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40 YEARS OF INNOVATIONS

Industrial Engineering at NASA Kennedy

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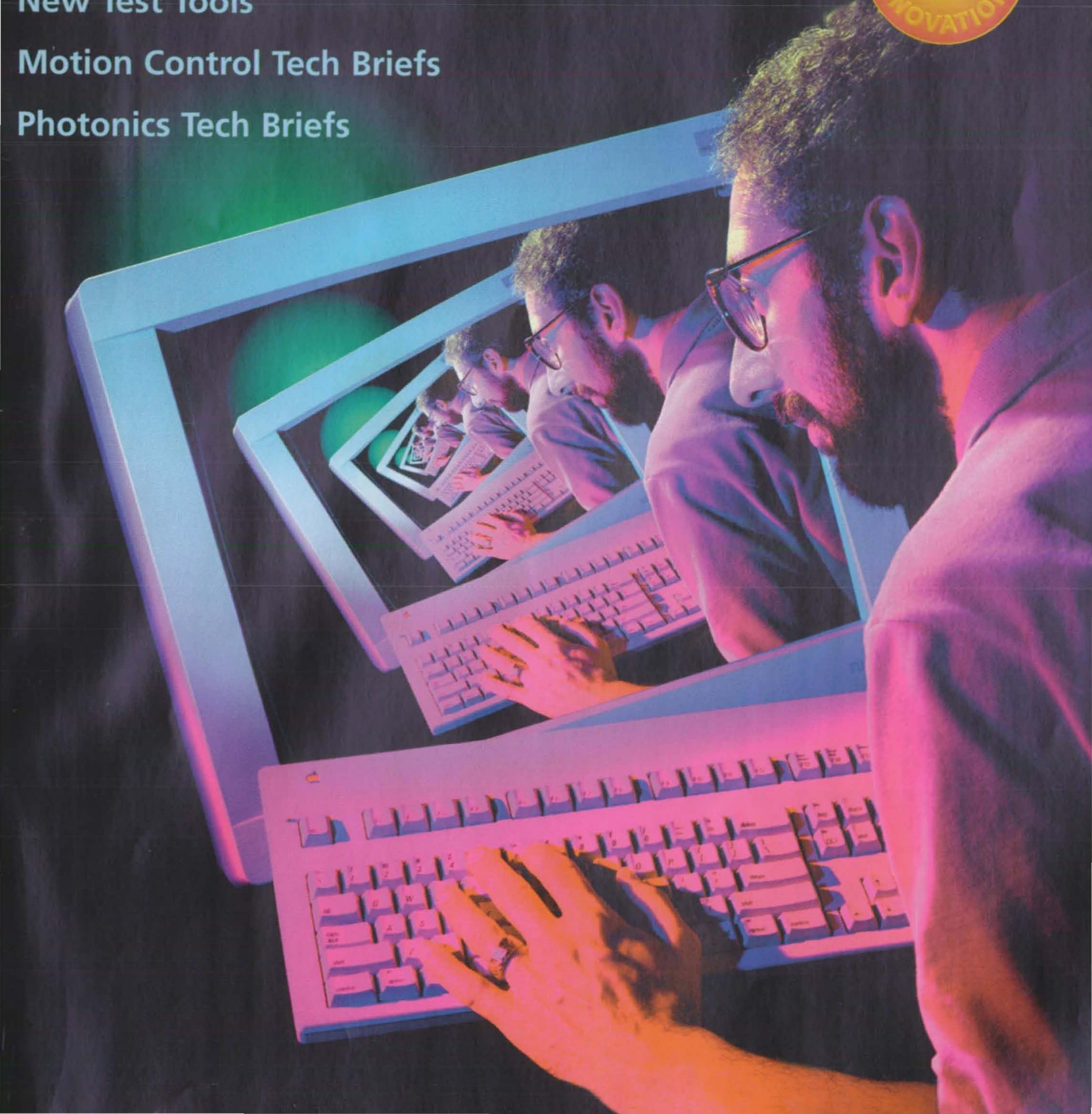
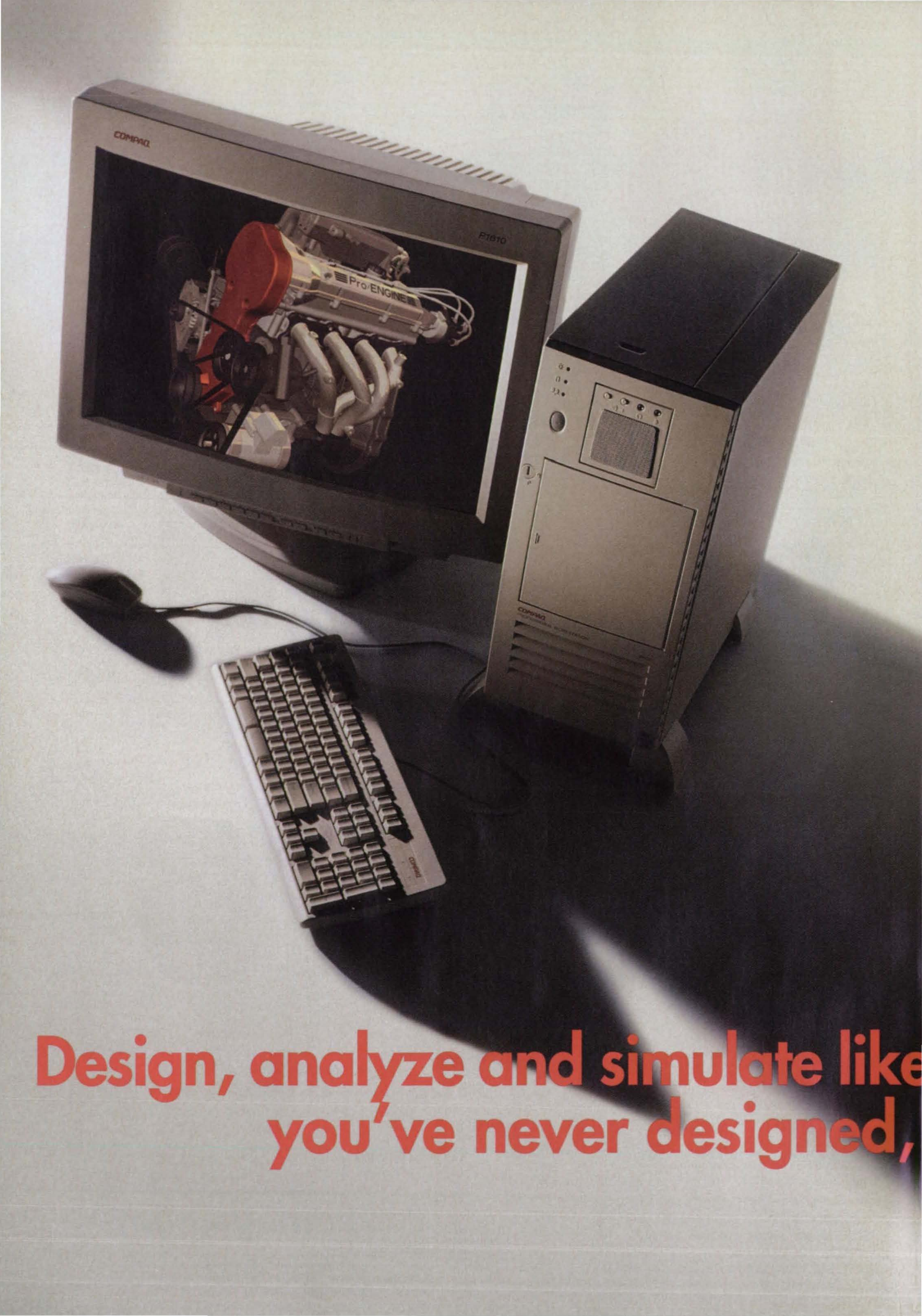
Motion Control Tech Briefs

Photonics Tech Briefs

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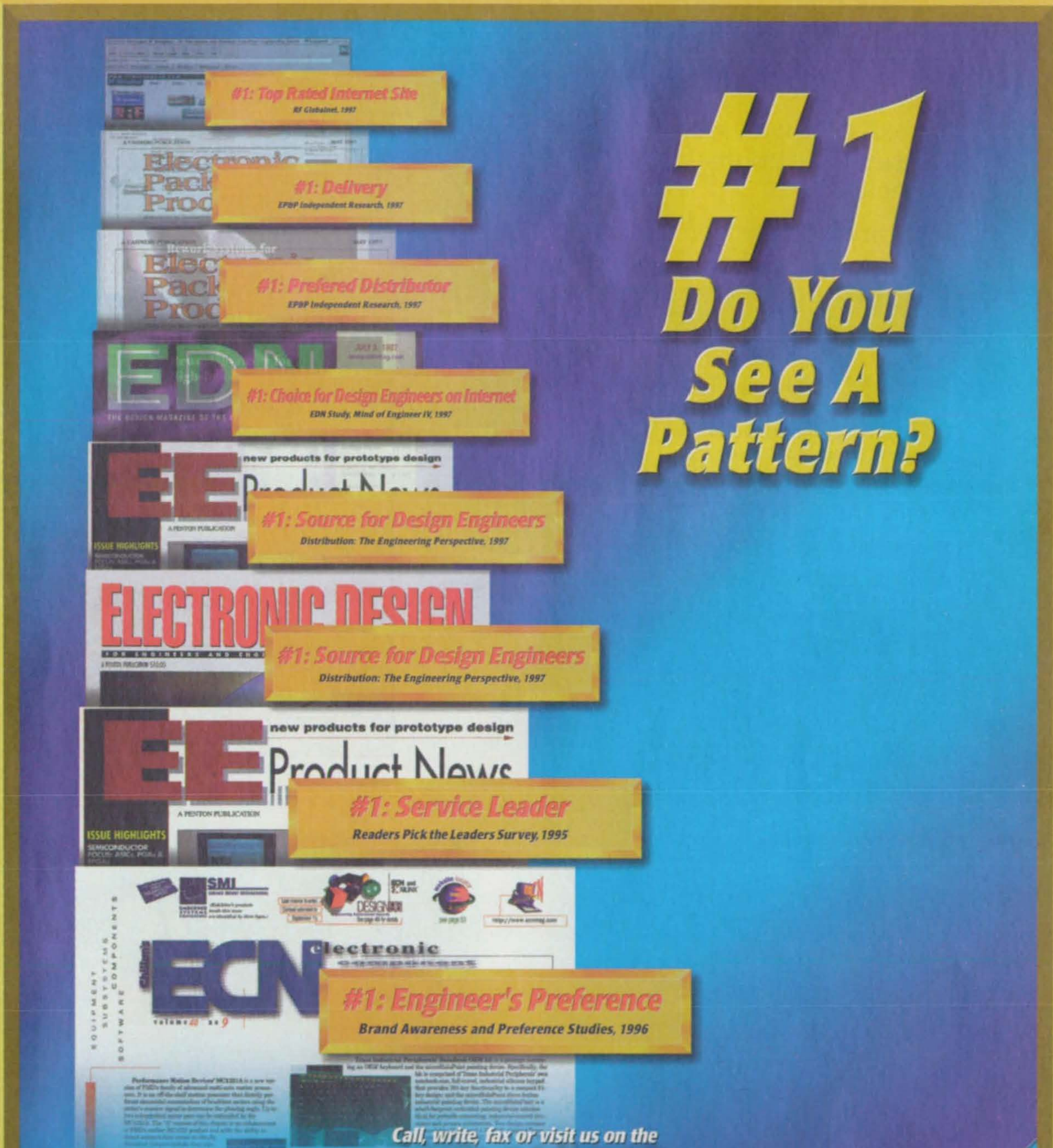
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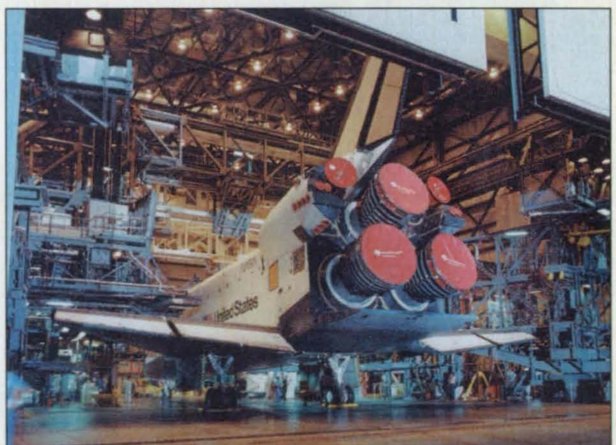

This issue features a section of briefs (pages 76-80) devoted to Industrial Engineering – Process Management and Improvement, from NASA's Kennedy Space Center. Technologies included in the Industrial Engineering discipline include performance metrics, human factors engineering, process simulation modeling, operations research, work methods engineering, benchmarking, and scheduling systems. From Kennedy Space Center's perspective, NASA's "factories" are the flight hardware processing facilities like the one shown here. These facilities are a prime domain for developing advanced industrial engineering disciplines.

(Photo courtesy of Kennedy Space Center)

Contents *continued*

Special Supplements

On the cover:

As a pioneer in the advancement of computer technologies, NASA has played an important role in developing computer-based products and processes, from laptop computers to digital image processing. These and other Computers and Information Technologies are highlighted in our continuing celebration of NASA's 40 Years of Innovations, beginning on page 22.

(Photo courtesy of Lewis Research Center)

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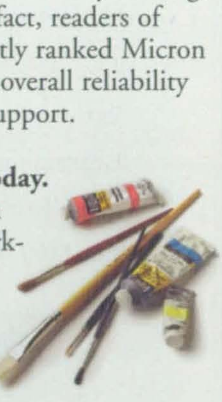

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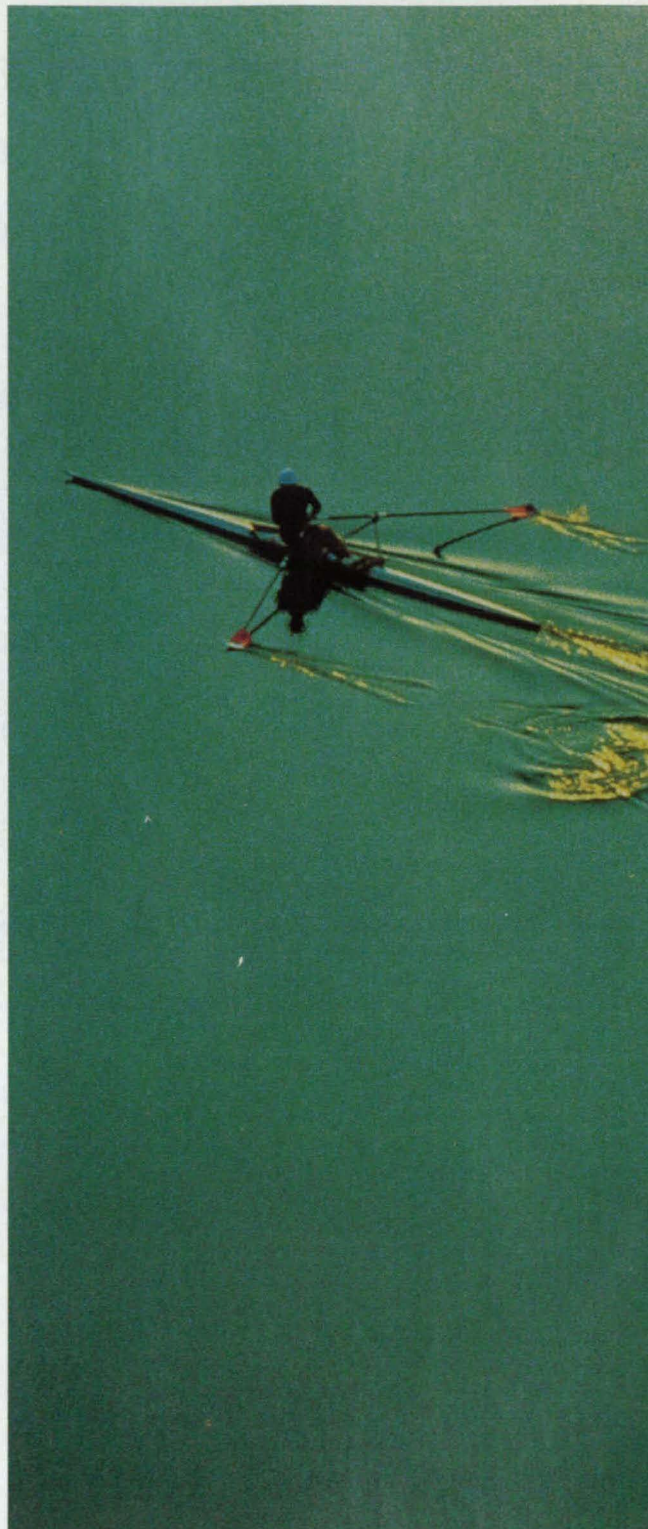

