411 Bubb Road Cupertino, CA 95014
Phone (408) 873-1001 · Fax (408) 873-1397

For More Information Circle No. 538

M_1 is suspended on a spring of stiffness k_1 that is attached to an intermediate mass M_2, which, in turn, is coupled to damped substrate mass M_3 via a spring of stiffness k_2. M_2 is chosen to be much greater than M_1; consequently, the frequency and mode shape of the higher-frequency (M_1,k_1,M_2) resonance does not differ greatly from that of the single-resonator design. M_3 is also chosen to be much greater than M_1; this choice, in combination with the choice of M_2, and with the choice of k_1 and k_2 to be approximately equal, ensures that the damping on M_3 exerts little effect on the Q of the higher-frequency resonance.

Because of the isolation provided by k_2, very little of any mounting stress that might be imposed on M_3 is coupled into k_1. In addition, because of the largeness of M_2 relative to M_1, very little of any vibration imposed on M_3 propagates to M_1. Another advantage of the double-resonator design is that M_2 can be tailored to exert a slight effect on the resonances (in other words, to tune the vibrating system); it is easier to tune in this way that to tailor k_1.

In the prototype double resonator, the substrate of a cloverleaf resonator substructure is suspended by four springs that connect it to an outer frame. The lowest resonance frequency of the cloverleaf is designed to be 6 kHz, while the lowest resonance frequency for vibration isolation is designed to be 200 Hz. It has been predicted that the cloverleaf resonance will have a $Q > 10^4$, and that because of damping in the outer frame, the substrate resonance will have $Q < 100$.

This work was done by Roman Gutierrez, Tony K. Tang, and Kirill Shcheglov 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.*

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

Technology Reporting Office
JPL
Mail Stop 122-116
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20658, volume and number of this NASA Tech Briefs *issue, and the page number.*

Mechanical Breakaway Clutch

Lyndon B. Johnson Space Center, Houston, Texas

A proposed mechanical breakaway clutch would not rely on friction. The clutch would be useful in environments in which the inherent inaccuracies of friction would make friction clutches erratic. The proposed clutch would comprise two primary assemblies: a driver assembly and a slip flange. The slip flange would be an internally splined cup driven by the driver assembly. The driver assembly would feature a sliding spring that would provide full adjustability. Roller bearings could be used to deflect the spring simultaneously as they were forced inward by the splines of the slip flange. In an alternate configuration, rotating cams would be used in place of the ball bearings. By varying the linear position of the spring assembly, one could adjust the level of torque at which the clutch would slip.

This work was done by Jeffrey K. Hostetler of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
MSC-22506

Molten-Carbonate Oxidation of Solid Waste

This process is relatively safe and efficient.

Lyndon B. Johnson Space Center, Houston, Texas

The molten-carbonate oxidation (MCO) process shows promise as a means of safe disposal and/or recycling of solid waste. The MCO process is being developed for use in regenerative life-support systems in outer space, but may also prove useful in managing institutional, industrial, and/or municipal solid waste. The MCO process completely oxidizes wastes as diverse as polytetrafluoroethylene, polyvinyl chloride, polyethylene terephthalate, polyethylene, feces, wheat straw, and cellulose. An MCO system can operate at atmospheric pressure without flames and without direct feed of fuel into the oxidation chamber — all important safety features.

In the MCO process, a mixture of approximately equimolar proportions of sodium carbonate and potassium carbonate is melted and heated to a temperature between 800 and 900 °C. The waste to be oxidized is fed into the melt. Oxygen or air is also fed into the melt. The chemical environment in the carbonate melt favors the formation of superoxide ions (O_2-), which catalyze oxidation of the waste. The result is a kinetically rapid three-dimensional homogeneous reaction in which the solid waste is converted to carbon dioxide and water vapor, which bubble away from the melt and can be reclaimed. Any inorganic materials in the waste are converted to minimal amounts of ashes and/or to inorganic salts, which can be removed by a commercial salt-splitting unit and reused.

Typically, the melt is contained in a stainless-steel or alumina tank. Both the oxidizing gas and the waste feed are introduced into the melt from the bottom: This practice forces the waste and gas to rise through the full depth of the melt, maximizing contact between the waste and the molten-salt mixture and thereby the degree and the overall rate of oxidation of the waste.

The melt is heated initially and thereafter maintained at the required high temperature by use of an electric furnace. Inasmuch as most wastes are low-grade fuels, the oxidation of the waste supplies some heat, thereby reducing the electric power needed to maintain the high temperature. The consumption of energy can be reduced further by efficient insulation of the tank and/or furnace and by regenerative recovery of heat from the reaction products.

The MCO equipment is relatively simple, with few moving parts. Pretreatment of waste is not strictly necessary, although some milling of the waste feedstock can be beneficial. The flow of oxidizing gas and the proportion of nonexothermic material in the waste feed can be adjusted to help keep the temperature of the melt in the desired range.

This work was done by G. Duncan Hitchens and Oliver J. Murphy of Lynntech, Inc., for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
MSC-22467

Water-Jet/Ultrasonic Removal and Real-Time Gauging of Paint

Ultrasound would loosen paint, and sensory feedback would guide the paint-removal apparatus.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved robotic water-jet system for stripping paint from a ship or other large metallic structure is undergoing development. In addition to utilizing a high-pressure water jet to remove paint and a robotic crawler to scan the jet along the painted structure, the system utilizes high-intensity ultrasound to loosen the paint just ahead of the water jet in order to ensure more nearly complete removal. The improved system also includes a quantitative gauging subsystem that measures the thickness of the paint and a qualitative gauging subsystem that generates an approximate map of paint residues; these subsystems provide real-time feedback for control of the crawler, water-jet, and ultrasonic subsystems.

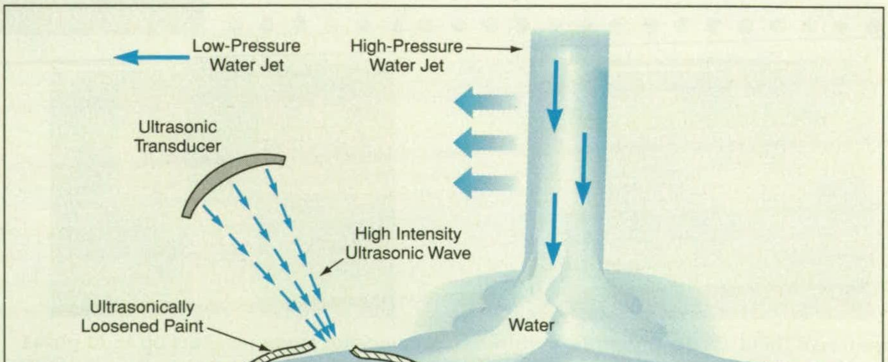


Figure 1. **Concentrated Ultrasound** blisters and otherwise loosens paint, facilitating the removal of the paint by a high-pressure water jet.

The ultrasonic subsystem exploits a combination of heating and mechanical stresses to loosen paint. In the focal zone, the intense ultrasound can raise the temperature several hundred degrees, causing the paint to blister. In the presence of the mismatch of acoustic impedances between the paint and the metallic substrate, the ultrasound gives rise to tensile and shear stresses that contribute to blistering. The paint is further damaged if ultrasonic cavitation is present.

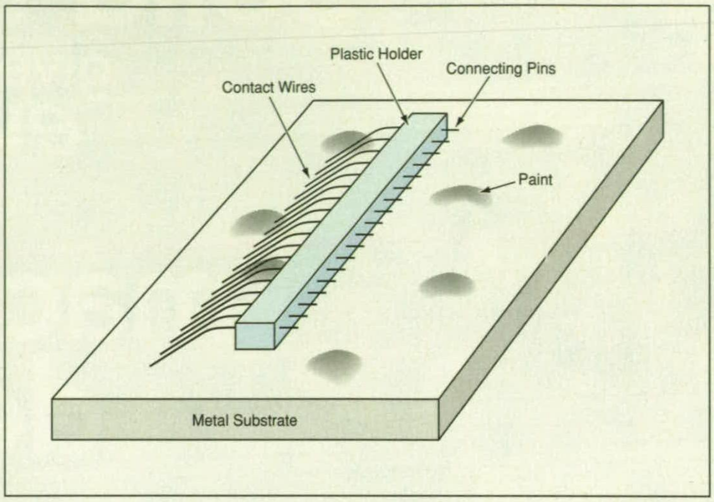


Figure 2. **A Comb of Springy Contact Wires** is scanned along the workpiece to test for removal of paint, as indicated by electrical continuity between the wires and the metal substrate.