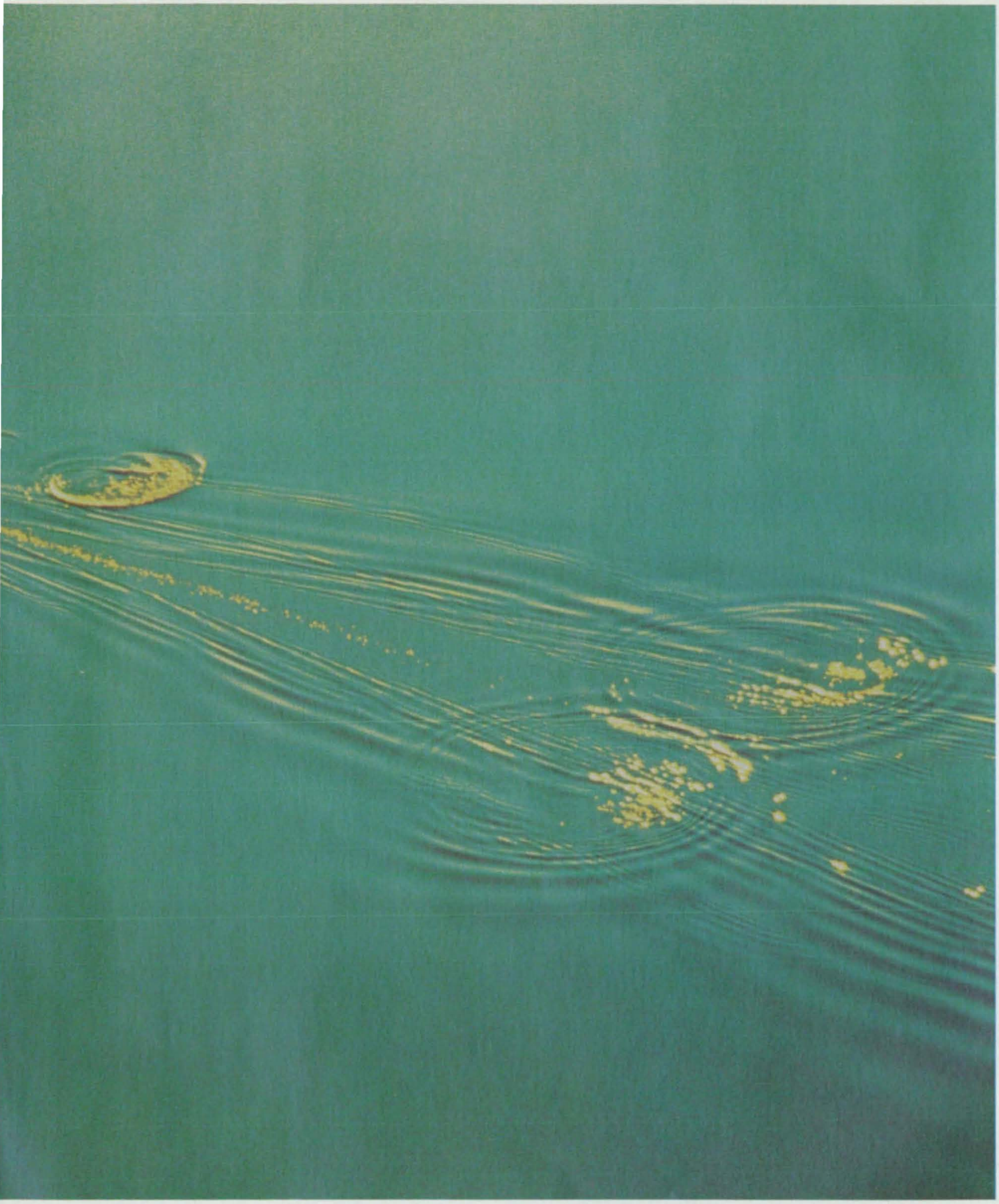

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (206) 683-1005 for the FLC coordinator in your area.

NASA's Technology Sources

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

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Bruce Webbon
(650) 604-6646
bwebbon@mail.arc.nasa.gov

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

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

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

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@gp101.jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Environmental Monitoring; Sensors; Corrosion Protection; Bio-Sciences; Process Modeling; Work Planning/Control; Meteorology.
Gale Allen
(407) 867-6626
galeallen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Dr. Joseph S. Heyman
(804) 864-6006
j.s.heyman@larc.nasa.gov

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

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(205) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(601) 688-1929
ksharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

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

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National Technology Transfer Center
(800) 678-6882

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Chris Coburn
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

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

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

Dr. Robert Norwood
Office of Aeronautics and Space Transportation Technology (Code R)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

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

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wsmith@sm.ms.ossa.hq.nasa.gov

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

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

NASA's Business Facilitators

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

Dr. Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1250

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

Joe Boeddeker
Ames Technology Commercialization Center
San Jose, CA
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Mississippi Enterprise for Technology
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If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622. For software developed with NASA funding, contact the **Computer Software Management and Information Center (COSMIC)** at phone: (706) 542-3265; Fax: (706) 542-4807; E-mail: http://www.cosmic.uga.edu or service@cosmic.uga.edu.

NASA Technology Spawns New Knee Brace

NASA's Marshall Space Flight Center, Huntsville, AL, has signed a licensing agreement with Horton's Orthotic Lab of Little Rock, AR, to manufacture a new knee brace that offers freedom of movement to patients suffering from lower extremity weakness. A five-person NASA team developed the technology, which will help those recovering from strokes and injuries. The Selectively Lockable Knee Brace will facilitate less painful rehab by allowing knee movement, unlike other braces that lock the knee in a straight-leg position.

"The new brace design helps patients who have a loss of muscle control from as high as the thigh because of a stroke or accident," said Michael Shadoan, one of the inventors. The brace "allows the knee to function while supporting the leg," according to co-inventor Neill Myers.

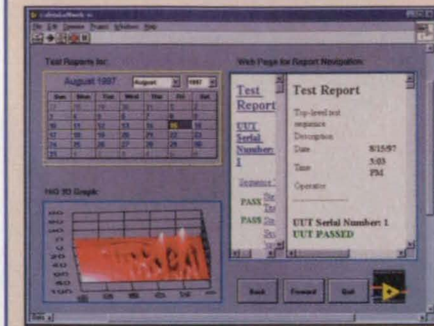
The upper part of the brace attaches around the thigh, and the lower part is secured by a stirrup around the shoe. It allows the knee to bend when the weight is not on the heel. When weight is placed on the heel, the brace locks into position.

Mike Horton of Horton's Orthotic Lab tests and fits the prototype of the Selectively Lockable Knee Brace, which was developed by engineers at NASA Marshall.

Shadoan, Myers, and the other three inventors — John Forbes, Kevin Baker, and Darron Rice — worked on the design for three years. "The brace is a spin-off of technology used in developing propulsion systems at Marshall," said Shadoan. Field tests of the original design were conducted in 1996 and 1997; the NASA team made adjustments to the brace based on the information those tests provided. Horton's will begin clinical trials soon.

For more information, contact Tony Miller of Horton's Orthotic Lab at 501-663-2968; e-mail: tmiller@hortonsoandp.com

Product of the Month



Version 5.0 of LabVIEW graphical instrumentation software has been introduced by National Instruments, Austin, TX. The new version is available for Windows NT/95/3.1, Mac OS, Solaris, HP-UX, and Concurrent PowerMAX. Enhancements include automatic multithreading of programs without code modifications; an Instrument Wizard that allows users to create programs for instrument control with GPIB, VXI, and RS-232 instruments; and ActiveX Container capability, allowing users to drop any 32-bit custom control or ActiveX document into a LabVIEW front panel to re-use code that has already been written. The software also provides tools for system developers to create distributed applications, whereby various sections of code can execute on different machines across a network. Users can automatically generate documentation for their application in HTML and RTF formats. Programmatic menu bars and a multistep Undo feature also are included. Prices start at $995 for the Windows version.

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Reader Comments

"I wanted to thank you for another fine year of tech briefs. I have enjoyed all of the articles, especially those pertaining to new software development. I have always been a firm believer in space exploration and NASA, and these articles mean a lot to me, too. I cannot image some of the technology that has come out of the space program and the impact that it has. You have done an excellent job of reporting some of these technical wonders. Thank you!"

Ronnie L. Dunn
Lab Technician
Pass & Seymour Legrand
ronnie_dunn@pass-seymour.com

*(**Editor's Note:** Ronnie, thanks for your compliments regarding the magazine. You're right —some unimaginable technologies have either come out of the space program or were a result of NASA research and development. Beginning on page 22, we continue our coverage of NASA's 40th anniversary by highlighting more of the most successful NASA spinoffs. You may be surprised to learn that many of the products we use every day actually were developed using NASA technologies.)*

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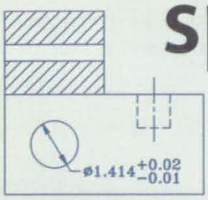

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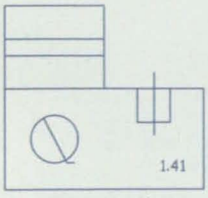

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We are involved heavily in high-pressure refrigeration circuits and the electronic sensing and control of such circuits. The articles and research contained in NASA Tech Briefs *have provided us with invaluable assistance in this field. Thank you.*

Raymond L. Sanborn
Emerson Electric Co.
Columbus, OH
ray_sanborn@liebert.com

In the November 1997 issue on page 64, the tech brief "Two-Wavelength Pyrometry With Self-Calibration" by Daniel Ng of Lewis Research Center directed me to making a successful measurement of surface temperature (buildings, roofs, etc.) Thank you.

Peter M. Kuhn, Ph.D.
Atmospheric IR Sensing
Stoughton, WI
kuhn@mailbag.com

We are attempting friction stir welding of polymers using previous articles in NASA Tech Briefs *regarding that process on metals. Thanks.*

H. Adam Tarpine
DuPont
Wilmington, DE
h-adam.tarpine@usa.dupont

*(**Editor's Note:** Thank you for the feedback, Adam. In case you missed it, the January 1998 issue featured a brief from Marshall Space Flight Center (page 78) on the use of a friction stir welding system for welding and weld repair either on the manufacturing floor or in the lab.)*

NASA Tech Briefs *keeps us up to date on new technologies, which should help us in the development of a workstation that accommodates all computer and non-computer equipment with optimum ergonomic design.*

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NASA PATENTS

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

Recombinant Protein Production and Insect Cell Culture and Process

(U.S. Patent No. 5,637,477)

Inventors: Glenn F. Spaulding, Thomas J. Goodwin, Kim C. O'Connor, Karen M. Francis, Angela D. Andrews, and Tacey L. Prewett, Johnson Space Center

Insect cells have shown unusual promise for recombinant protein product, but the promise is dependent on a large-scale production system that provides a favorable growth environment. Higher expression rates and greater yields can result in new biotherapies to treat disease, more sensitive diagnostic agents that will detect life-threatening illness sooner, and natural insecticides with greater species specificity. The invention describes a cell culture process that incorporates both reduced hydrodynamic forces and enhanced cell oxygenation. Insect cells were cultivated in a bioreactor that is a horizontally rotating vessel designed to create low shear by modulating the rotation, preferably in a bioreactor called the High Aspect Ratio Vessel (HARV). Cells are suspended in growth medium and mixed by the horizontal rotation of the vessel itself rather than by an impeller, greatly reducing turbulent eddy formation and reactor-cell collisions.

Dynamically Timed Electric Motor

(U.S. Patent No. 5,654,599)

Inventor: Ann M. Casper, Marshall Space Flight Center

In the past, "fine tuning" for maximum efficiency of electric motors was done statically by removing the end cap, loosening a plurality of commutation-board mounting screws, and manually rotating the board assembly by a minute amount. The unit was reassembled, a current reading taken, and the process repeated until minimum current flow was reached. The present invention eliminates this cumbersome procedure and improves the accuracy of the timing process. Hall-effect sensors for picking up rotor-position feedback signals are mounted radially on a circular commutation board, and this subassembly is mounted to the back of the motor's stator housing. The motor is timed by inserting a tool in openings in the motor's end cap, engaging commutation-board mounting screws to loosen the board from the housing and permit rotation. The board and therefore the sensors are rotated by inserting the tool in a second hole in the end cap and engaging a rack-and-pinion gear. Rotation of the commutation board and sensors is accomplished with the motor running and with electrical current readings being simultaneously taken. When maximum motor efficiency is reached, the commutation board is resecured.

Photonic Switching Devices Using Light Bullets

(U.S. Patent No. 5,651,079)

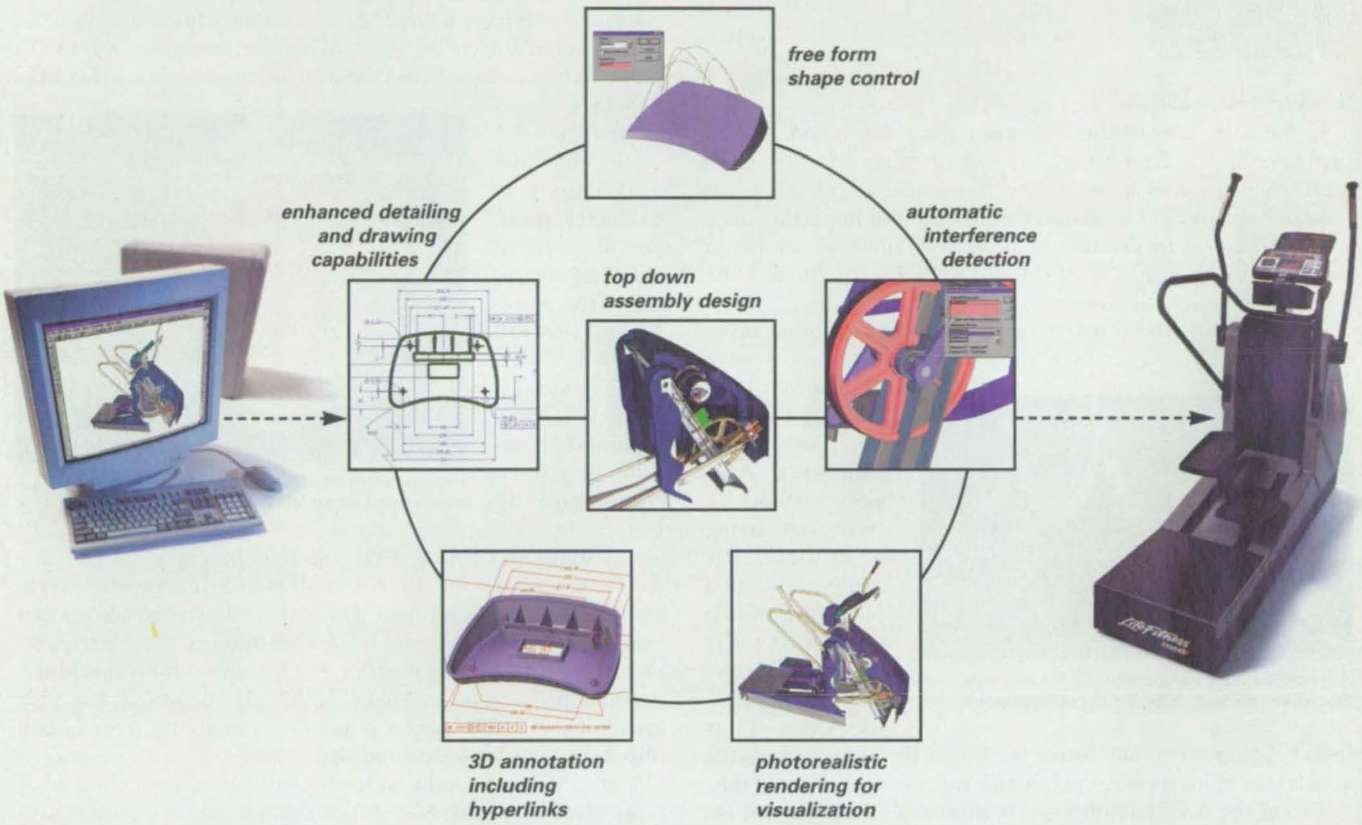
Inventor: Peter M. Goorjian, Ames Research Center

The term soliton describes light pulses that propagate in a medium without change; they may be temporal or spatial. Light bullets are a special type of soliton: they are essentially pulses of light which, when propagating in a nonlinear material, maintain their shapes under the effect of diffraction (spreading transverse to the direction of propagation), dispersion (spreading in the direction of propagation), and nonlinearity. The invention provides an all-optical switching device made with relatively inexpensive, highly nonlinear optical glasses. This device uses light bullets as optical pulses that switch each other's direction of propagation. The nonlinear response of the material of these ultrafast devices is electronic in origin, and hence the response of the material is on the order of a few femtoseconds. In one embodiment, the switching device of the present invention utilizes a planar slab waveguide. Another feature is the relative insensitivity of the collision process to the time difference in which the counterpropagating pulses enter the waveguide.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 14 for a list of office contacts.

SOLID THINKING IS OFTEN WHY ONE PRODUCT WORKS AND ANOTHER ONE DOESN'T.

YOUR ABILITY TO QUICKLY TRANSFORM THAT THINKING FROM AN ENGINEER'S MIND TO A FINAL PRODUCT IS ALL THAT WILL REALLY MATTER.



A ▶ FOLD THIS SECTION OVER LEFT AND BACK SO "A" MEETS "B" ◀ B

What's the fastest route between point A and point B? For Life Fitness and their 9500HR Cross-Trainer, it was SolidWorks®. Since pioneering the world's first Windows-native 3D mechanical design software in 1995, we've earned a reputation as the leader in mainstream solid modeling. And in 1998, we add to our track record of innovation by unveiling a new set of flexible, easy-to-use features that helps you go from concept to reality without wasting time on repetitive tasks or costly modifications. Add to that local technical support and surprising affordability and you've got a product that can really help you make things. Like money, for instance. For more information, visit our Web site or call 800-693-9000, ext. 3041. SolidWorks. **Mind to Matter.**

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SolidWorks

For More Information Circle No. 550

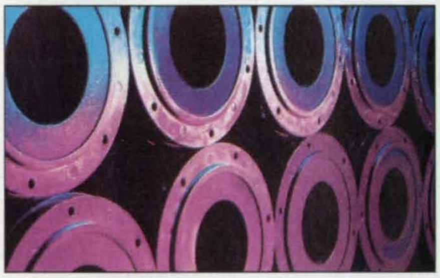
This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the area of Computers and Information Technologies.

1950s

A Whole New Industry

In the early days of the U.S. space program, NASA faced a problem: how to feed fuel to the engine of an orbiting spacecraft when the fuel is weightless. A scientist at NASA's Lewis Research Center in Cleveland, OH, thought of imparting magnetic properties to the fuel by dispersing finely ground iron oxide particles within it; the fuel could be drawn into the engine by a magnetic source.

These ferrofluids — magnetic liquids whose unusual properties offer advantages in a range of applications — were brought to NASA's attention again in the 1960s when scientists at Avco Space Systems Division were trying to control the temperature of a spacecraft, which is very hot on the Sun side and very cold on the opposite side. They found that a ferrofluid could be drawn through a pipe ring around the craft, cooling the hot side and warming the cold side.



A ferrofluid-based exclusion seal for computer disc drives protects them from contamination.

Two of the Avco scientists — Dr. Ronald Rosensweig and Dr. Ronald Moskowitz — commercialized the ferrofluid technology and formed Ferrofluidics Corporation of Nashua, NH in 1969. The company rapidly grew into many applications, including inertia dampers for stepper motors, failure-reducing coolants for hi-fi loudspeakers, medical equipment, plasma processes, artificial heart pumps, and cleaning up oil spills.

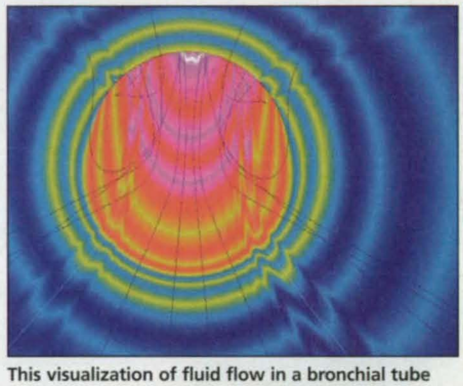
One of the most successful applications was the use of a ferrofluid-based exclusion seal for computer disk drives. Since the drives are extremely susceptible to contamination, one particle of dust, one-tenth the diameter of a human hair, can damage the disc head and cause loss of data in the disk's memory. Many computer manufacturers are using the Ferrofluidic seals, which have proven highly effective in protecting stored information.

1980s

Visualizing a Booming Success

In the early 1980s, a group of aeronautical engineers at NASA's Ames Research Center were looking for a way to visualize the massive amount of data generated by computational fluid dynamics (CFD) research. NASA wanted 3D, real-time graphics that would enable the engineers to manipulate the screen image instantly. Coincidentally, at the same time, a small computer company named Silicon Graphics Inc. (SGI) in nearby Mountain View, CA, was looking for customers for its 3D graphics technology. NASA's search led them next door to SGI.

NASA purchased about 25 of the first SGI workstations at $125,000 each, an expensive price tag at the time. The workstations were a hit with NASA, which subsequently worked with SGI to develop a way of communicating between the workstations and NASA's Cray supercomputers.



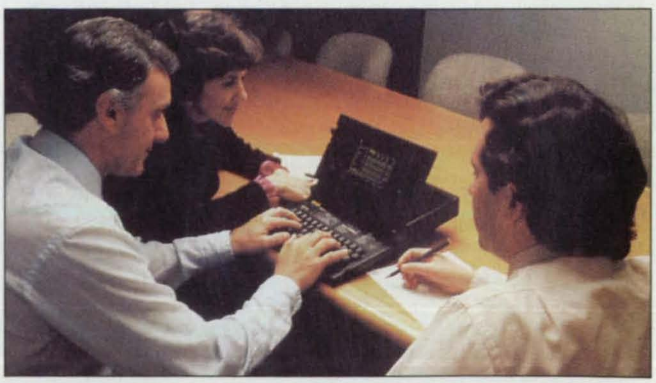
This visualization of fluid flow in a bronchial tube was created on an SGI Power IRIS workstation.

The relationship with NASA allowed SGI access to a technologically advanced user group that offered advice on SGI designs and products. And by striving to meet NASA's requirements for advanced capabilities, SGI improved their machines. As their first major customer, NASA also provided SGI with credibility in the business community, enabling it to obtain important development funding.

Today, SGI is the industry leader, with annual sales in the billions of dollars. The SGI/NASA relationship continues, with NASA lending technological advice and remaining an important SGI customer. According to SGI, "NASA was there, investing in those early and expensive boxes and funding the company because it had good technology, so that ten years later, it could produce something that's a fifth of the price with over a hundred times the graphics capability."

From the Shuttle To Your Desk

In 1983, a nine-day space shuttle mission marked the space debut of a high-performance navigation monitoring computer called SPOC (Shuttle Portable Onboard Computer), which



was an adaptation of the GRiD Compass from GRiD Systems Corp. of Fremont, CA. The GRiD Compass was the first true portable laptop computer.

NASA requirements meant that the hardware had to be modified, and new software had to be developed. These modifications led to changes in commercial models offered by GRiD Systems. Since the shuttle's main computers handle multiple processing functions, NASA required a separate computer to monitor the shuttle's orbit path, as well as a visual display of its position at any given moment. The computer also had to be lightweight, due to weight restrictions. At the same time, it had to have a large memory storage capacity, a high processing speed, and be rugged enough to withstand a launch.

The principal modification to the GRiD Compass was a fan to cool the computer, since the original model was cooled by convection, which does not work in the weightlessness of space. NASA also added a larger screen and Velcro strips to keep it from floating.

GRiD Systems' computers helped space shuttle astronauts keep track of their craft's position, control payload experiments, collect data, and transmit research results instantly back to Earth. While the original GRiD System computers are no longer manufactured by the company — which was purchased by another firm — laptop computers have enjoyed a modest success over the past decade!

Image is Everything

Through image analysis, it is possible to gain information from a picture by visually extracting and interpreting the photograph or x-ray. But NASA found that for space applications, basic image analysis was not fast enough or accurate enough. In response to these needs, Jet Propulsion Laboratory (JPL) developed digital imaging — computer-processed numerical representation of physical images. JPL also led the development of digital image processing, which enhances images to improve their quality and make them easier to analyze.

These processes formed the basis for some revolutionary applications, the best-known of which may be CAT scanners, which are based on digital imaging. Other medical applications for digital image processing include computerized image analysis of cardiological x-rays to provide quantitative data on heart valve and artery functions.

In 1985, Perceptive Systems Inc. (PSI) of Houston, TX, introduced the PSICOM 327 digital image analysis workstation to the general market. A NASA technology transfer company employing former NASA workers and operating under a NASA patent license, PSI was founded in 1984 by former NASA digital imaging experts Dr. Kenneth Castleman and Don Winkler.

Now known as Perceptive Scientific Instruments, the company is still led by Dr. Castleman, and has become a market leader in the field of cytogenetic and molecular cytogenetic digital imaging systems. PSI is currently working with NASA to develop and commercialize automated microscope instrumentation for the rapid, unattended assessment of chromosome breakage in human lymphocytes and other interphase cells. The system would support NASA shuttle missions that study spaceflight-induced genetic damage.

Keeping the Data Flowing

Kinetic Systems Corp. of Lockport, IL conducted a joint study with NASA's Langley Research Center in the mid-1980s to determine the feasibility of using high-speed Computer Automated Measurement and Control (CAMAC) data acquisition systems in Langley's Advanced Real Time Simulation (ARTS) system, which supports flight simulation research and development.

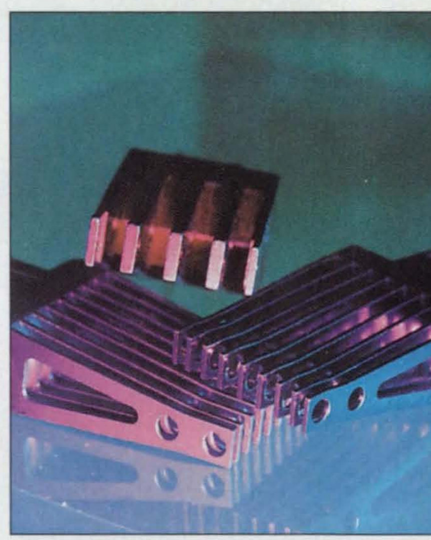
The study showed that CAMAC equipment could improve the ARTS system significantly through the use of 32 high-performance simulators located throughout Langley, controlled by centrally located host computers. Kinetic Systems developed the system hardware, including an advanced fiber-optic data highway and digital to analog, analog to digital, and digital to synchro converter modules.

Since then, the technology has turned into new applications for Kinetic Systems. Ford Motor Company uses the technology in its transmission test cell program in Livonia, MI, where auto transmissions are tested for durability and efficiency. Using sophisticated computer programs to control and monitor the tests, Ford operates 24 test cells, each containing a Kinetic Systems CAMAC-based data acquisition and control system.

1990s

Advanced Disk Drives

The National Aero-Space Plane (NASP) program conducted jointly by NASA and the Department of Defense was designed to develop the enabling technologies for future hypersonic and transatmospheric vehicles for low-cost space access. Although no longer active, the program's research applications produced an advanced material called AlBeMet™, a compression of aluminum beryllium metal matrix composite developed by Brush Wellman of Cleveland, OH.



AlBeMet is used in the manufacture of advanced disk drives.

NASP vehicles would be operating within the atmosphere for long periods of time, encountering temperature extremes even beyond what the Space Shuttle faces. In order for the vehicles to withstand those temperatures, a number of lightweight, high-strength, oxidation-resistant materials were developed by NASP researchers. These materials included metal matrix, organic, refractory, and highly conductive composites.

One such material was AlBeMet, which combines low density and high stiffness found in beryllium with the ductility and low cost of aluminum. The material reduces weight, removes heat, and increases the lifetime of an electrical system. It is now in the commercial market. Brush Wellman Applications Development Center has produced an AlBeMet rotary actuator for disk drives produced by Maxtor Corp. of San Jose, CA. The material used in the disk drive, AlBeMet 160, is as stiff as steel and lighter than aluminum. Disk performance is improved since the lighter, stiffer arm assembly allows the heads to move faster.

Striking the Right Chord

The BAT™ chord keyboard — developed with help from NASA — offers advantages to disabled people while also appealing to the majority of computer operators. Infogrip of Baton Rouge, LA, manufactures the device, which employs chordic technology — in which operators finger key combinations like striking a chord on a piano. Designed for single-hand use, it has only seven keys, with five of them positioned under the thumb and fingers. The other two are positioned so the thumb can reach them with slight movement.

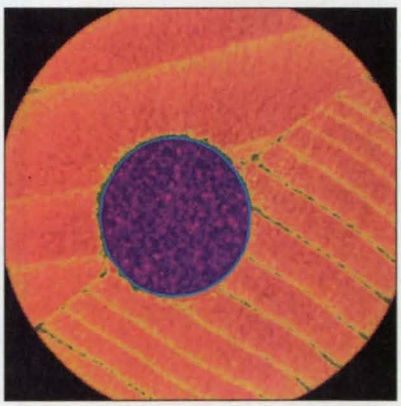
The BAT allows workers with disabilities such as amputation, paralysis, or impaired vision to operate a computer. For the general population, the BAT reduces strain and fatigue associated with use of traditional keyboards, and frees the other hand for flipping pages or holding a phone.

The chordic input technology was developed jointly by Infogrip and NASA's Stennis Space Center.

Finding Faults

In the 1980s, NASA developed digital image processing, which became the basis for computed tomography (CT) scanning systems (see "Image is Everything" p. 24). Perhaps better known to Americans is the term CAT scan, a diagnostic technique that incorporates digital image processing technology to scan the body, or parts of the body.

Bio-Imaging Research (BIR) of Lincolnshire, IL, developed for Marshall Space Flight center an industrial inspection system that used CT technology to find imperfections in aerospace structures and components. The system, called ACTIS (Advanced Computed Tomography Inspection System) has been in service at Marshall for almost nine years, and has been sold in commercial form as well. A smaller, PC version — called ACTIS+ — can "provide CT imaging capability at less than one-tenth the cost of current industrial CT systems," according to BIR.



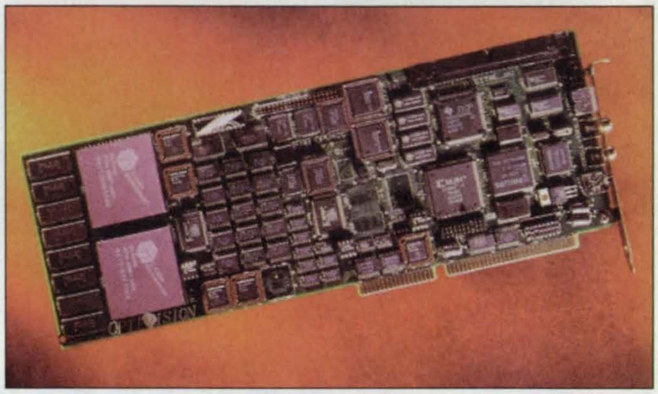
An ACTIS+ image of a pencil shows the detail in the graphite core (purple) and the glue joints between the wood sections.

ACTIS+ is designed to be added to an existing real-time radiography (RTR) system, using major RTR components and eliminating the expense of an x-ray system, detector system, and radiation-safe site modification. The system can find internal defects in parts before machining and processing; monitor the effects of process changes on product quality; verify assembly before a product is put into service; and generate or correct computer-aided design data.

The original ACTIS system at Marshall has found flaws in turbine and valve castings, and has scanned an entire automobile and a cruise missile's jet engine. A similar ACTIS system at Boeing scanned a complete satellite, avoiding the time and expense of opening it, resealing it, and resterilizing it. The system is being used by the U.S. Customs Service to see false compartments in the outer walls of vehicles.

Speeding-Up Video

NASA's Goddard Space Flight Center awarded an SBIR contract to Optivision of Palo Alto, CA to develop two PC-compatible boards and related software for real-time video compression and decompression for NASA applications in telerobotics and spaceborne experimentation. While working on the project, Optivision devoted its own funding to the parallel development of two commercial products: the OPTIVideo™ MPEG Encoder and Decoder.



The OPTIVideo Encoder converts video tapes and discs to compressed digital form.

Optivision introduced the commercial products in 1993-94 to users who wanted to speed up audio/video processing time and reduce costs. The company has sold systems to the telecommunications, cable, broadcast TV, and CD-ROM markets for use as television advertisement insertion, video CD authoring, interactive video databases, and remote learning.

The OPTIVideo Encoder converts video tapes and laser discs to a manageable compressed digital form at 30 frames per second; the Decoder decompresses the bit stream to provide high-quality digital playback.

Seeing the Whole Picture

IPIX™ is an interactive imaging technology developed through an SBIR contract with NASA Langley in the early 1990s. Interactive Pictures Corp. (IPC) of Knoxville, TN, developed the technology, which NASA uses in guiding space robots, in the Space Shuttle and Space Station programs, and in research in cryogenic wind tunnels and remote docking of spacecraft.

IPIX provides real-time control of live video data, allowing users to look in one direction from a single vantage point or four views simultaneously. It relies on digital image manipulation of a standard video signal, and permits independent panning, tilting, zooming, and rotating of the four video images, providing a panoramic 360-degree view. The system requires no moving parts, creates no noise, and responds faster than you can blink your eye. It uses a high-resolution charge-coupled device (CCD), image correction circuitry, and an image processing microcomputer.

The IPIX technology has been developed further for spherical photography in which a digital camera or standard 35mm camera fitted to a fisheye lens is used. Images are processed and electronically scanned to create a digital file. Once digitized, a

Mr. Sulu, I think you dropped something.

We admit the tri-corder is a pretty handy gadget. Unfortunately, you'll have to wait about 200 years to get one. Until then, consider the HP LogicDart. It's an advanced logic probe that not only performs basic logic monitoring, but also tests continuity, dc voltage, frequency, and does timing analysis. This eliminates the hassle of switching tools and keeps you focused on solving problems. Making it the perfect tool for first-level troubleshooting.

What's more, you can make all of these measurements from a single probe. So you don't have to fumble around hooking up different probes for different instruments. And the HP LogicDart's precise probe tip allows you to confidently probe fine-pitch surface mount circuitry.

But there's more to this 23rd-century tool than we can explain in 150 20th-century words. That's why we're offering a free brochure with key specifications and ten practical HP LogicDart applications.

To find out more about the HP LogicDart, visit our Web site or call HP DIRECT at 1-800-452-4844, Ext. 5215. At a price of only $795*, anything else would be illogical.

http://www.hp.com/info/LogicDart1

DC voltage, frequency, logic activity and timing simultaneously.