The ultrasonic paint-loosening subsystem includes a piezoelectric transducer that generates focused ultrasonic waves; the transducer is mounted on the crawler and positioned to concentrate the ultrasound into the surface layer of water on the workpiece near the advancing water jet (see Figure 1). The transducer is excited with a combination of two ultrasonic signals — one at a frequency of several hundred kilohertz (chosen for its shorter wavelength and thus greater amenability to focusing) and one at a frequency of tens of kilohertz (chosen because it is more effective in producing cavitation in water). The more highly focused higher-frequency ultrasound propagates into the lower-frequency ultrasonic field, raising the intensity of the total ultrasonic field in the focal region above the threshold for cavitation (U.S. Pat. No. 5,827,204).

Two candidate transducer concepts for the quantitative thickness-gauging subsystem have been identified. The first concept is that of an eddy-current thickness gauge: one would place a small electromagnet coil in contact with the paint, excite the coil with alternating current at a suitable frequency, measure the impedance of the coil, and deduce the thickness of paint from the known variation of impedance of the coil with distance from the metal substrate.

The second transducer concept is that of an ultrasonic thickness gauge that would give a direct reading of the thickness of the paint: This gauge would include ultrasonic transducers operating in the frequency range of 1 to 10 MHz. The high-pressure water jet would be used as the coupling medium. It would be necessary to compensate the gauge reading for the effects of stripped paint and bubbles. Rapid spectral analysis could be used to reduce the effects of noise and interference.

The qualitative thickness-gauging subsystem would include a comb array of springy wire electrodes that would be scanned along the workpiece behind the water jet. The number of wire electrodes would be chosen to obtain the desired resolution. By simple electrical contact (or lack thereof) with the metal substrate, the electrodes would give indications of the removal or nonremoval of paint from their respective locations. In real time, contact/noncontact signals from the wires could be multiplexed and sent as feedback to a control subsystem. For non-real-time inspection, contact/noncontact signal data acquired by scanning along the workpiece could be used to generate a map of paint residues.

This work was done by Yoseph Bar-Cohen, Xiaoqi Bao, and Neville Marzwell 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 Machinery/Automation 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

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-21063, volume and number of this NASA Tech Briefs *issue, and the page number.*

PCI *Data Acquisition*

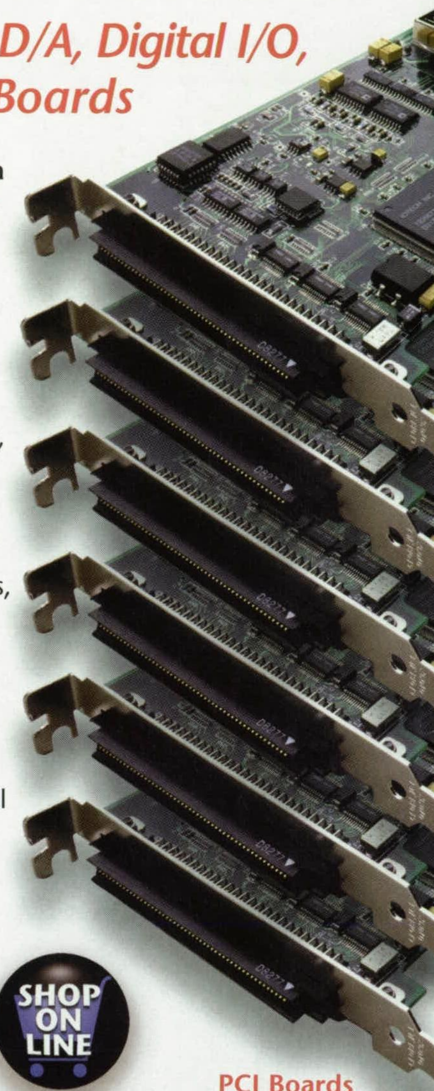
Now With Over 50 A/D, D/A, Digital I/O, & Signal Conditioning Boards

cPCI Boards

The new DaqBoard/2000™ series of PCI data acquisition boards are packed with features that other boards can't match, *at any price!*

- Synchronous scanning of analog input, digital input, & frequency input along with synchronous analog output, digital output, & timer output
- Analog input expansion up to 256 channels, with 30 DBK™ signal conditioning options for direct measurement of thermocouples, RTDs, strain gages, accelerometers, & more
- Digital I/O expandable up to 208 channels, including isolation & relay options
- Pre- & post-triggering on analog input, digital input, frequency or digital pattern
- 100% digital calibration on all ranges
- 16-bit/100-kHz analog waveform & digital pattern generation with infinite waveform/buffer depth
- Drivers for Windows® 95/98/2000/NT included plus support for LabVIEW®, TestPoint®, & DASYLab®
- *Out-of-the-Box*™ DaqView™ software available for instant setup & acquisition

SHOP ON LINE

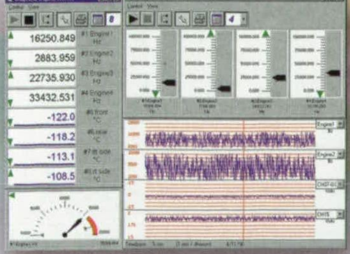


PCI Boards

DaqBoard/2000™ Series Selection Chart

Feature	DaqBoard/2001	DaqBoard/2000	DaqBoard/2005	DaqBoard/2004	DaqBoard/2002	DaqBoard/2003
Analog inputs (16 bit/200 kHz)	16	16	16	–	–	–
Analog outputs (16 bit/100 kHz)	4	2	–	4	–	4
Digital I/O	40	40	40	40	40	–
Frequency/pulse I/O	6	6	6	6	6	–
Signal conditioning options	27	27	27	5	5	–
PRICE	$895	$595	$495	$695	$295	$495

Out-of-the-Box™ Software for instant setup & verification



www.iotech.com/daqboards

WEB QUICK FIND #432*

IOtech®

1.888.724.9725

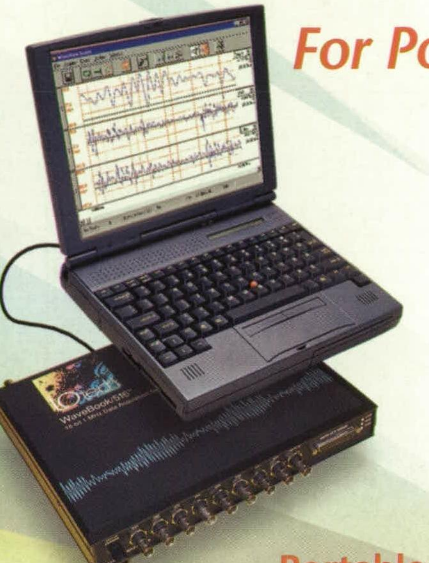
1.440.439.4091

* Visit iotech.com & enter WEB QUICK FIND # to quickly view product information

Multi-Sensor

Data Acquisition

For Portable, Lab, & Distributed Applications



Measure *all* of your sensors and signals with IOtech's family of portable, lab, and distributed data acquisition solutions. All products have a built-in set of channels, expandable with an extensive offering of signal conditioning options for nearly every sensor type.

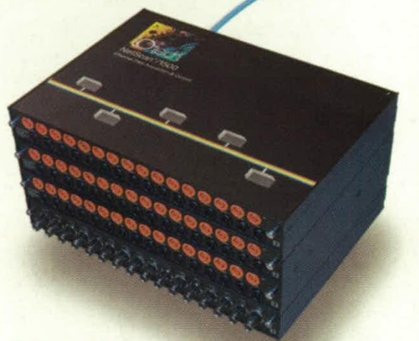
Out-of-the-Box™ software makes setup and data collection easy, without having to program. Drivers for all popular programming environments are also provided, including Visual Basic®, C++, LabVIEW®, and DASYLab®

SHOP ON LINE

Portable

WaveBook™–1-MHz, 12- & 16-bit sampling, expandable up to 72 channels. Fully programmable signal conditioning options for accelerometers, strain gages, & much more. ***From $2,995***

WEB QUICK FIND #433*

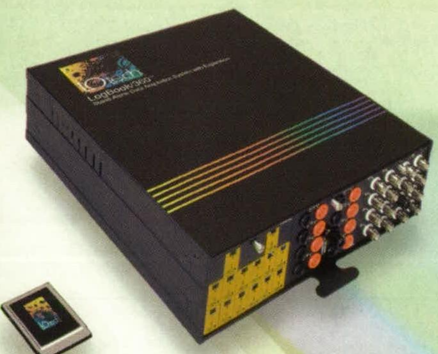


Distributed

NetScan™–Up to 128 channels of isolated voltage and TC inputs, 32 control outputs–built-in Ethernet port and optional OPC/DDE-server for HMI/SCADA applications. ***$2,995***

WEB QUICK FIND #434*

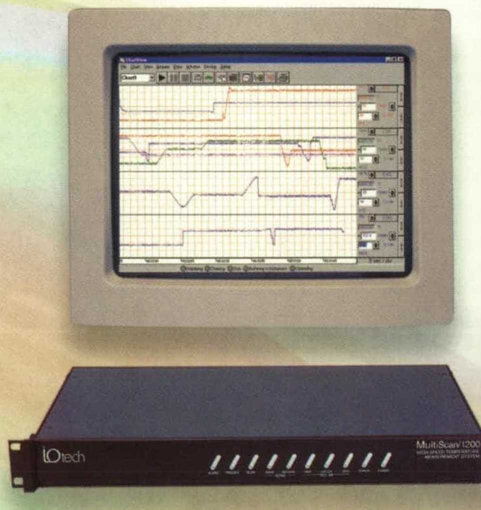
Sensors/Measurements
Thermocouples
RTDs
Accelerometers
Strain Gages
Pressure Transducers
Quadrature Encoders
Frequency
Voltage
Period
Pulse Counting
GPS
Vehicle Bus



Stand-Alone

LogBook™–100-kHz, 16-bit data logging without requiring a PC at the test site. Uses low-cost PC-Card memory for data storage. Signal conditioning for all transducer types. ***From $3,495***

WEB QUICK FIND #435*



Lab & Desktop

MultiScan™–Up to 744 isolated channels of voltage and TC inputs–ideal for low-cost-per-channel data collection systems. ***From $2,590***

WEB QUICK FIND #436*

IOtech®

www.iotech.com

* Visit iotech.com & enter WEB QUICK FIND # to quickly view product info.