Check up to 3 channels of logic timing.

Measure continuity, diode test, and resistance.

100 MSa/s sampling —up to 10 ns timing resolution.

* U.S. list price   Faxback: 1-800-800-5281, Document 12687

HEWLETT® PACKARD

For More Information Circle No. 530

IPIX imaging technology combines two images from 180° perspectives into a sphere.

single fisheye shot captures a hemisphere, while two opposing shots provide an entire sphere. With seaming tools, the two shots are fused without a discernible seam.

Images are captured in their entirety in a 360-degree immersive digital representation, inside which the viewer can navigate to any direction via a computer mouse, joystick, or other input device.

Uses for the IPIX technology are many, including museum exhibits, sports stadiums, and non-invasive surgery. Car manufacturers use the technology to give viewers a behind-the-wheel look at new cars. Other applications include the security and surveillance industry, military operations, teleconferencing, and virtual reality theme parks.

To Contact Profiled Companies, Call:

Bio-Imaging Research	847-634-6425
Brush Wellman	510-623-1500
Ferrofluidics Corp.	603-883-9800
Infogrip	805-652-0770
Interactive Pictures Corp.	615-690-5600
Kinetic Systems Corp.	815-838-0005
Optivision	415-855-0200
Perceptive Scientific Instruments	713-334-3027
Silicon Graphics	650-933-7777
Symbology Research Center	205-830-8123

Next Month:

NASA Technologies Used in CAD/CAM Software

Looking Ahead ...

• Bio-Imaging Research (BIR) has conducted tests of its ACTIS+ inspection system at NASA Marshall to inspect hazardous waste drum contents safely (see "Finding Faults," p. 26). Those tests have led to the development of Waste Inspection Tomography (WIT), a trailer-mounted portable system that can be taken to waste dump sites to identify the contents of drums found there. Along with custom software, the system enables BIR to combine 3D x-ray CT images of the drum's contents with 3D gamma-ray information on the location of radioactivity in the drum. The system can also identify and measure the volume of potentially corrosive free liquids, how much the drum's wall may have been thinned by corrosion, and the presence of objects that are supposed to be forbidden in storage drums.

BIR's Waste Inspection Tomography (WIT) trailer unit.

BIR hopes to increase the number of detectors on the system so it can scan drums from 5 to 30 times faster. The company also hopes to build two additional trailers to offer its scanning and analytic services to more industries.

• Over the next 25 years, the emerging field of molecular nanotechnology — the precise manipulation of atoms — may lead to ultra-fast supercomputers on an ever-shrinking scale. Approximately 10 atoms fit into one nanometer (a billionth of a meter). Research programs in chemistry and molecular biology are bringing us closer to a generation of "nanosized" computer components assembled atom by atom.

NASA Ames Research Center is currently collaborating with Dr. H. Dai of Stanford University to develop carbon nanotubes — rolled sheets of graphite from 0.7 to several nanometers in diameter — that eventually may be used to engrave patterns on a silicon surface, creating features perhaps 100 times finer than today's commercial semiconductor photolithography. In theory, nanotechnology could produce computers the size of a single human cell with data stored on DNA-like chain molecules. Potential applications in the distant future include micromachines that repair damaged cells by manipulating DNA, self-replicating materials, and large-scale space colonization.

The number and type of products now using digital data matrix identifier codes expands daily. (NASA photo by Emmett Given)

• Digital data matrix technology, developed by NASA Marshall in the 1960s and 1970s, is the next generation of bar codes used to mark products. Instead of using bars and stripes, the matrix technology incorporates a checkerboard of data etched directly onto a product or part. They symbol, which can range in size from 4 microns to 2 square feet, is read by a digital camera. This type of parts marking could be especially helpful to auto makers, allowing them to keep track of every part.

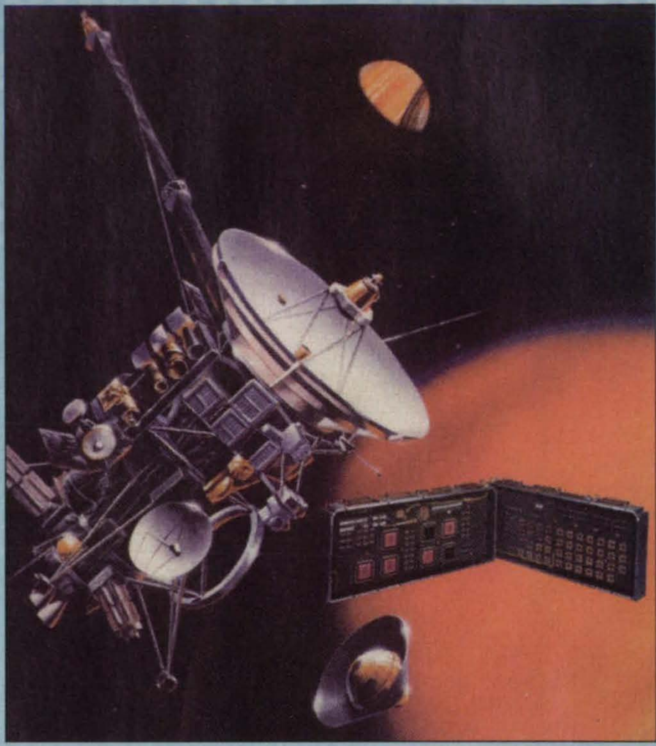
NASA and CiMatrix Corp. of Canton, MA, have partnered to form the Symbology Research Center in Huntsville, AL to commercially market the new marking technology. The Center expects to handle up to 500 product-marking problems each year.

• NASA Ames has developed DCTune, a computer technology that boosts efficiency in storage and transmission of documents, pictures, and videos. DCTune technology is compatible with JPEG and MPEG industry compression standards. It can be used as add-on modules to existing imaging-workstation software and imaging devices, or as add-on functions to existing microchip designs. Potential commercial applications include storage of medical X-rays and MRI images; Internet multimedia; and cable TV, advanced TV, and HDTV.

Application Briefs

Processors Fly With Cassini

1750A processors
Lockheed Martin Federal Systems
Manassas, VA
703-367-2841



The Cassini spacecraft began its seven-year journey to Saturn last October aboard a Titan 4B Centaur rocket. Scheduled to arrive near Saturn in 2004, Cassini will spend four years exploring the ringed planet and its moons, approximately one billion miles from Earth.

Seven radiation-hardened Military Standard 1750A processors help control Cassini: two control the Command Data System (CDM); two control the Attitude and Articulation Control System (AACS); and three control some of Cassini's instruments, including the wide and narrow angle camera lenses and the radar system for Saturn Moon research.

One of the largest spacecraft ever built, Cassini measures two stories high and weighs more than 12,000 pounds. The processors used are designed for low power consumption and can be operated at a selectable clock frequency to conserve power or adjust processor throughput, depending on the requirements. The processors use a radiation-hardened Generic VHSIC Spaceborne Computer (GVSC) chip set developed under a program sponsored by the U.S. Air Force's Phillips Laboratory in Albuquerque, NM.

For More Information Circle No. 749

Simulation Software Streamlines Shuttle Seat Design

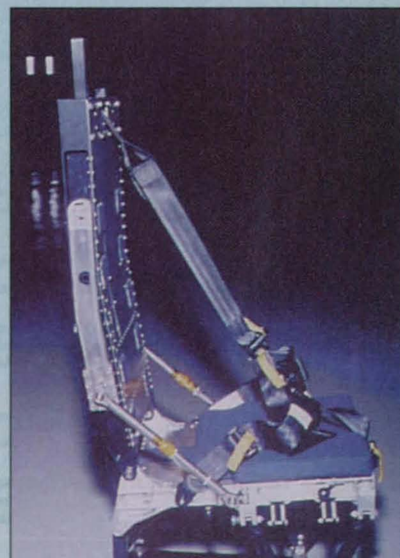
DADS dynamics analysis software
Computer Aided Design Software, Inc. (CADSI)
Coralville, IA
319-626-6700
Fax: 319-626-3488

Elimination of unnecessary weight in the space shuttle recently became a priority in order to allow heavy space station components to be launched using the shuttle. And recent work in the automotive and aircraft industries highlighted how important seat design is in passenger safety. So NASA began redesigning the space shuttle mission specialist seats.

The seats had to meet the same functional and envelope specifications as the original seats, located on both the shuttle's flight deck and the mid-deck. When folded for storage, they must fold into a volume of 25.5" long by 15.5" wide by 11" high. Strength requirements specified that the seat be able to tolerate a statically applied load of 20 Gs with an occupant weight of 113 pounds. Once these requirements were met, NASA began the task of dynamic crash testing.

Faced with a limited budget, NASA decided against the expensive approach of building a prototype of the seat and performing sled testing. Instead, NASA engineers used DADS software, which was able to import flexible body data from an already-existing seat finite element model that had been created using SDRC's I-DEAS finite element pre-processor and MacNeal-Schwendler's MSC/NASTRAN finite element analysis software.

The simulated crash testing allowed NASA to make design iterations to the seat before building a prototype, which was tested by the Federal Aviation Administration (FAA). The prototype passed the FAA dynamic tests, and is still in service in mission training applications. The simulation-driven design process resulted in a seat that weighs 48% less, and meets more severe load and flexibility requirements than the original design.



The redesigned space shuttle seat.

For More Information Circle No. 750

Commercialization Opportunities

Mass Analyzer With Rotating Electric Fields

A device for measuring the distribution of masses in an atmosphere or plasma does not require a magnetic field, can be made small, and is simple to construct.
(See page 37.)

Automated Window Inspection Device

A prototype apparatus for computer-controlled, noncontact inspection of windows has been developed to examine space-shuttle windows for damage by micrometeorites. The apparatus can be adapted to industrial inspection of window glass prior to cutting and to windows on aircraft and land vehicles.
(See page 38.)

Hybrid Superconductor/Semiconductor Planar Oscillators

The characteristics of these oscillators, which are designed to operate at 8.4 GHz, include frequency stability, low phase noise, and ability to withstand vibrations. Other advantages are compactness and suitability for integration into monolithic integrated circuits.
(See page 50.)

High-Performance Thermal Insulation for Racing Car

Space-shuttle type insulating blankets can protect a racing driver against hotspots. These insulating blankets offer effective passive thermal protection without adding complexity or weight to racing cars.
(See page 65.)

Highly Selective Gas-Phase Etching of Silicon

A technique of gentle, highly selective gas-phase etching of silicon enables the fabrication of microelectromechanical devices integrated with electronic circuits. This feature allows one to include microsensors without damaging the circuit already present.
(See page 66.)

High-Wind Masts for Meteorological Instruments

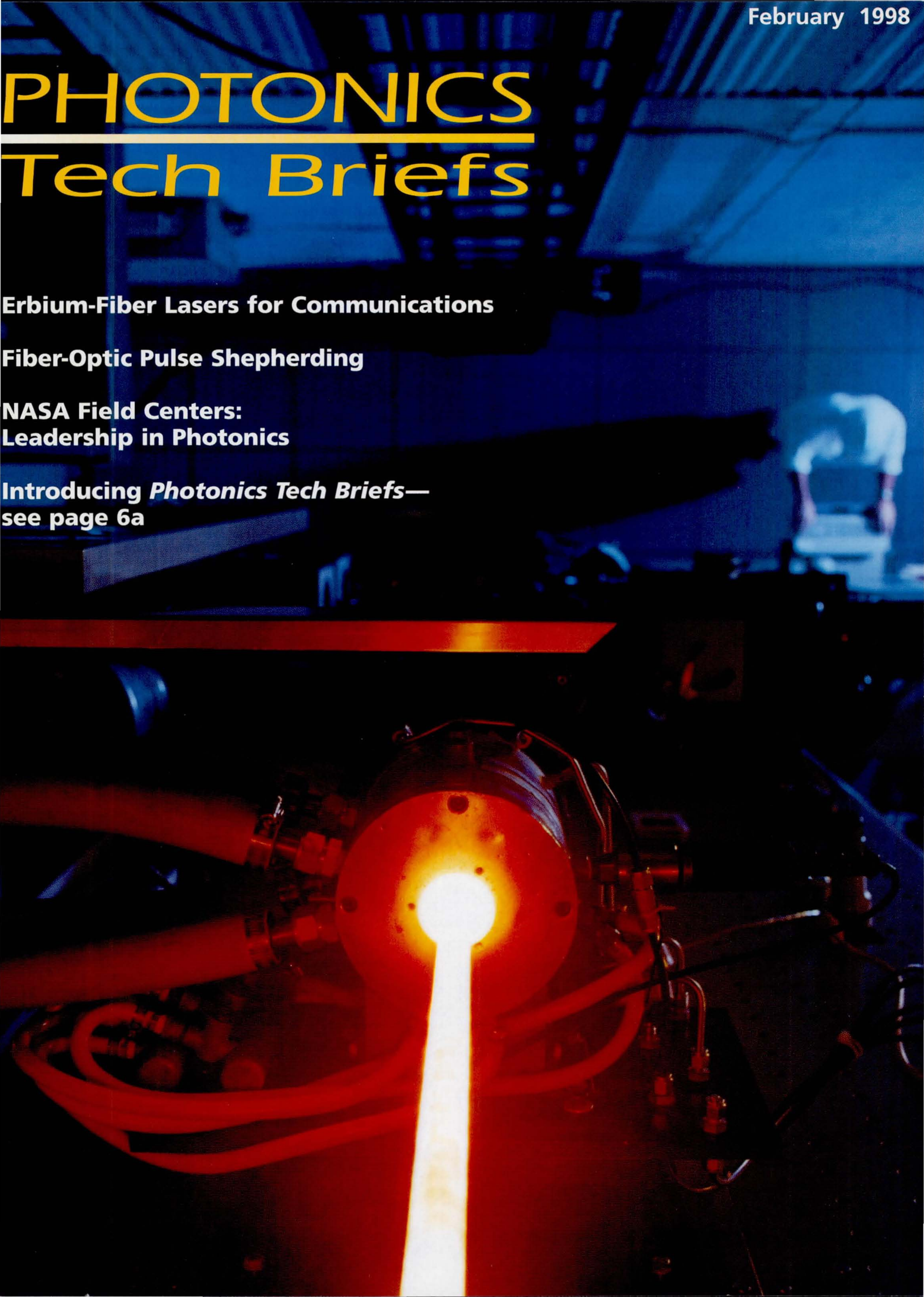
This mast for supporting meteorological instruments would withstand considerably stronger winds than conventional masts. Simple modifications can increase this endurance from typical 125 mi/h (56 m/s) up to 350 mi/h (156 m/s).
(See page 71.)

Compact, Noncontact Fiber-Optic Probe for Diagnosis of Eye Diseases

This probe is useful for diagnosis of interior parts of eyes. Developed originally for light-scattering measurements in microgravity, the probe is found to yield information on submicron particles inside the eye and reveal not only problems of the eyes themselves but also about cholesterol and blood sugar.
(See page 82.)

February 1998

PHOTONICS Tech Briefs



Erbium-Fiber Lasers for Communications

Fiber-Optic Pulse Shepherding

NASA Field Centers:
Leadership in Photonics

Introducing *Photonics Tech Briefs*—
see page 6a

PHOTONICS Tech Briefs

Photonics Tech Briefs Supplement to *NASA Tech Briefs'* February 1998 Issue Published by Associated Business Publications

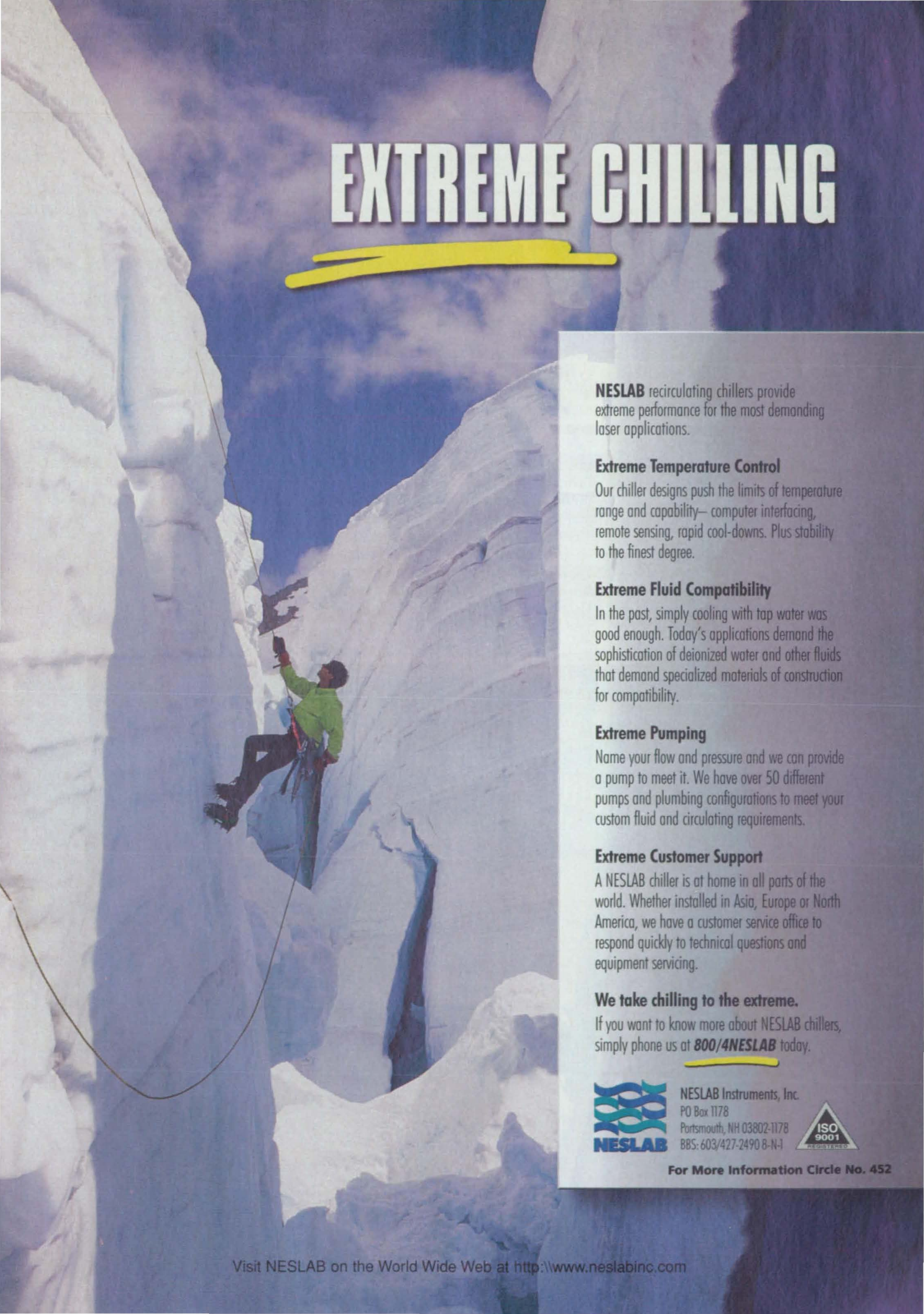
CONTENTS

Feature

Photonics Tech Briefs

Departments

On the cover:
A view from above of a state-of-the-art fiber optic drawing tower at the newly opened facilities of SpecTran Specialty Optics Company in Avon, CT. They enlarge the company's manufacturing capacity by more than 50 percent, and feature advanced equipment, including the new drawing towers that increase capabilities to manufacture a variety of integrated fiber optic solutions for communications, industrial, and other markets. The company is a wholly owned subsidiary of SpecTran Corp., a world-class supplier of optical fiber, cable, and special performance fiber optics products for communications and specialty markets. *Photograph courtesy SpecTran Specialty Optics.*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NEWS BRIEFS

Notes from Industry and the Federal Laboratories

QED Technologies, a startup company based in Rochester, NY, was formed to commercialize the optical polishing technique called magnetorheological finishing (MRF). MRF is a polishing method invented in the former Soviet Union, in what is now the Republic of Belarus, and refined through a collaboration between Byelocorp Scientific Inc. and the University of Rochester's Center for Optics Manufacturing. Though QED says that the process's flexibility and simplicity of operation make it suitable for rapid prototyping of any plano or spherical optical component, it is an enabling technology for polishing and fine-figuring of high-precision glass aspheres.

In the deterministic MRF process, a multiple-axis computer-controlled machine is programmed to perform specific tasks to very high accuracy–within 2 percent of the predicted result–and precision to $\lambda/20$ peak to valley. MRF may be used to uniformly remove subsurface damage from a ground lens, reducing its RMS microroughness to 10 angstroms without changing its figure. Alternatively, it can be instructed to simultaneously remove such damage and improve figure by a factor of 10 or more in a single iteration. The process works on aspheres because the subaperture MRF fluid polishing lap automatically conforms to the local surface being polished. MRF's high removal rates translate into attractive cycle times, QED says.

QED Technologies is located at 1080 University Ave., Rochester, NY 14607; phone (716) 256-6540; fax (716) 256-6541.

In mid-December President Clinton and Commerce Secretary William M. Daley announced eight new competitions in the 1998 Advanced Technology Program (ATP) managed by the department's **National Institute of Standards and Technology**. In this first round for 1998 are the general competition, open to proposals from all technological areas, and seven focused competitions in three existing ATP program areas—Catalysis and Biocatalysis Technology, Digital Video in Information Networks, and Tools for DNA Diagnostics—and four new programs: Microelectronics Manu facturing Infrastructure, Photonics Manufacturing, Selective-Membrane Platforms, and Premium Power.

The competition announcements appeared in the December 16 issue of *Commerce Business Daily*. In a related document in the *Federal Register* for December 15, ATP announced that it would have approximately \$82 million available in fiscal year 1998 for first-year funding of new projects, and may add further competitions later in the year.

Competition deadlines were also announced. Those for optional preproposals for Microelectronics Manufacturing and Photonics Manufacturing are February 27, and for full proposals April 8 for both. Further information on the ATP, including copies of the new Proposal Preparation Kit dated December 1997, ATP *Federal Register* notices, and the competition announcements, are available from ATP's web site at http://www.atp.nist.gov, by sending E-mail to atp@nist.gov, by calling 1-800-ATP-FUND (1-800-287-3863), or by faxing a request to (301) 926-9524 or (301) 590-3053.

EDITORIAL NOTE

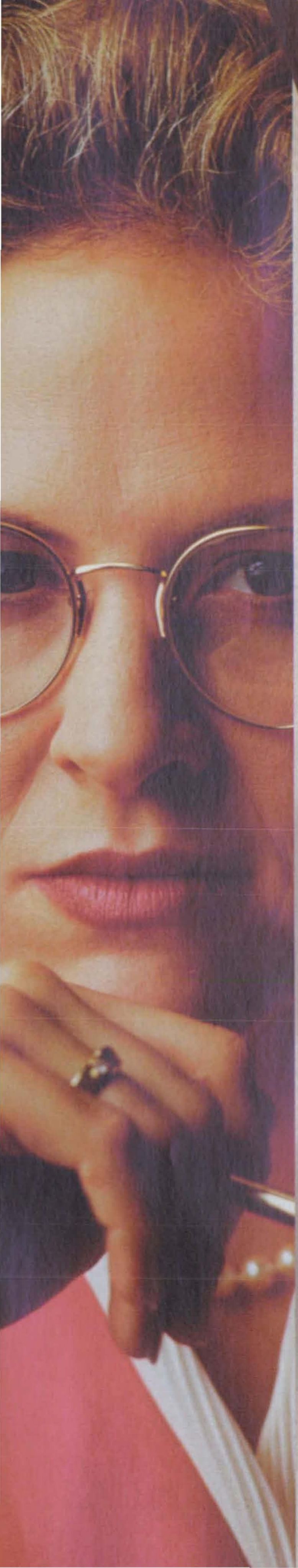
INTRODUCING *PHOTONICS TECH BRIEFS*

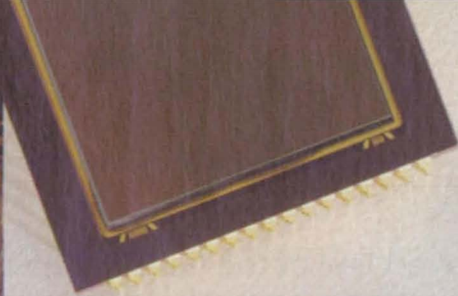
When *Laser Tech Briefs* was launched in 1993, it provided a vehicle for dissemination of an abundance of laser-related technology with commercial potential being developed in NASA and other federal laboratories. But as time went on it became evident that these labs, as well as those in the private sector, were producing advanced technology utilizing photonics that ranged well beyond the use of lasers and associated optics. For a glimpse of the magnitude of this work, see the story "Photonics Shines in NASA's Field Centers," the first part of which appears in this issue. Over the years these developments constituted an ever greater part of this supplement's coverage. So, beginning with this issue, we have changed our title to more accurately reflect our mission.

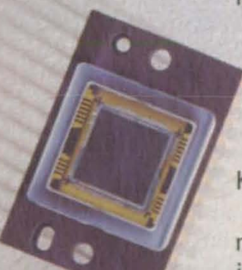
Just as our coverage has expanded over the years, so too has the photonics industry. It is astonishing to tally the technological developments that have emerged or come to maturity in just the last several years: single-point diamond turning, erbium-doped fiber amplifiers, a blue laser diode, soliton transmission, CCD cameras with a million pixels, magnetorheological finishing, efficient wavelength division multiplexing, diffractive optics, and more. Increasingly, all-photonic or optoelectronic devices are doing the work once done by electronics. New uses are being found for radiant energy at both extremes of the photonic spectrum. *Photonics Tech Briefs* will bring readers word of all these leading-edge developments as they emerge from NASA, other federal laboratories, and OEMs.

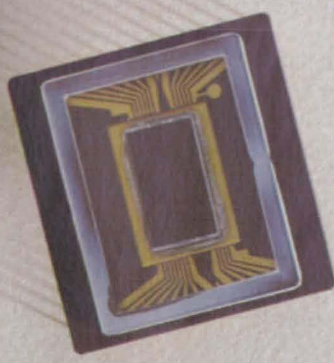
Concurrent with the name change, Linda Silver joins Associated Business Publications as Associate Publisher of *Photonics Tech Briefs* to bring heightened awareness of our message to the photonics community. A seasoned professional, Linda has a decade of experience in our burgeoning industry, and will manage sales and marketing for *Photonics Tech Briefs* from her Los Angeles area office. She can be reached at 1130 South Wetherly Drive, Los Angeles, CA 90035; (310) 247-0317; fax (310) 859-0285; lindas@abptuf.org.

Robert S. Clark
Senior Editor









PHOTONICS SHINES IN NASA's FIELD CENTERS

An overview of the Centers' leadership role in optics, lasers, and other photonics disciplines.

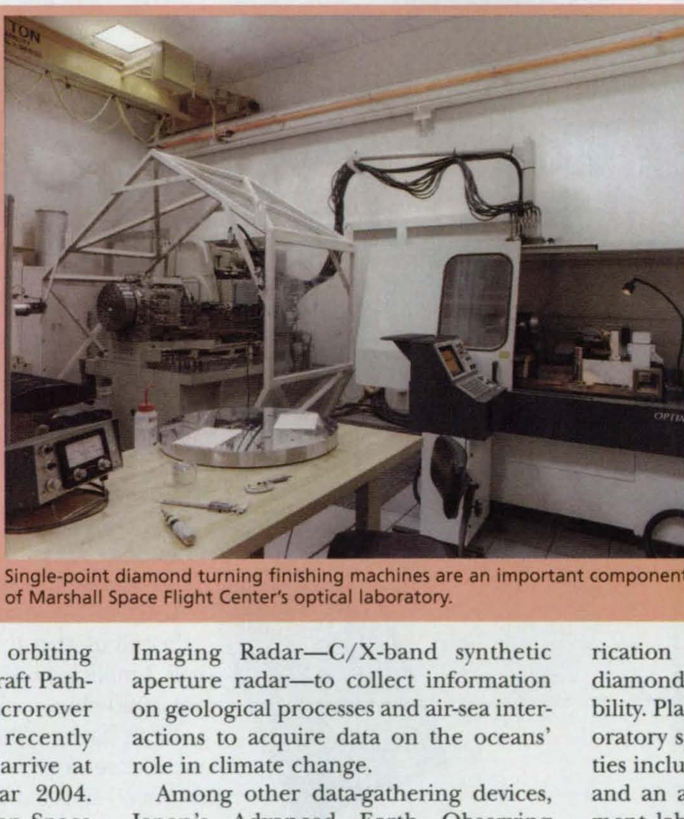
"NASA has traditionally measured its progress in terms of technical performance, cost and schedule. Now, in the post-Cold War era there is another measure: contribution of technology to national economic security." So says the document *NASA Commercial Technology: Agenda for Change*, adopted by the agency in 1994.

NASA programs generate a great wealth of advanced technology, and the agency, through its technology transfer programs, employs a variety of mechanisms to stimulate such transfer to the commercial sector of the economy. Probably the most important linkage is the group of ten NASA field centers located across the country. Many of them have significant work going on in the disciplines of photonics: lasers, optics, fiber optics, electro-optics, video and imaging, design and fabrication, and related areas.

NASA's Jet Propulsion Laboratory

The Jet Propulsion Laboratory (JPL) in Pasadena, CA, is probably best known as the manager of the recent missions to Mars—the orbiting Global Surveyor, the landing craft Pathfinder, and the winning microrover Sojourner—as well as the recently launched Cassini, which will arrive at its target, Saturn, in the year 2004. Cassini is carrying the European Space Agency's Huygens probe, which will land on the surface of Titan, Saturn's largest moon. This moon may be the locale of organic chemistry possibly like that which led to life on Earth. Managed by the California Institute of Technology, JPL is NASA's Center of Excellence in deep space science.

Obviously, JPL labs abound in remote sensing technology, lens and optical train design, test and measurement technology, and similar areas. As an example, the innovative New Millennium program, which will initiate new industry and university partnerships with JPL, is intended to change the way space science missions are conducted. The program's microspacecraft will be geared to validate state-of-the-art electronics and sensors. The Deep- Space 3 mission will use interferometry to search for planets circling other stars, and Deep-Space 4 will test an array of Earth remote sensing technologies. Both are scheduled for the year 2000. Meanwhile, closer to home, JPL's sensor technology expertise has been applied to the Spaceborne Imaging Radar—C/X-band synthetic aperture radar—to collect information on geological processes and air-sea interactions to acquire data on the oceans' role in climate change.



Single-point diamond turning finishing machines are an important component of Marshall Space Flight Center's optical laboratory.

Among other data-gathering devices, Japan's Advanced Earth Observing Satellite carries a NASA scatterometer to help improve weather forecasting and detection of destructive storms. Earlier this year JPL selected four industry teams to implement LightSAR, a proposed new Earth-imaging satellite. LightSAR would use advanced technologies to reduce the cost and enhance the quality of radar-based information for scientific research, commercial remote sensing, and emergency management applications.

Much of the productive interaction between NASA laboratories and American industry comes through the Small Business Innovation Research, or SBIR, and the Small Business Technology Transfer (STTR) programs. One instance of such cooperation was the SBIR contract that brought JPL and Lambda Research Corp. of Littleton, MA, together. Developed at JPL's behest, TracePro is state-of-the-art interactive software to detect stray light in the design of optical systems. It is a Windows 95/Windows NT application with the ACIS solid modeling tool as its kernel. It can model solids such as lenses, baffles, light pipes, integrating spheres, and complete illumination systems.

Marshall Space Flight Center

A second locus of signifcant work is Marshall Space Flight Center in Huntsville, AL, which has been proposed as a NASA Center of Excellence for Space Optics. Marshall currently has more than 90,000 feet square of laboratory space and contains several unique facilities including a one-of-a-kind stray-light test facility, a coherent LIDAR test facility and a video test facility, a diffractive optics facility, and a precision optical fabrication facility with both single-point diamond turning and ion figuring capability. Plans are under way to expand laboratory space, adding several new facilities including an expanded optical shop and an advanced x-ray mirror development lab. The fabrication area has the basic equipment to receive bulk optical materials, cut them to rough blanks, generate to radius of curvature, thickness, and diameter, and then to smooth and polish to the final figure and finish. Materials normally worked include optical glass for refractive elements, low-expansion materials for reflective elements, and occasionally metal or such advanced reflective elements as silicon carbide. The shop can produce flat work to about 16 inches in diameter with flatness on the order of 1/20 wave, and radius work of up to about 2 inches in diameter and accuracy on the order of

1/20 wave. Associated with the shop is a facility capable of coating single or multilayer optical coatings on any work the shop can produce.

The optics measurement capability includes mechanical and optical equipment to qualify materials and to verify final dimensions and figure, including wavefront error and spectral transmission. A machine shop supports both the optics fabrication tasks and the general work of the branch by constructing specialized, small work to a high order of precision. The precision optical fabrication facility includes a 2-meter single-point diamond turning machine which can also be used for experiments in ductile grinding.

Marshall's management of the Advanced X-Ray Astrophysics Facility, or AXAF, project has positioned it for its leadership role. AXAF is a NASA observatory for studying x-ray emission from all kinds of astronomical objects and phenomena ranging from stars and quasars to the distribution of "dark matter" in galaxies and galaxy clusters. The AXAF's two next-generation focal plane instruments, a high-resolution camera and a CCD imaging spectrometer, will each have two detectors. The first of these will image the x-rays that pass through the optics, and the second will image those that are dispersed by two objective transmission gratings that can be moved into position behind the mirror assembly. These instruments will provide better angular resolution by a factor of about ten, and greatly improve resolution.

In addition to these facilities, Marshall formed a joint laboratory with the Army Missile Command to marry disciplines for producing hybrid geometric-diffractive-integrated optics. In both stray-light testing and coherent LIDAR, Marshall has unique facilities. For x-ray telescope and instrument calibration, Marshall has both the world's largest and third largest test facilities.

Finally, in partnership with the University of Alabama at Huntsville, Marshall has demonstrated what it terms the most advanced techniques for the replication of x-ray mirrors in the country. A key Marshall team is concentrating on development of high-resolution replicated optics in lightweight materials. Its aim is to produce grazing-incidence optics using electroformed-nickel replication off an electroless-nickel-coated aluminum mandrel.