1.888.724.9725

1.440.439.4091

For a complete listing of IOtech worldwide sales offices, see **www.iotech.com/sales.html**.

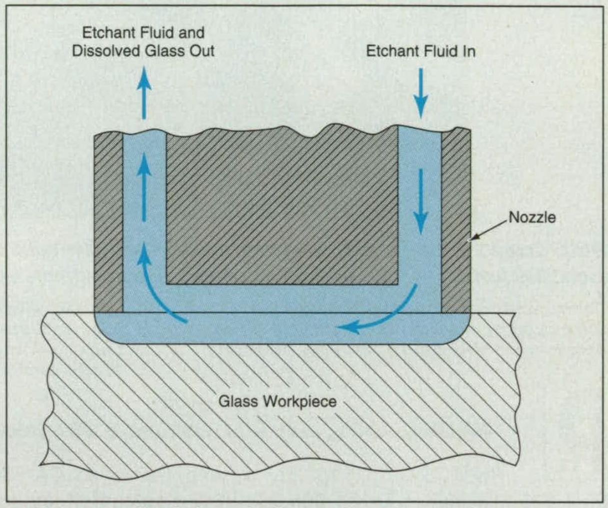
Chemical Machining of Microscopic Holes and Grooves in Glass

This technique overcomes disadvantages of conventional macro- and micromachining.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for making precise, microscopic holes and grooves in glass workpieces has been invented. The technique differs from both (1) traditional macroscopic mechanical drilling and milling and (2) conventional micromachining that involves etching through photolithographically patterned masks. The technique can be used, for example, to make holes between 20 μm and 1 mm in diameter.

The technique involves wet chemical etching, but unlike in conventional micromachining, the etch is localized. As shown in the figure, a hole in a glass workpiece is formed by use of a nozzle that contains at least one delivery channel and at least one return channel for the flow of an etchant fluid. Both channels open out to the tip of the nozzle. By use of a pressure pump at the far end of the delivery channel and/or a suction pump at the far end of the return channel, the etchant fluid is made to flow across the tip of the nozzle. The flowing etchant dissolves and carries away the glass along the flow path in the tip region. Unlike in conventional machining, the surface of the workpiece does not



Etching Is Localized along the flow path at the tip of the nozzle.

become roughened by abrasion, and there is no contamination by particles of workpiece material.

The shape and width of the resulting hole or groove is determined by the size and shape of the nozzle. As etching proceeds, the nozzle is either moved deeper into the workpiece to deepen the hole or else moved laterally (along the surface of the workpiece) to lengthen the groove. The nozzle can be fabricated, to the required precision, by use of photolithography and deep trench etching. The movement of the nozzle can be automated easily with computerized control. The precision of the movement, and thus of the final product, can be as high as 1 μm; such a level of precision has been demonstrated in robotic equipment commonly used in micromachining in a clean room.

This work was done by Kirill Shcheglov and William Tang 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.*
NPO-20732

Hermetic Wafer Bonding by Use of Microwave Heating

Clamping is unnecessary, and the only appreciable heating occurs in the metal bond.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microwave heating is the basis of a simple technique for quickly and gently bonding two metallized dielectric or semiconductor wafers to each other. The technique can be used, for example, to bond a flat, gold-coated silicon wafer to another gold-coated silicon wafer that is flat except for a cavity, in order to hermetically seal the cavity (see figure). The technique has the potential to become a standard one for bonding in the fabrication of microelectromechanical systems (MEMS).

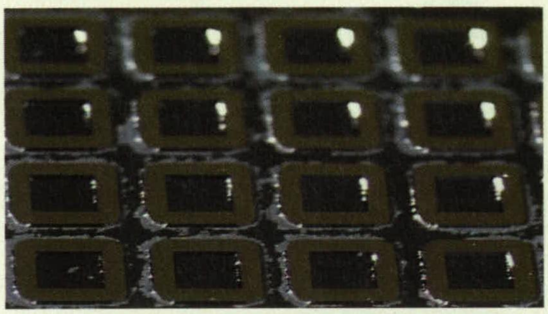
The predecessor of this technique is thermocompression bonding, in which two substrates to be bonded are clamped together with considerable pressure and the entire resulting assembly is heated to melt eutectic metal alloy coats on the faying substrate surfaces. (Even though

elemental metals could be more desirable under some circumstances, eutectics are used because they have lower melting temperatures.) The bonding process can take as long as 24 hours. The heat and pressure can degrade the product; the degradation can include deleterious effects of clamping stresses, diffusion of the metal into the substrate material, and diffusion of substrate material into the metal bond.

In the present technique, bonding could be effected in a few seconds, with minimal or no clamping, and without heating the entire assembly. Two pieces to be bonded are simply placed (e.g., one atop the other), in a microwave cavity. The position and orientation of the pieces in the microwave cavity is chosen to optimize coupling of the metal in the bond with the electromagnetic mode that is to be excited in the microwave cavity. The microwave cavity is evacuated to prevent the formation of a plasma. A pulse of microwave power (typically a few hundred watts for a few seconds) is applied.

Because the substrates are nearly transparent to microwaves in the presence of metal layers, heating by the microwave field is concentrated in the metal layers in the bond region. More precisely, by virtue of the electromagnetic skin effect, most of the deposition of electromagnetic energy occurs within a skin depth (≈1 µm at microwave frequencies) at the surface of the metal. Thus, heating is concentrated exactly where it is needed — at the interface between the two metal layers that one seeks to melt together. By the time the pulse is turned off, the metal layers have been melted together, yet the substrates remain cool. Of course, heat is conducted from the interface to adjacent depths, but the resulting heating of the substrate is transient and minimal — not enough to cause appreciable diffusion of metal or substrate material.

The figure depicts some aspects of silicon workpieces that were fabricated and tested to demonstrate the present technique. Each piece started as 5-mm square silicon wafer. A strip 2 mm wide around the edge of one face of each piece was coated with Cr to a thickness of 150 Å, then Au to a thickness of 1,200 Å. The gold coat was to serve later as the bonding metal. Each piece was etched to form 3-by-3-mm, 100-µm-deep recess in the middle of one face; the recess was to become half of a hermetically sealed cavity. Then pairs of these pieces were bonded to form the hermetically sealed cavities. In a test of their hermeticity, the bonded pairs were found to leak at low rates comparable to the background level of a leak-measuring mass spectrometer.


Test Pieces Before Bonding


Scanning Electron Micrograph of Au/Au Bond (350× Magnification)


Closeup Scanning Electron Micrograph of Au/Au (14,000× Magnification)

Test Pieces containing square recesses were bonded to form hermetically sealed rectangular parallelepiped cavities. The closeup micrograph clearly shows the fusion of metallic layers.

This work was done by Nasser Budraa, Martin Barmatz, John Mai, Tom Pike, and Henry Jackson 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.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; 818-354-4770. Refer to NPO-20608.

"Breathprint" Analysis of Microbial Communities

John F. Kennedy Space Center, Florida

A technique for assessing changes in the densities and compositions of communities of microorganisms in environmental samples is based partly on redox chemistry. Suspensions of microbes from environmental samples are inoculated into 95-well microtiter plates. Each well contains an initially colorless redox-sensitive dye and a source of carbon different from the sources of carbon in the other wells. If the microorganisms in a well can utilize or degrade the source of carbon, then the colorless dye is reduced to a colored crystal. The overall pattern of color in the various wells can be regarded as a "breathprint" of the microbial community. Because inoculation of the wells takes less than a minute and the reading of colors and analysis of the resulting data are largely automated, an assay by this technique can be performed relatively quickly. The technique has been used for such diverse purposes as monitoring the stability of microbial populations in artificial plant-growth and life-support systems, testing for toxicity, monitoring bioremediation, monitoring industrial bioreactors, studying subsurface microbiology, and studying fertility of agricultural soils.