In a different sector of photonics technology, scientists at Marshall's Rapid Prototyping Center are using laser technology to build parts with photocurable resins. Working from CAD files, a machine creates parts by directing the laser to cure the resin, layer by layer. Next the prototype parts are post-cured in a UV oven. Although stereolithography has been used mainly to produce concept models, the process has also created parts that were later cast in Marshall's foundry, using various types of metals ranging from aluminum to superalloys.

Goddard Space Flight Center

A third major facility with comprehensive expertise in photonics is Goddard Space Flight Center in Greenbelt, MD. One key mission of Goddard is to expand knowledge of Earth and its environment through observations from space. This has led the Optics Branch to develop a wide range of sensing and data-gathering technologies. Goddard has made significant advances in acousto-optic spectral imaging: several miniature acousto-optic tunable filter, or AOTF, cameras have been built that produce side-by-side, orthogonally polarized spectral images with resolving powers approaching 1000. These cameras, using tellurium dioxide AOTFs, are capable of tuning from 400 nanometers through 5 microns with angular apertures up to 10 degrees. AOTFs can be fabricated from other materials that allow tuning in the UV down to 120 nanometers and in the infrared out to 11 microns.

Researchers in the Optics Branch are world leaders in developing, testing, and evaluating components for laser diode transmitter and miniature light detection and ranging, or LIDAR, systems for ground-based, airborne, and space-based systems. Among test equipment in the Laser and Electro-Optics Laboratory are a 400-to-1600-nanometer spectrum analyzer with one-tenth of a nanometer resolution, a 700-Megabit-per-second bit error rate test set, several interferometric optical spectrum analyzers including two with super-high finesse of 10,000, and Mach-Zehnder and shear-plate laser wavefront measuring interferometers.

The Optics Branch at Goddard offers extensive expertise in the field of ultraviolet mirror technology, including complete design and performance characterization of UV mirrors. The Diffraction Grating Evaluation Facility has the ability to measure imaging performance, scattered light, and spectral efficiency at the sub-arcsecond level over a spectral range of 30 to 1000 nanometers. It was used to evaluate 16 grating types that were incorporated into the Space Telescope Imaging Spectrograph installed in the Hubble Space Telescope this year. Instruments in the Surface Metrology Laboratory generate data from evaluations of commercial mirrors that are fed back to U.S. industry to help improve fabrication processes.

In the field of coatings, an extensive optical materials and process R&D program has resulted in the development of a low-temperature ion-beam process for producing high-quality silicon carbide and boron carbide coatings for mirrors and diffraction gratings. The significantly improved efficiency of these coatings represents the opportunity to exploit the extreme and far UV for industrial and research applications in such areas as semiconductor manufacture, biomedical research and medical instrumentation, microscopy, and spectroscopy.

Work done for the Hubble Space Telescope has been a particularly fertile source of outreach to American industry. Last year Goddard formed an industry team to transfer advanced precision optics developed for Hubble to the industry. The High Precision Optics Joint Sponsored Research Agreement brought together Goddard, Tinsley Laboratories of Richmond, CA, Silicon Valley Group Lithography Systems of Wilton, CT, and SEMATECH Inc., an industry-funded not-for-profit consortium headquartered in Austin, TX. The agreement, signed at the Technology 2006 conference, NASA's annual showcase of commercial technologies, in Anaheim late last year, calls upon Goddard to identify technologies to automate the manufacture of ultra-precision optics, particularly ultraviolet optics, and to transfer these technologies to the photolithography industry.

For the past two years technology developed for the Hubble's Space Telescope Imaging Spectrograph has been at the core of an advanced diagnostic breast biopsy procedure that has benefitted thousands. With Scientific Imaging Technologies (or SITe) of Beaverton, OR, Goddard led the development of a CCD that has greater sensitivity, lower noise, finer resolution, wider dynamic range, and greater contrast over a larger area than had been available before. SITe now sells these CCDs to LORAD of Danbury, CT, which uses them in an x-ray digital imaging device called Stereoguide. This system enables a nonsurgical, much less traumatic biopsy technique. Performed with a needle instead of a scalpel, it leaves just a small puncture rather than a large scar and is done as an office procedure under a local rather than a general anesthetic.

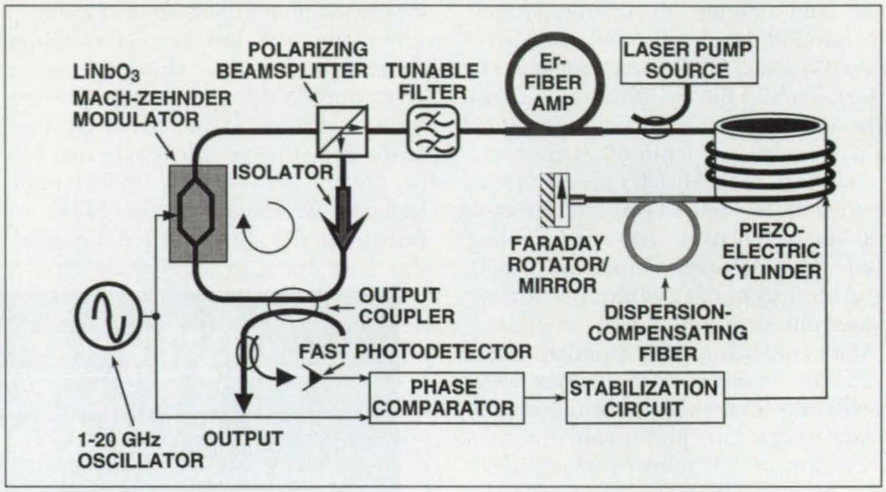
To be continued

A High-Repetition-Rate Optical Communications Source

A picosecond pulsed Er-fiber laser for communications, research, and industrial applications demonstrates error-free operation.

Naval Research Laboratory, Washington, DC

High-speed communications, medical applications, and semiconductor processing would all benefit from a laser that can produce stable, high-repetition-rate pulses at 1.55 micrometers. One goal of the Naval Research Laboratory's program in ultrahigh-speed communications research is to develop such an optical source, and an all-fiber laser has been developed that produces pulses from 0.74 to 2 picoseconds in duration at gigahertz repetition rates.



A schematic diagram of the **Er-fiber Laser for Communications.**

The laser is in effect a polarization-maintaining (PM) ring laser harmonically modelocked by a $LiNbO_3$ modulator, and up to 10,000 pulses circulate in its 200-m-long fiber cavity. The advantage of using PM fiber in the laser is that the instabilities caused by random birefringence variations of non-PM fiber are avoided. The laser also includes a tunable wavelength filter that can control the operating wavelength over its tuning range of approximately 1535-1570 nm.

The laser's pulse duration is determined by the standard Kuizenga-Siegman modelocking equation, which predicts a 5-picosecond duration for a 10-GHz drive frequency. However, if briefer pulses are desired, the laser can operate in a regime in which solitons propagate in the fiber and become compressed in duration. The laser has produced pulses as brief as 740 femtoseconds at a 10-GHz repetition rate in this mode of operation.

Part of the cavity modification that is necessary to produce soliton pulse shaping is to reduce the overall chromatic dispersion in the laser cavity. This is accomplished by adding dispersion-compensating fiber (DCF) to the laser. DCF is not available as PM fiber, and to retain the stable operation of a PM ring laser it is necessary to devise a polarization-maintaining configuration that can incorporate this fiber. By using a fiber-integrated polarizing beamsplitter, Faraday rotator, and mirror, it is possible to construct a birefringence-compensating section of fiber that incorporates non-PM fiber but avoids its instabilities. It is in this section that the DCF is placed. In fact, the arrangement works so well that a standard Er-doped fiber amplifier is also placed in this section of the laser, rather than using a rarer (and more expensive) PM Er-fiber amplifier.

Since the laser is actively modulated, it can be synchronized to repetition rates demanded by other factors in the system. The drive frequency must be an exact multiple of the fundamental cavity mode spacing (f_0=c/nL) where c is the speed of light, L is the length of the cavity, and n is the refractive index of the fiber. A simple feedback circuit has been constructed to adjust the length of the cavity by controlling the DC voltage to a piezoelectric cylinder around which is wound a length of fiber. The circuit uses variations in the relative timing of the pulse generated by the laser as an input error signal.

A critical requirement for the laser in communications applications is that it produce an uninterrupted stream of pulses; dropouts in the pulse stream would introduce errors in transmitted data. The laser has a demonstrated dropout rate of less than one in every 10^{15} pulses. The laser also demonstrates excellent pulse timing and amplitude stability.

The laser has been demonstrated to run for weeks without adjustment, and it is in routine use for experiments in 100-Gb/s communications. The laser could also be frequency-doubled to produce pulses in the range of 775 nm, which could be useful for semiconductor processing or medical applications.

This work was done by Irl Duling, Tom Carruthers, and Michael Dennis of the **Naval Research Laboratory**. *For further information, contact Irl Duling, NRL, Optical Sciences Division, Code 5670, Washington, DC 20375; (202) 767-9351; fax (202) 404-1576. Inquiries concerning rights for the commercial use of this invention should be directed to Dr. Richard Rein, Office of Technology Transfer, Code 1004, NRL, Washington, DC 20375; (202) 767-7230; fax (202) 404-7920.*

Program for Analysis of a Complex Optomechanical System

NASA's Jet Propulsion Laboratory, Pasadena, California

The IMOS computer program contains subprograms that, collectively, provide a unique capability for multidisciplinary analysis of a system represented by a combination of mathematical models of structural (mechanical), control, thermal, and optical characteristics. One example of such a system would be a telescope equipped with an attitude-control subsystem. IMOS enables a user to (1) define the geometry of the system, (2) build a finite-element mathematical model of the system structure, (3) define the system optics in the coordinate system of the finite-element model, (4) add control elements to the model, (5) add mechanical and thermal disturbances to the model, and (6) evaluate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the open- and closed-loop performances of the system. IMOS also includes graphical subprograms that enable viewing of structural-assembly operations, structural deformations, and layouts of optical elements. IMOS is written in MATLAB and can be used on any computer that supports MATLAB. The core subprograms are easily coupled in MATLAB, and the user can write additional MATLAB function subprograms. The additional capabilities afforded by the MATLAB control-design, signal-processing, and optimization "toolboxes" enhance the versatility of IMOS. Also included in IMOS are interface subprograms for optical analysis by the MACOS program, thermal analysis by the TRASYS and SINDA programs, and finite-element modeling by the NASTRAN program.

This program was written by Hugh C. Briggs, Daniel Edred, Robert Norton, Andy Kissil, William Ledeboer, Samuel Sirlin, Marie Levine, Jim Melody, Mark Milman, and Laura Needels 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 Computer Programs category,* ***or circle no. 171*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20238

General-Purpose Optically Powered Sensor and Control System

Both power and data are transmitted via optical fibers.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure schematically illustrates a prototype general-purpose, microprocessor-based sensor and control system in which power, data, and control signals are transmitted via optical fibers. This system serves as an experimental model for the further development of networks of remote sensors connected to monitoring and controlling base stations via optical fibers.

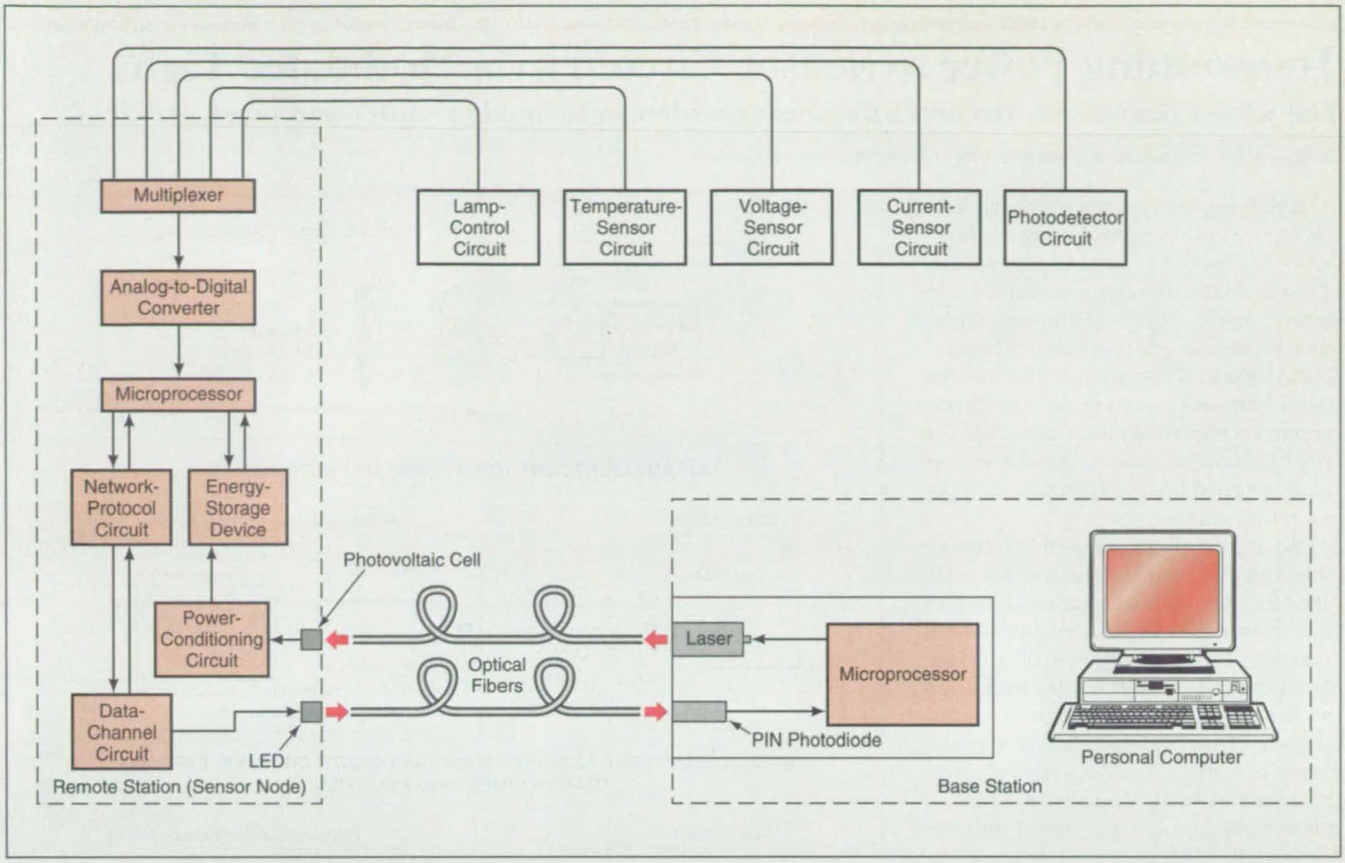
In one important class of potential applications, networks of the type envisioned would be embedded in structures to monitor strains and vibrations. Another important class of potential applications would take advantage of the electrical isolation afforded by optical fibers; networks of sensors could be deployed to monitor voltages and currents and/or to command the operation of switches at critical locations along high-voltage power lines. Some aspects of systems that might eventually be developed were discussed in "Fiber-Optic Distribution of Pulsed Power to Multiple Sensors" (NPO-19420), *NASA Tech Briefs*, Vol. 20, No. 5 (May 1996), page 18a, and "Data Protocol for Optically Powered Sensors" (NPO-19421), *NASA Tech Briefs*, Vol. 21, No. 6 (June 1997), page 6a.

In the present system, power for the remote station (sensor node) is supplied by a small laser of the type used in compact-disc players. The laser light is transmitted via an optical fiber to the remote station, where a photovoltaic cell converts the light to electric power. By modulating the laser light, the base station can transmit commands to the remote station; this amounts to an optical analogue of the established power-line-carrier technique, in which an electric power line is used to carry small ancillary control or data signals superimposed on the main power signal.

At the remote station, the outputs of sensors are multiplexed, digitized, and preprocessed, and the resulting data are converted to pulses of current supplied to a light-emitting diode (LED). The resulting pulses of light from the LED are transmitted along a second optical fiber to the base station, where a PIN (positive/intrinsic/negative) photodiode converts the light pulses to electrical data pulses. The returned sensor data are sent to a personal computer for further processing and display.

The operations of the base and remote stations are controlled by microprocessors. The microprocessor in the remote station is of a low-power type and is programmed with software that puts the remote-station circuitry into a low-power "sleep mode" most of the time to conserve energy. When needed, this circuitry can be "awakened" by transmitting a command via the power-supply optical fiber.

This work was done by Harold Kirkham, Larry A. Bergman, Shannon P. Jackson, Alan R. Johnston, and Duncan Liu 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 Systems category,* ***or circle no. 172*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19604



The **Prototype Optically Powered Sensor and Control System** has been used to measure a voltage, a current, and a temperature; to turn a lamp on and off; and to verify that the light is on or off.

Transmitting Power to Sensor Circuitry via Modulated Light

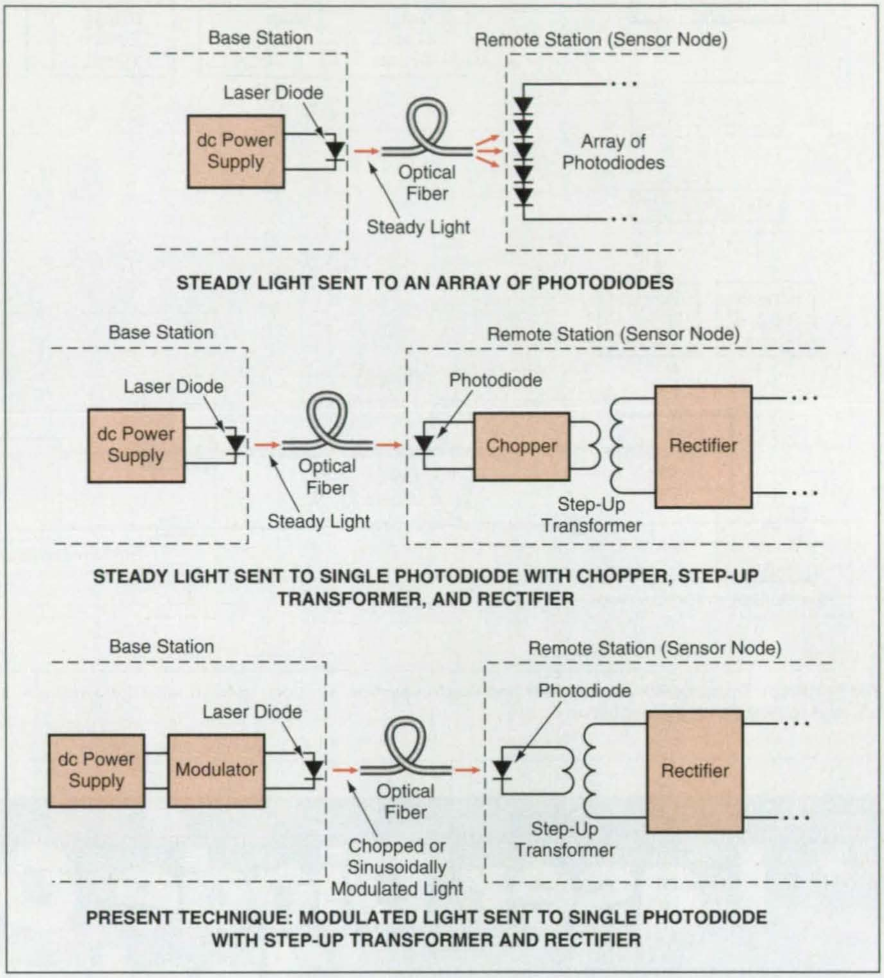
The power-conversion circuit in the sensor node can be made simpler and more efficient.

NASA's Jet Propulsion Laboratory, Pasadena, California

Modulated (as opposed to steady) light can be used in the optical transmission of power to remotely located sensor circuitry in a system like that described in the preceding article, "General-Purpose Optically Powered Sensor and Control System" (NPO-19604). This is analogous to the use of alternating (as opposed to direct) current on electrical power lines, and the benefit is similar; namely, that the voltage can be stepped up to a desired level by use of a transformer.

The figure illustrates two alternative techniques as well as the present technique for fiber-optic transmission of power from a base station to a remote station (sensor node) and conversion of optical to electrical power at the remote station. In the first technique, steady light is sent to an array of photodiodes, which are connected in series to build up the voltage to the required level. The disadvantage of this technique is that an array of photodiodes can be expensive, and there can be significant losses in the coupling of light from the optical fiber to the array, depending on the shape of the array.

In the second technique, steady light is sent to a single photodiode, and the output steady voltage of the photodiode is increased to the required higher level by a chopper, a step-up transformer, and a rectifier. The disadvantage of this technique is that the chopper consumes a substantial part of the power, thereby reducing the overall power-conversion efficiency of the remote station.



The **Optical-to-Electrical Power-Conversion Circuit** in the remote station can be simplified and made more efficient when modulated light is used, because there is no need for a power-hungry chopper.

In the present technique, the optical power is modulated at the source in the base station, where efficiency is somewhat less of a consideration because power is more abundant there. Preferably, the light is either modulated with a sine wave or is chopped into square pulses ("on" during the first half cycle, "off" during the second half cycle). The modulated light illuminates a single photodiode, the output of which is now modulated. The modulated output of the photodiode is fed directly to a step-up transformer; because of the modulation, there is no need to process it through a chopper. Therefore, the chopper is eliminated and the power-conversion efficiency correspondingly increased. In practice, the conversion efficiency will not be high unless care is taken in the design of the step-up transformer and the rectifier circuit. Techniques to recover the magnetic energy in the transformer that are similar to those used in chopper circuits should be used.

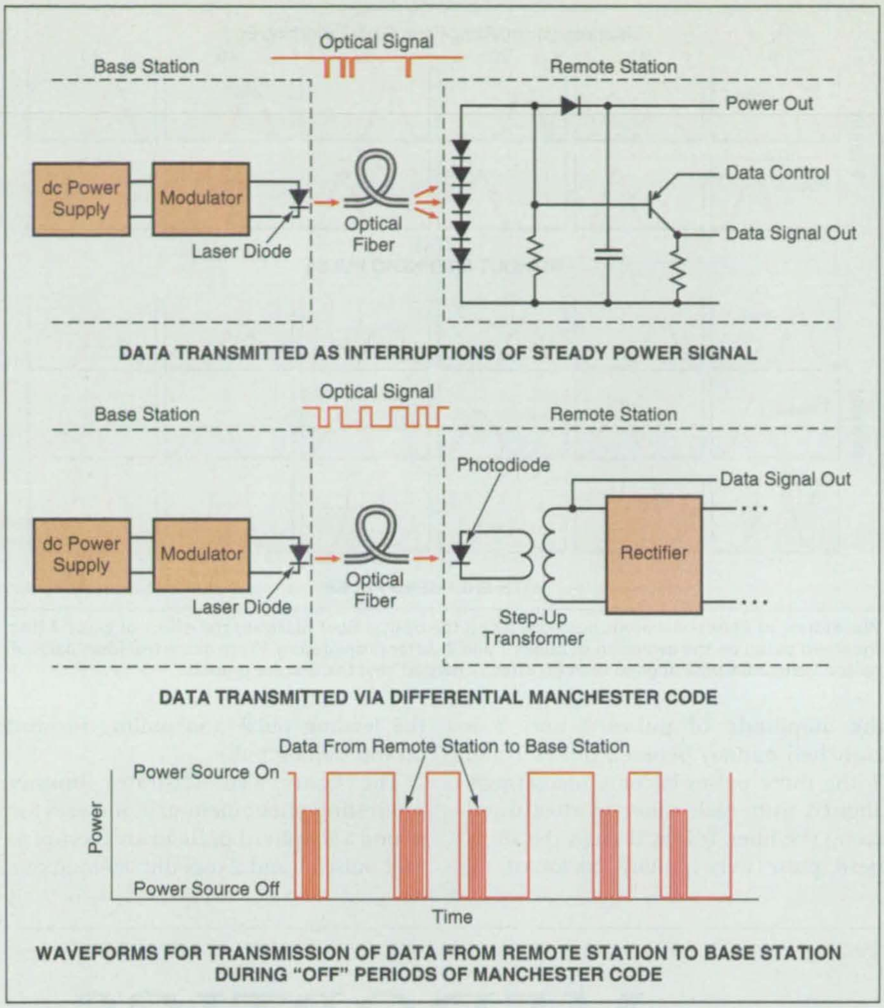
This work was done by Shannon P. Jackson, Harold Kirkham, and Colonel McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category,* ***or circle no. 173*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19603

Transmitting Data Signals via Fiber-Optic Power Lines

Optical power carrier signals are modulated with data signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

Data signals can be transmitted via the same optical fibers that are used to transmit power from base stations to remote stations containing sensors and associated circuitry. [A prototype system based on fiber-optic transmission of data and power is described in "General-Purpose Optically Powered Sensor and Control System" (NPO-19604), which is the first of two articles preceding this one.] The implementation of the present data-transmission/power-transmission concept involves the choice of one of several possible modulation schemes (see figure); the choice of a scheme for a specific system depends, in



Optical Data Pulses Can Be Transmitted from the base station to the remote station as interruptions of an otherwise steady optical power-supply signal. Higher-frequency data pulses can be transmitted back to the base station during the "off" periods of the Manchester code.

part, on whether the power-supply optical signal is steady or is modulated as described in the immediately preceding article, "Transmitting Power to Sensor Circuitry via Modulated Light" (NPO-19603).

In the case of a nominally steady power-supply optical signal, the data modulation can consist of brief interruptions of this signal; the modulation can be picked off by a simple amplifier circuit added to the power-conversion circuit in the remote station. In an experiment, data were transmitted at rates as high as 9.6 kb/s. The power-conversion circuit can be designed with sufficient reserve capacity and with a capacitor, or other energy-storage device to supply power to the other circuits in the remote station during the interruptions.

If the power-supply optical signal is nominally a steady pulse train in which the light is on half the time and off half the time, then the pulse train can be modified for transmission of data by the differential Manchester code. In the absence of data, the pulse train continues undisturbed; when data are present, some of the "on" pulses are changed to "off" pulses, and an equal number of "off" pulses are changed to "on" pulses. Because the total numbers of "on" and "off" pulses remain the same, the time-averaged transmitted power does not change.

In principle, it should also be possible to transmit data from the remote station back to the base station along the power-supply optical fiber. A microprocessor-controlled data-transmission optoelectronic circuit in the remote station would be synchronized with the Manchester-code pulses; during the "off" periods of the Manchester code, this circuit would transmit trains of relatively high-frequency data pulses.

This work was done by Shannon P. Jackson and Harold Kirkham 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 Systems category, or* ***circle no. 174*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19605

Pulse Shepherding in Nonlinear Fiber Optics

Copropagating pulses at different wavelengths can be maintained in alignment.

NASA's Jet Propulsion Laboratory, Pasadena, California

Pulse shepherding is a nonlinear signal-propagation phenomenon that can occur when several pulses of light at different wavelengths are launched simultaneously or nearly simultaneously along the same single-mode optical fiber under suitable conditions. As its name suggests, pulse shepherding involves the use of one pulse (denoted the shepherd pulse) to "herd" together a number of other pulses that propagate along with it.

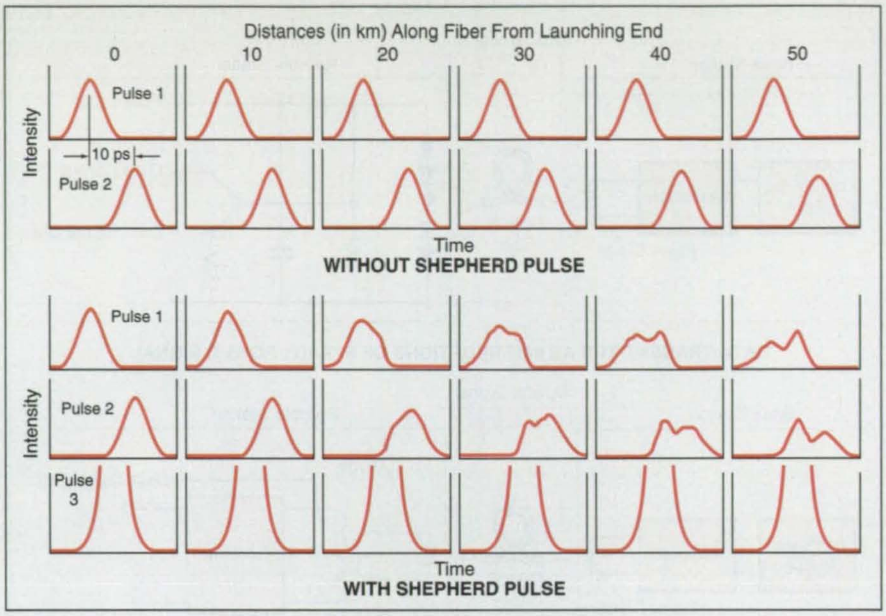
Pulse shepherding could likely be exploited to ensure the simultaneity of arrival of pulses at different wavelengths that represent parallel bits of data in a wavelength-division-multiplexing digital communication system — in other words, to "herd" together the bit pulses of each byte. Without pulse shepherding, wavelength dispersion in the fiber material causes pulses traveling at different wavelengths to arrive at somewhat different times; in a high-speed digital system with a long optical fiber, differences between times of arrival can become excessive relative to the byte period.

Discovered through theoretical analysis and computer simulation, pulse shepherding involves cross phase modulation, which is an unavoidable interaction between copropagating pulses that arises from nonlinearity in the response of the fiber-optic material. In cross phase modulation, copropagating pulses affect each other through the intensity dependence of the index of refraction. Cross phase modulation does not cause exchange of energy among the pulses, but it does affect the shapes and relative locations of the pulses. In designing for pulse shepherding, one designs the optical fiber to eliminate group-velocity mismatches among the wavelength channels and selects the timing, amplitudes, and shapes of the pulses in the various wavelength channels to exploit cross modulation to bring and keep the pulses together as they propagate.

In the theoretical analysis, the copropagation of M pulses is modeled by M simultaneous, coupled, nonlinear equations. The solution is generated numerically by the split-step Fourier method, which involves a forward-stepping process in which the solution is first advanced using only the nonlinear parts of the equations, then advanced using only the linear parts of the equations. The Fourier transform in this method is generated by the fast-Fourier-transform technique.

The figure illustrates the results of these computations for an example of two Gaussian-shaped pulses of 10-ps duration, propagating both without and with a third (shepherd) pulse along a suitably designed optical fiber 50 km long. In this example, pulse 1 at a wavelength of 1.550 μm is launched at one pulse duration before pulse 2 at a wavelength of 1.546 μm. In the absence of a shepherd pulse, the pulses 1 and 2 remain separated throughout their travel. When pulse 3 (the shepherd pulse) at a wavelength of 1.542 μm and at twice the amplitude of pulses 1 and 2 is launched midway between pulses 1 and 2, the three pulses become increasingly aligned with each other as they travel along the fiber. It is as though the shepherd pulse were pulling backward on the leading pulse and pulling forward on the trailing pulse.

The figure also illustrates another interesting phenomenon: if one uses too strong a shepherd pulse in an attempt to pull pulses 1 and 2 together sooner, one



Waveforms of Pulses at various positions along the optical fiber illustrate the effect of pulse 3 (the shepherd pulse) on the evolution of pulses 1 and 2. After propagating 50 km along the fiber, parts of pulses 1 and 2 become aligned with (in effect, "herded" by) the shepherd pulse.

may not succeed. Instead, pulses 1 and 2 could be broken up, with one part of each pulse becoming shepherded and the remainder continuing to propagate by itself.

This work was done by Larry Bergman and Cavour Yeh 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 Circuits category,* ***or circle no. 175*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-19987, volume and number of this NASA Tech Briefs *issue, and the page number.*

Measuring Flow Using Spectrally Resolved Rayleigh Scattering

Instantaneous flow can be measured simultaneously at multiple locations in a supersonic wind tunnel.

Lewis Research Center, Cleveland, Ohio

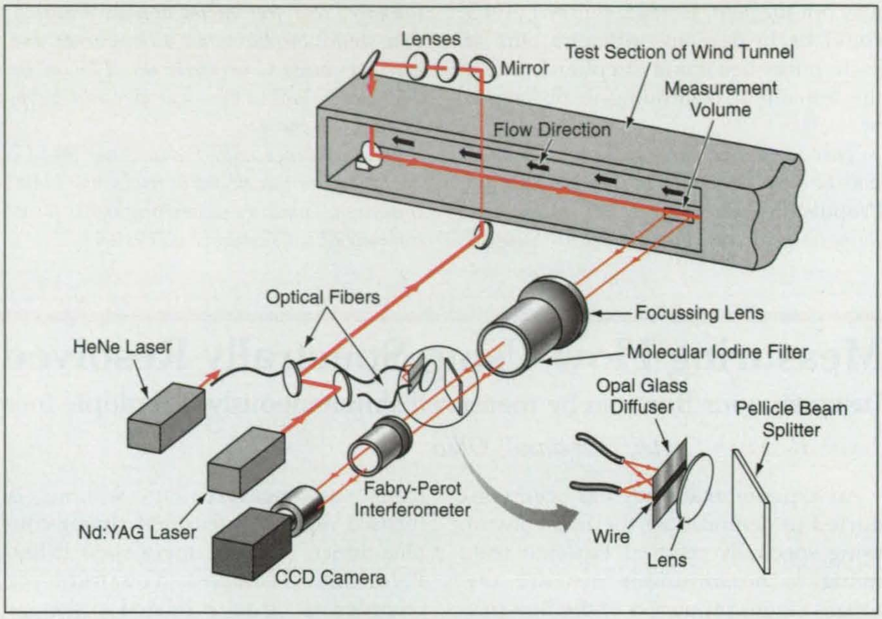
An experimental study has been conducted to demonstrate the feasibility of using spectrally resolved Rayleigh scattering to nonintrusively measure the instantaneous properties of the flow in a small supersonic wind tunnel. Unlike conventional probe flow measurements, Rayleigh scattering of a laser beam does not perturb the flow. Because the Rayleigh scattering uses the actual gas molecules that make up the flow under study, it is not necessary to seed the flow. Another important advantage of this technique is that properties of the flow can be determined simultaneously at multiple locations along the laser beam; moreover, if the laser beam is pulsed, then these flow properties can be obtained at multiple locations with a single laser pulse.