This work was done by John Sager of **Kennedy Space Center** *and Jay L. Garland of the Dynamac Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical 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-12065.

Macroextraction for Purification of Nucleic Acids

Nucleic acids can quickly be extracted from relatively large volumes of starting materials.

Lyndon B. Johnson Space Center, Houston, Texas

A technique for extracting samples of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) for use in diagnosing and studying infectious and genetic diseases has been developed. The technique enables the concentration and purification of nucleic acids from large (in comparison with older techniques) volumes of bodily fluids or digested tissues, with minimal nuclease activity and minimal loss of the nucleic acids.

The technique involves the use of a centrifuge equipped to handle 15-milliliter polypropylene conical tubes that are standard equipment items in biomedical research. Fresh or frozen samples with volumes up to 4 milliliters can be used without prior concentration steps and without numerous microfuge tubes; these features minimize the loss of nucleic acids and the cross-contamination of samples, both of which are observed when numerous concentration steps and numerous tubes are used. Isolation of DNA and/or RNA can be accomplished in as little time as 40 minutes.

The technique involves the use of an extraction solution of the following composition:

- 1 part by volume of a solution that has a pH of 7.0 and that contains (a) guanidinium thiocyanate at a concentration 4 M, (b) sodium citrate at a concentration of 25 mM, (c) sarcosyl at a concentration of 0.5 percent by volume, and (d) 2-mercaptoethanol at a concentration of 0.1 M;
- 0.1 part by volume of a 0.2-M solution of sodium acetate;
- 1 part by volume of an aqueous solution of phenol at a pH of 7.9; and
- 0.2 part by volume of chloroform.

The following are the steps of the extraction procedure according to this technique:

1. Add the extraction solution to each sample.
2. Transfer the entire volume sample (usually 2 to 3 mL) of each sample to one of the 15-mL polypropylene conical tubes.
3. To each such tube, add 2.5 mL of RNAzol™ and 0.25 mL of R-chloroform, then vortex for 20 seconds.
4. Put each such tube on ice for ten minutes.
5. Spin the tubes in the centrifuge at a speed that yields a centripetal acceleration of 10,000 times normal Earth gravitation for 10 minutes.
6. Take the top layer of each sample that has been centrifuged, add an equal volume of isopropyl alcohol, and vortex briefly.
7. Let each such sample stand for at least 2 hours at a temperature of −20 °C to allow precipitation to take place. Alternatively, faster precipitation of nucleic acids can be achieved through addition of ammonium acetate.
8. Perform centrifugation (again at 10,000 times normal Earth gravitation) for 10 minutes on the samples that have undergone the precipitation treatment.
9. Remove and discard the liquid from each sample, which now takes on the form of a pellet.
10. Wash each pellet by gently overlaying it with an aqueous solution of 75 percent ethanol.
11. Decant the liquid.
12. Use a disposable laboratory towel wrapped around forceps to wipe, from inside each sample tube, the solid sample material left behind by decanting of the liquid.
13. Resuspend the solid material in 30 µL of a buffer solution of 1x tris-ethylenediaminetetraacetic acid (EDTA).

This work was done by Duane L. Pierson of **Johnson Space Center** *and Raymond P. Stowe. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*
MSC-22841

Simple Fiber-Optic Coupling for Microsphere Resonators

The "pigtailed" ultra-high-Q microcavities make a novel building block for fiber-optic systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

Simple fiber-optic couplers have been devised for use in coupling light into and out of the "whispering-gallery" electromagnetic modes of transparent microspheres. The need for this type of coupling arises in conjunction with the use of transparent microspheres as compact, high-Q (where Q is the resonance quality factor) resonators, delay lines for optoelectronic oscillators (including microlasers), and narrow-band-pass filters.

In the whispering-gallery modes of a transparent microsphere, light orbits inside the sphere, where it is confined by total internal reflection. The high degree of confinement results in high Q (up to about 10^{10} in the absence of loading). To couple light into or out of the microsphere, it is necessary to utilize overlapping of (1) the evanescent field of the whispering-gallery modes with (2) the evanescent field of a phase-matched optical waveguide or of an optimized total-internal-reflection spot in a prism or similar component. Heretofore, such coupling has been implemented, variously, by use of tapered optical fibers, side-polished optical fibers, or prisms, all of which entail disadvantages:

- Tapered optical fibers are fragile, bulky, and difficult to fabricate.
- Side-polished optical fibers offer low efficiency.
- Prisms are bulky and require collimation and focusing optics to work with optical fibers.

In contrast, the present fiber-optic couplers are simple, compact, and relatively inexpensive. A coupler of this type is essentially a hybrid of a waveguide and a prism coupler, and provides direct coupling with high-Q whispering-gallery modes. The coupler is fabricated by cleaving and polishing the tip of a single-mode optical fiber at an angle to form a microscopic coupling prism integral with the fiber. The cleaved and polished surface lies at a small angle ($\pi/2-\Phi$) with the longitudinal axis of the fiber (see Figure 1). The angle is chosen to secure matching of phases of the waveguide and whispering-gallery modes; by Snell's law, the angle is given by $\Phi = \arcsin(n_{\text{sphere}}/n_{\text{fiber}})$, where n_{sphere} is the effective index of refraction for the whispering-gallery modes propagating around the sphere in closed circumferential orbits and n_{fiber} is the effective index of refraction for the guided wave in the truncated region of the fiber-optic core.

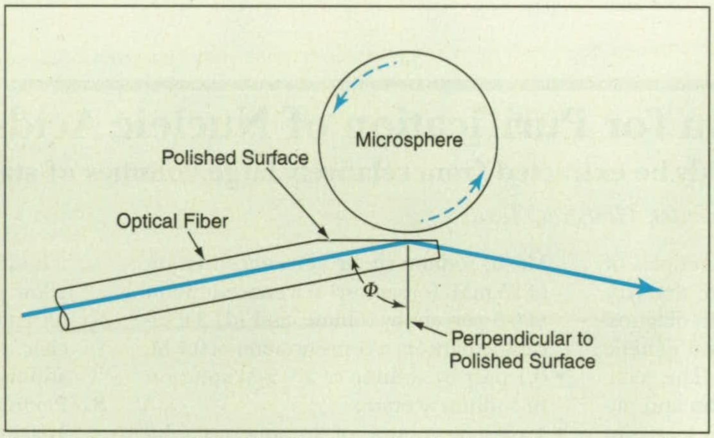


Figure 1. **Evanescent-Wave Coupling** takes place in the gap between the microsphere and the angle-polished surface on optical fiber. The angle (Φ) is chosen to match phases of waves propagating in the optical fiber and the microsphere.

In the absence of a nearby microsphere, light propagating along the fiber is totally internally reflected at the angled surface and then escapes through the end face of the fiber. If a microsphere is placed near the angled surface and within the evanescent field of the fiber-optic core, then there is an efficient exchange of energy in resonance between the waveguide mode of the fiber and a whispering-gallery mode of the sphere. Inasmuch as the angle-cut area of the fiber coincides, to a close approximation, with the area of overlap of the evanescent fields, the present coupler is functionally equivalent to a prism coupler, without need for collimation and focusing optics.

Figure 2 depicts an experimental setup that was used for testing this coupling method. Efficiency of input and output coupling was measured by simultaneous monitoring of the intensity of the light escaping from the end of the input optical fiber and the power transmitted to the output optical fiber. In the experiments, the gaps between the microsphere and the angled coupling faces of the optical fibers were adjusted to optimize contrast of resonances in input coupling and maximize the power transmitted to the output optical fiber.

The experiments showed that this method of coupling works well, allowing to couple, at resonance, up to 60 percent of the light from the input fiber into the microsphere. The total fiber-to-fiber insertion loss at resonance was about 6 dB, with the quality-factor ~10^8 at the wavelength 1.55 μm.

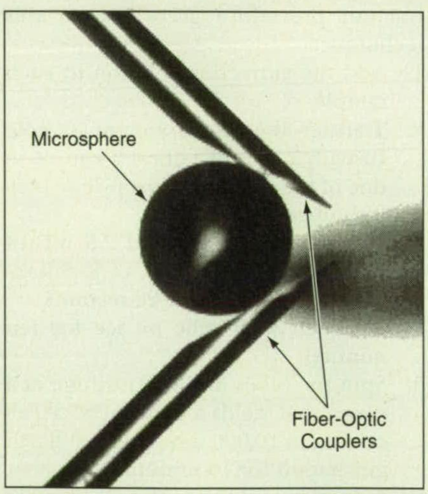


Figure 2. **Input and Output Fiber-Optic Couplers** were placed in proximity to a silica microsphere of 203-μm radius. The total fiber-to-fiber transmission loss at resonance was 6.3 dB (~25 percent of the input light passing through the cavity), with the quality-factor ~1 × 10^8 at 1.55 μm.

This work was done by Lute Maleki, Vladimir Iltchenko, and Steve Yao 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-20619

Surface Gratings for Optical Coupling With Microspheres

Far-field coupling offers advantages over near-field coupling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A diffraction grating consisting of a periodic gradient in the index of refraction of a thin surface layer has been shown to be effective as a means of far-field coupling of monochromatic light into or out of the "whispering-gallery" electromagnetic modes of a transparent microsphere. This far-field coupling can be an alternative to the near-field (evanescent-wave) coupling afforded by prism- and fiber-optic couplers described in the immediately preceding article. Far-field coupling is preferable to near-field coupling in applications in which there are requirements for undisturbed access to the entire surfaces of microspheres. Examples of such applications include (1) a proposed atomic cavity in which cold atoms would orbit in a toroidal trap around a microsphere and (2) a photonic quantum logic gate based on coupling between a high-Q (where Q is the resonance quality factor) microsphere and trapped individual resonant ions.

In preparation for experiments to demonstrate this concept, fused silica microspheres with a diameter of about 180 µm were fabricated, then coated with layers of molten germanium-doped glass powder 3 to 5 µm thick. The purpose served by the germanium doping was to increase the photosensitivity of the surface layers for the grating-fabrication step described next. An index-of-refraction grating was formed in the surface layer of each microsphere by exposing the layer to ultraviolet light (wavelength = 244 nm) from a frequency-doubled argon laser. The laser beam power was 40 mW, the exposure time was 5 to 10 minutes, and the expected index modulation was (1 to 3) × 10^{-4}. The spatial period and length of the grating were ≈2 µm and ≈15 µm, respectively. The spatial period was chosen to provide first-order phase matching between a whispering-gallery mode of the microsphere and a free-space beam oriented at ≈45° to the surface of the microsphere.

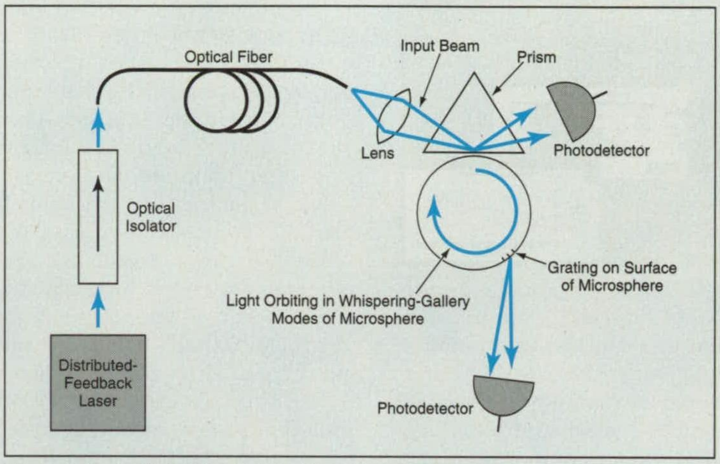


Figure 1. **Laser Light Was Coupled** into the microsphere via the prism, then coupled out via the grating. The output beam was oriented at an angle of about 40° with the surface, with 80 percent of its power concentrated in a single lobe with a divergence of 11°.

Figure 1 schematically depicts the experimental setup used to demonstrate the grating-based coupling scheme. Laser light at a wavelength of ≈1,550 nm was coupled into the whispering-gallery modes of a microsphere by a standard prism coupler, then coupled out of the microsphere by the grating. The laser was gradually tuned over a frequency range that included some whispering-gallery-mode resonances. The resulting measurements (see Figure 2) showed that at the resonances, some light was depleted from the input beam and there were corresponding increases in the amount of light emitted from the microsphere through the surface grating.

From the measurement data, the maximum grating coupling efficiency was calculated to be 14 percent. The grating loaded the resonance sufficiently to decrease the Q of the microsphere to a value in the range of (0.2 to 2) × 106. [The initial Q (without the grating) was 1.2 × 108.] Higher Q could be obtained by reducing the strength of the grating. Efficiency of coupling could be increased by optimizing the exposure to ultraviolet light, improving the grating profile, and minimizing scattering losses. Parasitic coupling to low-Q higher-order modes in the microsphere could be prevented by decreasing the diameter of the microsphere.

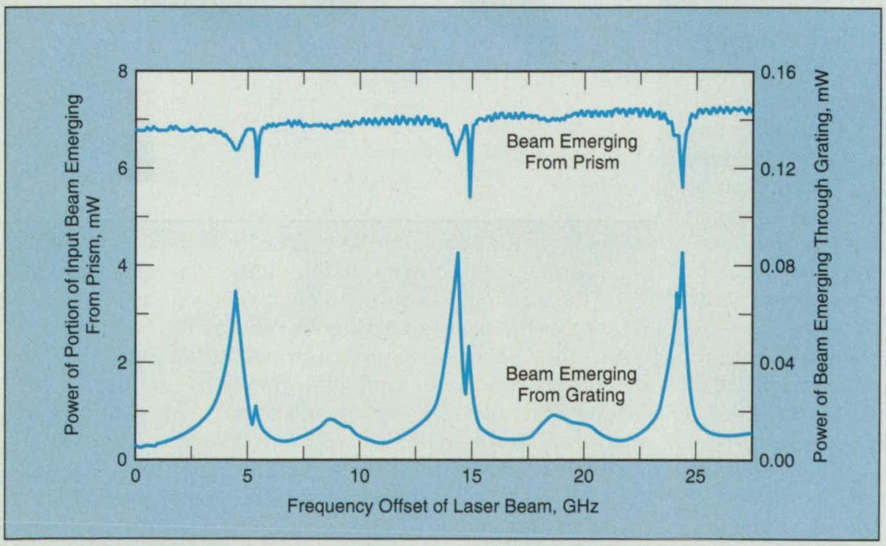


Figure 2. **Whispering-Gallery-Mode Resonances** are readily apparent in the spectra measured in the setup of Figure 1.

This work was done by Vladimir Iltchenko and Lute Maleki 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.*

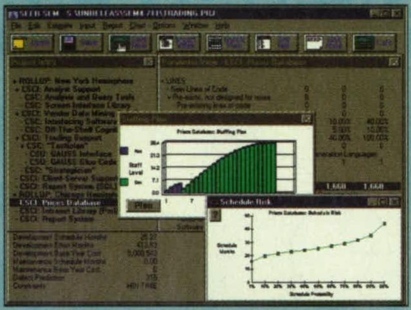
In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20618, volume and number of this NASA Tech Briefs *issue, and the page number.*

NASA Uses Software to Estimate Mars Rover Costs

SEER-H and SEER-SEM cost estimation software
Galorath
El Segundo, CA
310-414-3222
www.galorath.com



Two 300-pound Mars Exploration Rovers (MERs) are scheduled to roam the Red Planet in 2003 to determine the aqueous, climatic, and geologic history of a site on Mars. A review team evaluated the performance, schedule, risk, and cost of the project using a knowledge base that estimated the price of rover hardware and software modules by comparing them to a database of thousands of real-world projects. The original cost estimate for the rover was prepared using the traditional bottoms-up method of breaking down all components of the rover and searching through previous programs to find similar components used in the past. "The result was that we were able to create a cost estimate with the same level of accuracy and detail as the original in only about one-fourth as much time," said Rey Carpio, program analyst at NASA's Langley Research Center in Hampton, VA.

Carpio gathered the information required for input into the SEER-H and SEER-SEM estimation programs such as the systems architecture and characteristics of the individual components, including their quantity, functionality, material composition, and manufacturing processes. SEER-H began predicting development and manufacturing costs by identifying similar components from its knowledge base.

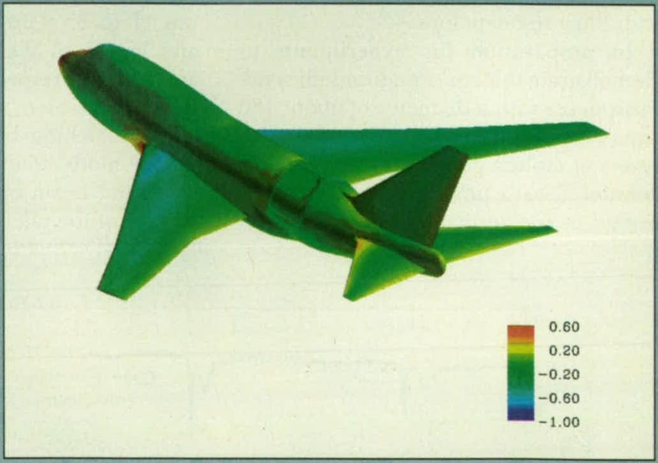
The next step was to estimate the cost of the software used to run the rovers. Carpio determined the parameters that are used by SEER-SEM to estimate the cost for each module of the program, including size, personnel, complexity, environment and constraints, platform and application, development and acquisition methods, and standards. The software allowed Carpio to choose the probability level of estimates and determine the impact of adjusting project schedules.

"We have only a one-month window of opportunity in 2003 to launch the rovers," explained Carpio. "If we miss the window, we won't be able to launch again for two years. The beauty of the SEER tools is that they allow you to define a schedule and then build requirements around it. I have recommended to the cost analysis improvement group at NASA that we make this a permanent part of our review process," Carpio said.

For More Information Circle No. 730

Simulation Software Helps Get Telescope Off the Ground

Gridgen grid generation software
Pointwise
Bedford, TX
817-377-2807
www.pointwise.com



Raytheon Systems and NASA used computer simulation to help certify and ensure the safety of a specially modified Boeing 747 that will carry the Stratospheric Observatory for Infrared Astronomy (SOFIA) telescope, the world's largest airborne telescope. The modifications to the plane include a 10 x 10' opening in the side of the aft portion of the fuselage. A computational fluid dynamics (CFD) model of the complete aircraft was created to evaluate the aerodynamics, performance, stability, control, and structural loads of the modified plane.

The aerodynamics of SOFIA were simulated by creating the CFD model of the complete aircraft to the level of detail required to accurately model the aircraft in the allocated time. A high level of detail was required around the rear control surfaces, including the horizontal stabilizer, the elevator, and the rudder, in order to determine the impact of the aft cavity.

Raytheon developed a surface model of the 747 geometry using Aero Grid Paneling System, designed by Boeing. The model was modified to add the aft cavity, and was exported in IGES format into Gridgen, which defined the grid topology. Once the topology was laid out, engineers generated the grid. Solutions were computed using Overflow +MPI, a special version of the CFD code developed by NASA that is used for parallel processing on a network of workstations - in this case, SGI Octane workstations. Overflow solved for fluid motion in the regions of interest by determining flow through a series of connected 3D grids, or zones, that cover the region in a patchwork fashion. The software solved the fluid motion problems for the entire aircraft, requiring tens of millions of points.

For More Information Circle No. 750

LITERATURE & WEB SITE SPOTLIGHT

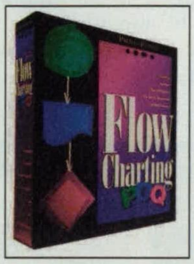
Free catalogs and literature for NASA Tech Briefs' readers. To order, circle the corresponding number on the Readers Information Request Form on page 78.

QUALITY COMPONENTS, MATERIALS & TOOLS

Packed with products for engineering design, R&D, prototypes and modeling, and production. Large or small quantities — always in stock. Miniature fasteners, specialty components, fluid and motion control devices, select materials, and precision tools. Ask for a free catalog at www.smallparts.com, or call 800-220-4242.

Small Parts, Inc.

For More Information Circle No. 626 or Visit www.nasatech.com/626



FLOW CHARTING PDQ

Professional people that draw flow charts may hear the noise and see the glitter, but they know Flow Charting PDQ was designed for flowcharting. It is the simple flowcharting program used in quality and manufacturing environments — and used by auditors, attorneys, and engineers. It is actively being used to chart ideas, workflows, and data flow diagrams. Try Us! Download a 15-day trial version at www.patton-patton.com or call 1-800-525-0082.

Patton & Patton Software Corp.

For More Information Circle No.627

INSTRUPEDIA™

Instrupedia™, the interactive encyclopedia of instrumentation, is a source of abundant information useful for building PC-Based measurement and automation applications. This FREE-CD includes the entire National Instruments product catalog, evaluation software, application notes, customer solutions, the searchable Knowledge Base, and more. Compatible with Windows 2000/NT/9x/3.1, and Mac OS systems, Instrupedia also provides links directly to the National Instruments Web site. National Instruments; Tel: 800-443-3488, 512-794-0100; Fax: 512-683-9300; email: info@ni.com; www.ni.com/info/instrupedia

National Instruments

For More Information Circle No. 628

DATA ACQUISITION CATALOG

IOtech's Data Acquisition & Instrumentation Catalog. This free 320-page catalog features our complete line of products pictured for the first time in full color. New products include an Ethernet-based recorder, plug-in PCI board, and temperature and voltage instruments. A wide range of data acquisition systems and signal conditioning options, as well as IEEE 488 instruments and controllers are also featured. IOtech, Inc.; Tel: 440-439-4091; Fax: 440-439-4093; e-mail: sales@iotech.com; www.iotech.com

IOtech, Inc.

For More Information Circle No. 629

INSTRUMENTATION SOURCEBOOK

The all new Davis Instruments sourcebook is "Hot Off The Press". It contains over 750 pages of pressure, flow, electrical, temperature, air velocity instruments. Additional products include process calibrators, data loggers, controllers and recorders. Over 450 premier manufacturers like Fluke, Tektronix, Agilent, Biddle, AEMC, Extech, Dresser and Honeywell are featured. Request your FREE copy today by calling troll free 800-829-9602 or visiting us on the web at www.davis.com. Davis Instruments Manufacturing Company, Inc., 4701 Mt. Hope Drive, Baltimore, MD 21215; Tel: 410-358-3900; Fax: 410-358-0252

Davis Instruments

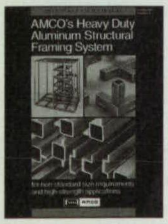
For More Information Circle No. 630

NEW ICCD CAMERA DELIVERS

Roper Scientific, Inc. has just released the Princeton Instruments PI*MAX$_{MG}$ line of intensified CCD cameras for time-resolved imaging and spectroscopy applications. These cameras utilize novel gating techniques to achieve gate speeds of <9 ns while still delivering >25% quantum efficiency, making them ideal for photon-starved applications. PI*MAX$_{MG}$ cameras support a full range of 16-bit scientific-grade CCDs that are offered with Roper Scientifics' proprietary photocathodes. Each system incorporates a state-of-the-art Programmable Timing Generator (PTG) for easy execution of complex gate sequences. Roper Scientific, Inc.; Tel: 609-587-9797; Fax: 609-587-1970; email: info@roperscientific.com; www.roperscientific.com

Roper Scientific, Inc.

For More Information Circle No. 631



ALUMINUM FRAMING SYSTEMS

AMCO offers a one-of-a-kind aluminum structural system to simplify the design of specialized and nonstandard enclosures. This system allows customers to build enclosures, racks, or stands from 8" to 20' in any 90-degree plane. Features include high-strength extruded tubing with 11 different integral flange configurations; 3 types of accessory-mounting channels; 7 joining and corner castings, and more. Request catalog 203. AMCO Engineering Co., Schiller Park, IL; Tel: 1-800-833-3156, 847-671-6670; Fax: 847-671-9469; www.amcoengineering.com

AMCO Engineering Co.

For More Information Circle No. 632

THEY CAME FROM OUTER SPACE

Exciting new commercial products in medicine, computing, manufacturing, transportation, and other major fields that have applied NASA technology and expertise.

Read all about them in the latest edition of NASA *Spinoff*, available free online at:

www.nasatech.com/spinoff

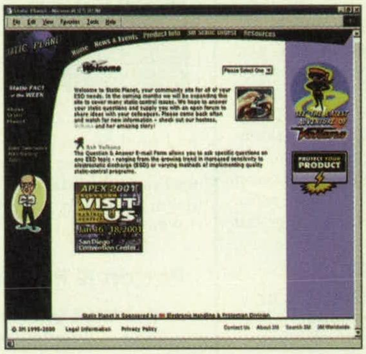
(choice of PDF or HTML formats)

New on the WEB

Fiber Optic Cable

Seiko Instruments USA, Torrance, CA, has launched a redesigned Fiber Optics Group Web site that provides on-line purchasing of NetConnect fiber-optic cable assemblies. Users of the Custom Cable Selection Guide portion of the site can create custom cable assemblies according to specific applications. The site also includes documentation for connectors, adapters, cable assemblies, and ferrules. A glossary of fiber-optic terms and an introduction to fiber optics also are included. **www.seikofiber.com**

Static Control

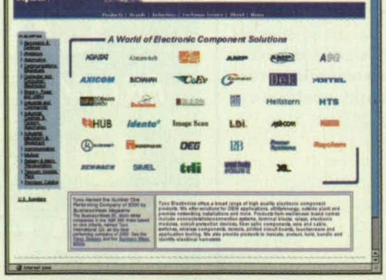


StaticPlanet, a new Web site offered by the 3M™ Electronic Handling and Protection Division, Austin, TX, provides industry news, standards, trends, links to electrostatic discharge (ESD) professional organizations, and a forum for visitors to share ideas. A new feature will be "Protect Your Product," a tool that will allow ESD managers to develop control programs for their specific facilities. **www.static-planet.com**

Measurement and Control

Lake Shore Cryotronics, Westerville, OH, has introduced a revamped Web site that includes product information, specifications, selection guides, and application notes on temperature sensors, monitors, transmitters, and accessories, as well as magnetometers, Hall Effect systems, and industrial encoders. Users now have the ability to order products on-line, and may request a quote or more information. **www.lakeshore.com**

Electronic Components



Tyco Electronics Corp., Harrisburg, PA, offers an updated site that provides information on major brands of Tyco electronics, as well as links to information on the brand's Web site. A new eCatalog search function lets users access information from AMP, Potter & Brumfield, HTS, and selected Raychem products. Also highlighted are industries served, and information on the company's wireless and fiber-optic active components. **www.tycoelectronics.com**

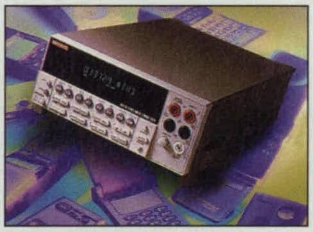
New on the MARKET

Measuring System

Kaman Instrumentation Operations, Colorado Springs, CO, offers the DIT-5200™ true differential measuring system that uses inductive technology. The system makes angular measurements in pointing and tracking, image stabilization, vibration and jitter compensation, and infrared applications. It features balanced bridge technology for nano-radian resolution, high gain analog DC output, and low noise. The system is available in single- and dual-channel configurations, with small-package-size electronics. It is immune to environmental conditions and is linear down to 0.1% full range, with sensitivity to 10V/mil. **Circle No. 700**

Digital Multimeter

Keithley Instruments, Cleveland, OH, has announced the Model 2015-P audio analyzing digital multimeter (DMM) for audio quality testing in telecommunication applications. The instrument is designed for production applications that require fast, automated testing, especially in the 300-4000 Hz spectrum where human voice frequencies are found. The instrument is housed in a single half-rack package and can characterize an acquired signal spectrum without use of a computer, data transfer, or separate analysis software. It can report the frequency and amplitude of the highest value in a spectrum, or within a specified frequency band. Built-in IEEE-488 and RS-232 interfaces enable the instrument to connect to a PC in order to acquire, store, process, and display results automatically. **Circle No. 702**



Digital Multimeter/Thermometer

The Supermeter™ Model HHM290 from OMEGA Engineering, Stamford, CT, operates as a RMS multimeter, a non-contact infrared pyrometer with laser sighting, and a dual-input Type-K thermocouple meter with a differential measurement feature. The multimeter measures DC/AC voltage, current, resistance, frequency, and capacitance, and features a built-in logic and diode tester. The infrared pyrometer offers adjustable emissivity, a wide temperature range, and a laser-sighting selector. A backlit LCD display shows simultaneous readings in digital and analog bar graph format. Each unit features fused multimeter inputs, battery or optional AC adapter operation, safety test leads, and dual type-K temperature probes. **Circle No. 703**

Piezoelectric Accelerometers

Endevco Corp., San Juan Capistrano, CA, offers the Models 525 and 528 piezoelectric accelerometers with internal electronics. The 525 and 528 are configured in TO-5 and TO-8 packages, respectively, and are designed for high-volume OEM applications. The accelerometers provide integrated vibration measurement of machines, structures, or vehicles, and can be mounted by either adhesive or soldering methods. Dynamic range of the Model 525 is ±50, ±100, or ±500 g's, while the Model 528 offers dynamic range of ±5, ±25, and ±50 g's. **Circle No. 704**

New on DISK

Motion Analysis

Instrumentation Marketing Corp., Burbank, CA, offers TrackEye motion analysis software that handles and analyzes large quantities of data from both high-speed and standard film and video images, as well as other types of sensors in a test set-up. It provides sub-pixel tracking accuracy, filters data and results, presents results in different graphs, and calibrates cameras for lens distortion and focal length. The program reads FDRS, HDRS, and serial timing codes automatically, and includes analysis calculation of speed, acceleration, and angles. The package provides 2D and 3D capability, reads coding on image files, handles obscured points, and enables accurate position readings of target points and synchronization of film and data sequences. **Circle No. 707**

Test Software

TestStand 2.0 from National Instruments, Austin, TX, allows users to automatically test multiple units in parallel. Users can choose to run batch test or asynchronous tests, depending on their needs. The software includes built-in synchronization tools to schedule and manage parallel tests and balance test throughput and equipment use. Single users can track test sequences with a project window that organizes test code modules and test sequences. Multiple users can work on test codes as a team using commercial source code programs. Test data can be published to the Web through an XML reporting feature. Users can mix and match TestStand instrument steps with code written in programming languages such as LabVIEW™ and Measurement Studio™. **Circle No. 708**

Finite Element Analysis

Aegis Software, Murrysville, PA, has released its Windows-based FEVA (Finite Element Visual Analysis) software system that is comprised of five separate modules: VisiSage, SageView, SAGE FEA, SageCFD, and SageEM. VisiSage is a mesh generator and SageView is a pre- and post-processing finite-element system. SAGE FEA consists of two components: SageLinear, a thermal/stress linear code for design and analysis; and SageNonlinear, a multiphysics thermal/elastro-plastic/incompressible/contact/impact solver. SageCFD is a fluid dynamic solver and SageEM is an electromagnetic solver. **Circle No. 710**

DSP Developers' Kit

The MathWorks, Natick, MA, has introduced the Developer's Kit for Texas Instruments™ Digital Signal Processing (DSP), which integrates MATLAB 6 and Simulink 4 with TI's eXpressDSP real-time software technology to eliminate the software gap between DSP algorithm research and implementation. The kit provides engineers working throughout the product design cycle to gain earlier access to DSP hardware and development tools for real-time evaluation and optimization. System designers and embedded engineers working in communications, electronics, and aerospace can simulate, generate, and validate solutions for TI DSP platforms of fixed- and floating-point DSPs. **Circle No. 711**

New
LITERATURE

Specialty Materials

Pall Specialty Materials, Port Washington, NY, offers The Media Book, which highlights hydrophobic and hydrophilic membrane products for healthcare, molecular biology, diagnostics, and industrial applications such as automotive vents and gas and chemical sensors. The catalog features four sections based on the product application industries, and is cross-referenced by application, membrane characteristics, and product name. **Circle No. 715**

Strain Gauge Sensors

A four-page brochure from Strain Measurement Devices, Meriden, CT, describes applications for cantilever beam load cells, miniature platform load cells, center-mounting load cells, button load cells, and thin-film pressure diaphragms used in aerospace, medical, and other applications. The company designs and manufactures thin film strain gauge sensors for the OEM transducer, instrumentation, medical, and measurement markets. **Circle No. 716**

Coaxial Connectors

A catalog from Dynawave, Haverhill, MA, describes microwave coaxial connectors, including Dynamate™ Blind-Mate connectors, Dynacon™ interconnects, and Dynaseal™ cable assemblies. The catalog provides specification data for electrical, mechanical, and environmental parameters, along with material and finish information for the connector body, spring, center contact, insulator, and o-ring. It also offers schematics for connectors, jacks, adapters, interconnects, and other accessories. **Circle No. 717**

Panel PCs

Advantech Technologies, Irvine, CA, has introduced a 30-page brochure describing its rugged panel PCs. Included are units with various processor sizes and speeds, a selection of display sizes, and capacitive touchscreens. Installation options such as swing-arm, desktop, wall-mount, and panel-mount are described, as well as applications in the medical, machinery automation, instrumentation and control, and transportation industries. **Circle No. 719**

CCD Imaging

Roper Scientific, Tucson, AZ, offers a CD-ROM that combines animation and information to illustrate the basic technology associated with digital imaging. The interactive presentation includes informational modules on CCD history, theory, application, architecture, readout, performance, optimization, and image intensification. A library of technical notes and a glossary also are included. The CD is available in PC formats only. **Circle No. 729**

Vol. 25, No. 5 May 2001 This form expires: October 2001

FREE INFORMATION REQUEST FORM

For quickest service:

Fax this form to (413) 637-4343

Use the online reader service center at www.nasatech.com (click on "Get More Information…FAST")

Or mail your completed form to *NASA Tech Briefs*, PO Box 5077, Pittsfield, MA 01203-9109.

Name: ____________________

Company: ____________________

Address: ____________________

City/St/Zip: ____________________

Phone: ____________________

Fax: ____________________

e-mail: ____________________

Please tell us below how *NASA Tech Briefs* has helped you solve a problem or been applied to your business/product line.

____

____

____

____

____

Do you currently receive *NASA Tech Briefs*? ☐ **Yes** ☐ **No**

If no, would you like to receive *NASA Tech Briefs*? ☐ **Yes** ☐ **No**

ARE YOU AN INSIDER?

Subscribe today to receive the INSIDER, a FREE e-mail newsletter from *NASA Tech Briefs*. The INSIDER features exclusive previews of upcoming articles…late-breaking NASA and industry news…hot products and design ideas…links to online resources…and much more.

❑ I want to be an INSIDER. Send my newsletter to the following e-mail address:

____

Name ____________________

Company ____________________

I also want to receive special-focus e-newsletters on the following technology topics: (check all that apply)

- ❑ CAD/CAE
- ❑ Lasers
- ❑ Optics
- ❑ Sensors
- ❑ Fiber Optics/Communications
- ❑ Test & Measurement
- ❑ Imaging/Cameras

For fastest service, sign up online at www.nasatech.com. Look for this button at the top of the home page ➤ ➤ ➤ ➤ ➤ ➤ ➤

FREE NEWSLETTER

Circle the numbers below to receive more information about products and services featured in this issue.

401	402	403	404	405	406	407	408	409	410
411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460
461	462	463	464	465	466	467	468	469	470
471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490
491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510
511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530
531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590
591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610
611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670
671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710
711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730
731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750
751	752	753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790
791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828	829	830
831	832	833	834	835	836	837	838	839	840

Advertisers Index

Advertisers listed in bold-face type also have banner ads on the *NASA Tech Briefs* web site this month. Visit **www.nasatech.com**

NASA Tech Briefs, ISSN 0145-319X, USPS 750-070, copyright ©2001 in U.S. is published monthly by Associated Business Publications Co., Ltd., 317 Madison Ave., New York, NY 10017-5391. The copyright information does not include the (U.S. rights to) individual tech briefs that are supplied by NASA. Editorial, sales, production, and circulation offices at 317 Madison Ave., New York, NY 10017-5391. Subscription for non-qualified subscribers in the U.S., Panama Canal Zone, and Puerto Rico, $75.00 for 1 year; $135 for 2 years. Single copies $5.00. Foreign subscriptions one-year U.S. Funds $195.00.

Remit by check, draft, postal, express orders or VISA, MasterCard, and American Express. Other remittances at sender's risk. Address all communications for subscriptions or circulation to *NASA Tech Briefs,* 317 Madison Ave., New York, NY 10017-5391. Periodicals postage paid at New York, NY and additional mailing offices.

POSTMASTER: Send address changes to *NASA Tech Briefs,* PO Box 10523, Riverton, NJ 08076-9023.

Vol. 25, No. 5 May 2001 This form expires: October 2001

FREE INFORMATION REQUEST FORM

For quickest service:

Fax this form to (413) 637-4343

Use the online reader service center at www.nasatech.com (click on "Get More Information...FAST")

Or mail your completed form to *NASA Tech Briefs*, PO Box 5077, Pittsfield, MA 01203-9109.

Name: ____________________

Company: ____________________

Address: ____________________

City/St/Zip: ____________________

Phone: ____________________

Fax: ____________________

e-mail: ____________________

Please tell us below how *NASA Tech Briefs* has helped you solve a problem or been applied to your business/product line.

____

____

____

____

____

Do you currently receive *NASA Tech Briefs*? ☐ Yes ☐ No

If no, would you like to receive *NASA Tech Briefs*? ☐ Yes ☐ No

ARE YOU AN INSIDER?

Subscribe today to receive the INSIDER, a FREE e-mail newsletter from *NASA Tech Briefs*. The INSIDER features exclusive previews of upcoming articles...late-breaking NASA and industry news...hot products and design ideas...links to online resources...and much more.

☐ I want to be an INSIDER. Send my newsletter to the following e-mail address:

____

Name ____________________

Company ____________________

I also want to receive special-focus e-newsletters on the following technology topics: (check all that apply)

- ☐ CAD/CAE
- ☐ Lasers
- ☐ Optics
- ☐ Sensors
- ☐ Fiber Optics/Communications
- ☐ Test & Measurement
- ☐ Imaging/Cameras

For fastest service, sign up online at www.nasatech.com. Look for this button at the top of the home page ➤ ➤ ➤ ➤ ➤ ➤ ➤

FREE NEWSLETTER

Circle the numbers below to receive more information about products and services featured in this issue.

401	402	403	404	405	406	407	408	409	410
411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460
461	462	463	464	465	466	467	468	469	470
471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490
491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510
511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530
531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590
591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610
611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670
671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710
711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730
731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750
751	752	753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790
791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828	829	830
831	832	833	834	835	836	837	838	839	840

intel inside pentium III

IMPROVE YOUR SKILLS AS A MANIPULATOR.

IBM IntelliStation M Pro
(monitor sold separately)

Get a Spaceball 3D motion controller FREE with an IBM® IntelliStation® M Pro 3D workstation.

IBM IntelliStation E Pro

Affordable workstation power
Intel® Pentium® III processor 933MHz[3]
256MB ECC SDRAM
9.1GB[4] Ultra160 SCSI HDD
NVIDIA™ GeForce2 MX graphics
48X-20X[5] CD-ROM
10/100 Ethernet
3-year limited warranty[6]
Part #684637U

$2,336[7]

SuccessLease™ for Small Business $83/MO.[8]**, 36 MOS.**

CUSTOMIZE YOURS:

21" FDT Monitor
Stealth Black, not shown
(Part #655263N) $1,059 or $37/month

128MB ECC SDRAM
(Part #33L3081) $109 or $4/month

IBM IntelliStation M Pro

Exceptional workstation performance
Intel Pentium III processor 1.0GHz
512MB ECC RDRAM
18.2GB Ultra160 SCSI HDD
IBM Fire GL2 graphics[9]
48X-20X CD-ROM
10/100 Ethernet
3-year limited warranty
Part #686878U

$3,896

SuccessLease for Small Business $129/MO., 36 MOS.

BONUS: Spaceball (Part #SPBMPRO)

CUSTOMIZE YOURS:

17" TFT Monitor
(Part #9495AG1) $1,499 or $53/month

9.4/4.7GB IDE DVD-RAM Drive
(Part #10K3561) $489 or $17/month

Purchase the powerful IntelliStation M Pro 3D workstation shown here and you'll receive a Spaceball 3D Input Device at no extra charge. That's a $489 value! Offer valid through June 30, 2001, in the US only, while supplies last. Cannot be combined with other offers or promotions. Shipping and handling not included. Promotion limited to one per qualifying order.

IBM IntelliStation workstations deliver exceptional performance running your 2D/3D design, architecture, solid modeling and GIS applications – in part, because they're tuned and optimized for over 50 CAD applications (plus 44 other compatible applications).[1] That's why IntelliStation M Pro has earned "5 out of 5 stars" for outstanding graphics at a stellar value from leading CAD publications.[2] And why they're among the most highly recommended by application vendors. IntelliStation E Pro workstations share many of the same features at an even lower price.

FREE SPACEBALL **OFFER**

Free Spaceball 3D Input Device included (a $489 value) when you purchase the IntelliStation M Pro featured above.

Shipping and handling not included. Valid in the US only through June 30, 2001, while supplies last. Cannot be combined with other offers or promotions. Limited to one per qualifying purchase. Part #SPBMPRO

IBM®

DIRECT TO YOU

Toll free **1 866 426-0496**
ibm.com/smallbusiness/M048
to buy direct or to locate an IBM reseller.

IBM recommends Microsoft® Windows® 2000 Professional for business.

An IBM price advantage for small business

[1]Warranty, service and support for non-IBM products are provided directly to you through third parties. IBM makes no representations or warranties regarding non-IBM products. [2]The following publications have awarded 5 out of 5 stars: *CATIA Solutions*, *Pro E*, *Solid Solutions*, *Computer Aided Design*, *Cadalyst*. [3]MHz/GHz only measures microprocessor internal clock speed; many factors affect application performance. [4]GB equals one billion bytes when referring to storage capacity; accessible capacity may be less. [5]CD-RW, DVD-ROM and CD-ROM drives list a variable read rate. CD-RW write and re-write speeds vary and list only the maximum possible. Actual CD-RW, DVD-ROM and CD-ROM speeds will vary and are often less than the maximum possible. The read and write results of the CD-RW drive depend on the quality and characteristics of the CD-R and CD-RW media used. Poor results may be obtained with some media suppliers. [6]For terms and conditions or copies of IBM's Statement of Limited Warranty, call 1 800 772-2227 in the US and in Canada call 1 800 426-2255. Telephone support may be subject to additional charges. [7]Pricing shown is price available from IBM directly. Reseller prices may vary. IBM price does not include tax or shipping and is subject to change without notice. [8]SuccessLease is offered and administered in the US, Canada and other countries by third-party providers of business financing approved by IBM Global Financing. SuccessLease terms and conditions provided by the third party. Featured monthly lease payments are based on a 36-month term with prespecified purchase option at the end of lease, to qualified business customers only, installing in the US. A documentation fee and first month's payment due at lease signing. Any taxes are additional. Other lease terms and structures are available. Offer may be withdrawn or changed without notice. Options listed cannot be leased separately from system unit. [9]Fire GL2 is a trademark of Diamond Multimedia Systems, used under license. IBM reserves the right to alter product offerings and specifications at any time, without notice. SuccessLease and all IBM product names are registered trademarks or trademarks of International Business Machines Corporation. Intel, the Intel Inside logo and Pentium are registered trademarks of Intel Corporation. Microsoft and Windows are registered trademarks of Microsoft Corporation. Other company, product and service names may be trademarks or service marks of others.

For More Information Circle No. 535