The principle of operation can be explained with the optical setup used in the feasibility study, as illustrated schematically in the figure. The main light beam for measuring the flow is generated by a pulsed, injection-seeded, frequency-doubled Nd:YAG laser, which is tuned to an absorption spectral band of iodine for the purpose of subsequent filtering, as explained below. By use of a series of lenses and mirrors, the beam is focused to a line, introduced into the wind tunnel, and directed upstream along the test section of the wind tunnel. As described thus far, this arrangement provides for Rayleigh scattering measurements from a number of regions along the illuminated downstream-to-upstream line. If the laser were sufficiently powerful, the beam-forming optics could be set to expand the laser beam to a sheet in the test section, making it possible to measure Rayleigh scattering in hundreds of regions within the test section.

The Rayleigh-scattering spectrum is directly related to the velocity distribution of the illuminated molecules; it contains information about the temperature, bulk velocity, and density of the fluid in the measurement volume. Light from the measurement volume is focused into an intensified charge-coupled-device (CCD) camera via a Fabry-Perot interferometer. The width of recorded spectrum is related to the gas temperature, the shift of the spectral peak is proportional to one component of the bulk velocity, and the total intensity is proportional to the gas density. However, the recorded image also includes unwanted light that is not the result of Rayleigh scattering, but is caused by spurious laser scattering from windows and internal wind-tunnel surfaces. This unwanted laser light is at the laser frequency. Because the Fabry-Perot is not selective enough to eliminate this non-Rayleigh scattered light, an iodine absorption cell is placed in front of the Fabry-Perot to block light at the laser frequency.

Success in the use of the iodine absorption cell depends on knowledge of the Nd:YAG-laser frequency for each measurement. In this setup, part of the CCD is used to record simultaneously the Fabry-Perot interference-fringe patterns of (1) the unshifted light from the Nd:YAG laser, (2) light from a frequency-stabilized HeNe laser, and (3) light collected from the tunnel and filtered through the iodine cell. The frequency of the light from the Nd:YAG laser can be determined by analysis of the fringe patterns.

The apparatus performed well in the feasibility experiments. One disadvantage of this technique is the need for postprocessing of data to perform the fringe-pattern analysis to determine the frequency of the Nd:YAG laser; an on-line laser-frequency readout subsystem would be desirable in future implementations. A problem in this particular experiment was the relatively low mach number (about 2.0), which necessitated the assumption of adiabatic flow to avoid indeterminacy between velocity and temperature in the data-reduction process; however, at higher mach numbers, such indeterminacy would not occur, and therefore velocity and temperature could be determined independently of each other. The feasibility study also revealed the desirability of several improvements, including frequency stabilization of the Nd:YAG laser, vibration isolation of the Fabry-Perot interferometer, automatic (instead of time-consuming manual) alignment of the Fabry-Perot, and on-line data reduction.



The **CCD Camera Is Aimed at the Measurement Volume** through a Fabry-Perot interferometer and an iodine absorption cell to obtain an image of the measurement volume in Rayleigh-scattered light. The measurement volume can be any convenient region along the laser beam in the test section of the wind tunnel.

This work was done by Richard G. Seasholtz and Alvin E. Buggele, of **Lewis Research Center** *and Mark F. Reeder, a National Research Council Associate. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 176*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16425.

Thermal Lens Spectrometer Yields High Sensitivity

An optical parametric oscillator provides a wide spectral tuning range.

Cornell University, Ithaca, New York

Thermal lens spectrometry is a highly sensitive method for detecting very small quantities of material by the absorption of light from a laser source. It takes advantage of the thermal lens effect to measure the absorption spectrum of a sample. This invention utilizes an optical parametric oscillator (OPO) to obtain a continuously tunable laser source over a wide spectral range. A pump beam from the OPO and a probe beam from a laser are directed coaxially through a flow cell containing a sample. Sensors measure the intensity of the light from the probe beam after it has passed through the sample, while the OPO is tuned through a range of frequencies. Changes in the probe beam intensity measurement result from the wavelength-dependent heating of the sample by absorption of the pump beam. A plot of these intensity changes therefore provides a characteristic signature of the substance in the flow cell.

For many spectroscopic and spectrometric applications, such as nonlinear, photothermal, and fluorescence spectrometry, widely and continuously tunable laser sources are required. Until recently dye lasers generally have been used for tunable laser spectroscopy. However, the tuning range of dye lasers tends to be severely limited: each dye can cover only a few hundred angstroms, and the total range is limited to approximately 400 nm to 1 micrometer. In contrast, a spectrometer using a single OPO system could have a tuning range of 200 to 2500 nm.

The thermal lens system is extremely sensitive. In comparison to conventional absorption spectrometry, for example, it is almost 1000 times more sensitive for probing NO_2 diluted in air. Because of this sensitivity, only a small sample volume is needed and excellent spatial resolution can be obtained. As a demonstration experiment, the system was used successfully in measuring the entire visible thermal lens spectrum of NO_2 in a single scan with adequate resolution to resolve the important peaks. As long as a line of sight to the sample is maintained, the spectrometer is capable of operating at a distance.

The compact OPO system provides high output power and efficiency as compared to conventional sources, making highly sensitive measurements possible. The OPO system is completely solid-state, except for the pump laser, and consists of commercially available components. It is therefore a cost-effective alternative to conventional systems. Because of the compactness of the design and the simplicity of operation, it could be operated as a remote sensor. It would be possible, for example, to design a mobile system that could monitor smokestack emissions by aiming the beams from the spectrometer at retroreflectors mounted at the smokestack tops. Similarly, auto emissions could be monitored by spectrometers mounted at highway toll booths.

An experimental system using a beta barium borate OPO invented at Cornell and exclusively licensed to Spectra-Physics Lasers, Inc., Mountain View, CA, was built and tested. Data on the detection of NO_2 was collected and is available. The OPO is commercially available, and Spectra-Physics has expressed willingness to cooperate in the commercialization of this invention.

This work was done by C. L. Tang, S. Kawasaki, and R. Lane at **Cornell University**. *For more information call Robert F. Schleelein, Technology Marketing and Licensing Specialist, Cornell Research Foundation Inc., 20 Thornwood Drive, Suite 105, Ithaca, NY 14850; (607) 257-1081; fax (607) 257-1015; E-mail: rfs@cornell.edu; http://www.research.cornell.edu/crf.*

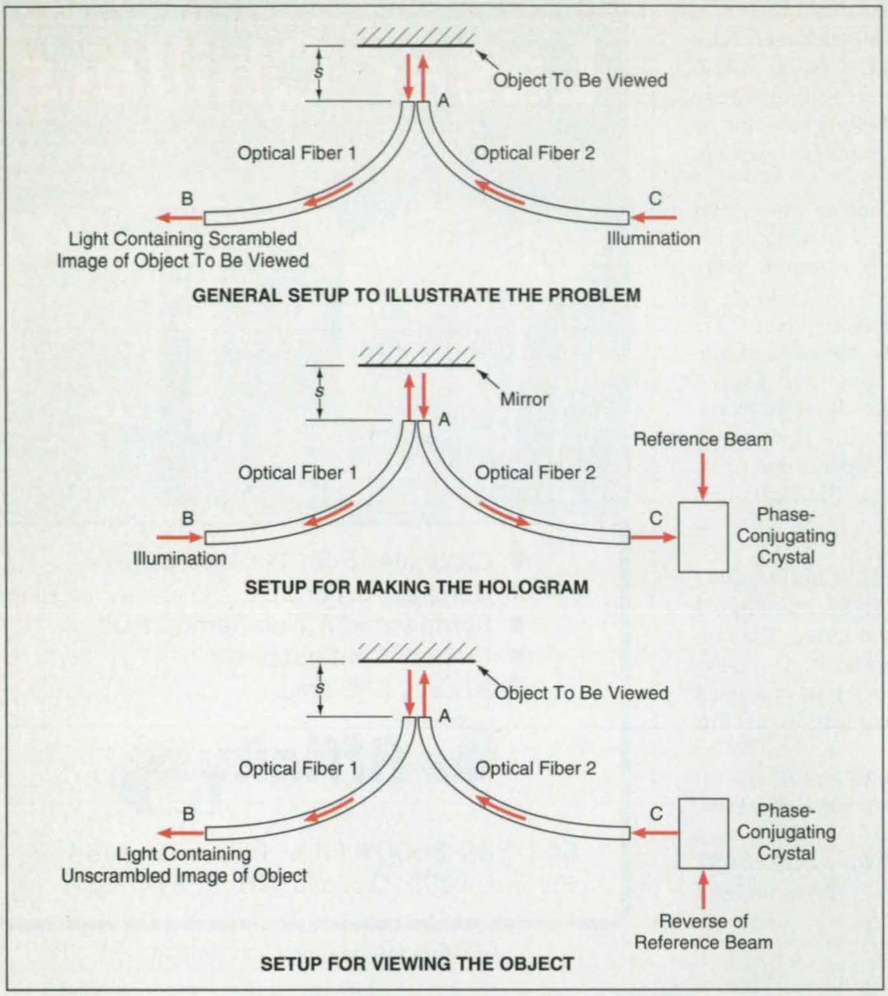
Multimode Optical Fiber as Imaging Probe

Phase conjugation in a hologram would provide compensatory prescrambling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed electro-optical image-processing system would enable remote viewing of an object through a multimode optical fiber, as though the fiber were a conventional image-transmitting optic like a lens or prism. Ordinarily, it would be impractical to use a multimode optical fiber as an imaging probe or imaging optic because image information would become distorted (scrambled) during propagation along the fiber. The proposed system would provide compensation for this scrambling. Fiber-optic imaging probes of this type could be made very thin and could be particularly useful as minimally invasive probes in medical diagnosis.

The system (see figure) would include two multimode optical fibers, which would be terminated side by side at one end (point A) facing the object that one seeks to view. The tips of the fibers would lie at a short distance, *s*, from the object. A source of light at point C would illuminate the object via fiber 2. An observer at point B would attempt to view the illuminated object through fiber 1. The problem is to predistort the illumination (prescramble the amplitudes and phases of the fiber-optic waveguide modes of the illuminating electromagnetic field) in such a way as to compensate for the scrambling that occurs during transmission of the image along fiber 1 from point A to point B, so that the image of the object would arrive



An **Unscrambled Image of the Object** could be generated at point B by exploiting phase conjugation at point C to reverse the scrambling that occurs during propagation along the optical fibers.

unscrambled at point B.

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

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

This work was done by Deborah Jackson of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 177*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19671

Multicolor Transceiver for Optoelectronic Communication

Potential uses range from multiple or two-way fiber optic transmission and optically multiplexed electronic circuits to optical computing.

National Renewable Energy Laboratory (NREL), Golden, Colorado

A great increase in the effectiveness of fiber optic systems is possible with a device that allows for simultaneous two-way signalling of multiple data streams on a single optical fiber. By using a highly efficient multijunction solar cell to emit as well as detect two or more distinct wavelengths within a broad band of near-infrared (0.93-1.65-micron) light, this new technology provides such a capability and many others.

NREL scientists have developed a single-crystal multicolor light emission and detection device that is capable of simultaneously transmitting and receiving multiple optical signals. The underlying technology for this optical transceiver capability is a lattice-matched monolithic device with multiple layers of thin-film P-N junction InP/GaInAs varied in composition so that each layer has a different bandgap and therefore a different wavelength. With two layers, a pair of tandem devices can each simultaneously transmit and receive. With a multiple cascade of decreasing bandgap layers, numerous separate data streams can be transmitted by a single device on a single fiber or other optical medium. The technology could be used for optically coupled circuits within microelectronic systems, for long-distance optical fiber communication systems, or for any optical communication use. The ability to transmit and receive multiple independent signals should greatly increase data transmission rates and simplify optical interconnections and networks compared to current optical transceivers. This should allow significantly improved performance or cost and space savings for a wide variety of equipment.

NREL's multicolor transceiver uses materials and epitaxial fabrication methods widely employed in the manu-

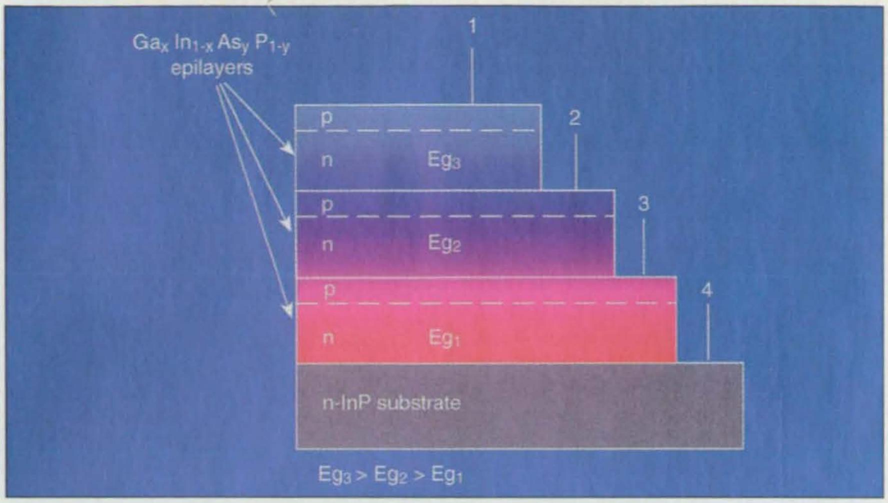
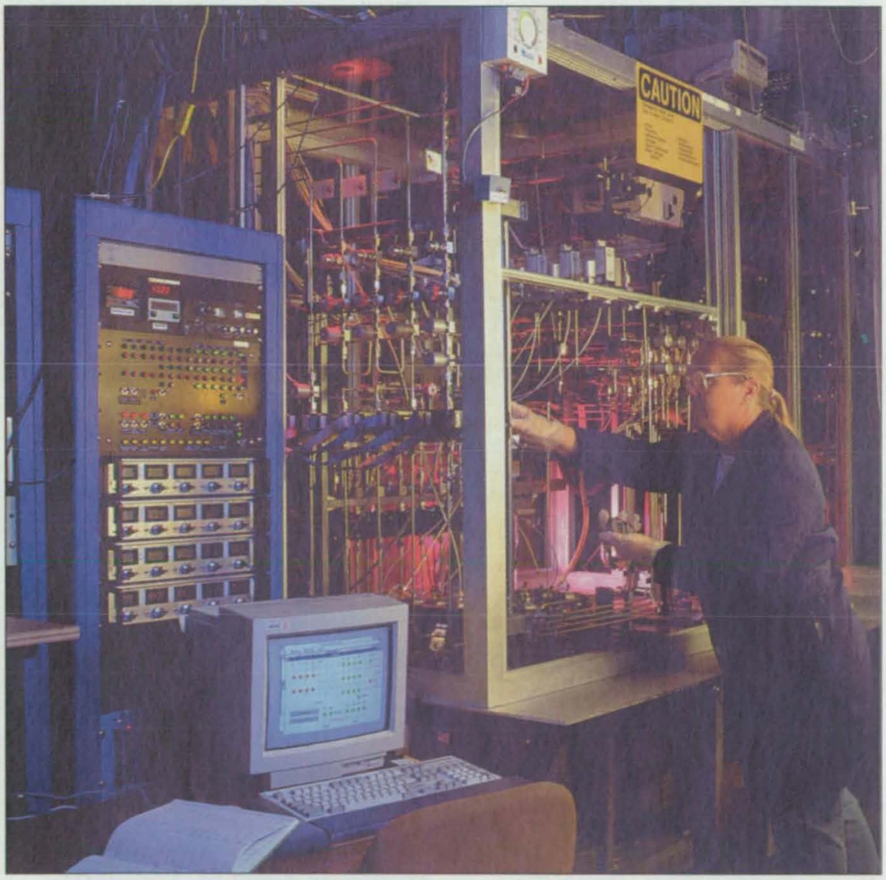


Diagram of the **Multicolor Transceiver.** E_g stands for bandgap energy. The top layer might be straight indium phosphide with a relatively high bandgap of 1.35 eV (0.93-micron wavelength). Light of that frequency is detected by that layer; lower-energy light passes through that layer to be detected by lower layers. The bottom layer might be straight gallium indium arsenide with a relatively low bandgap of 0.75 eV (1.65-micron wavelength). Intermediate layers would have varying percentages of phosphide and gallium arsenide to detect intermediate bandgap/wavelength light.



The **Multicolor Optical Transceiver** can be fabricated with currently available manufacturing equipment such as this metallorganic chemical vapor deposition reactor.

facture of near-infrared lasers, so it should be easy to produce. It should also substitute directly for less effective monochromatic devices currently in use. With more than nine years of experience in developing InP/GaInAs tandem solar cells, NREL has the expertise to facilitate setup of effective manufacturing processes and is seeking industry partners to develop valuable uses of the technology. The principal patent number is 5,391,896.

The lead researcher for development of the multicolor transceiver is Mark Wanlass of the **National Renewable Energy Laboratory**. *Inquiries concerning the patent status and availability of rights and licenses should be directed to NREL's Business Ventures Center; (303) 275-3009; E-mail: technology_transfer@nrel.gov.*

NEW PRODUCTS

PRODUCT OF THE MONTH

Digital Laser Marking System Kit

Synrad, Mukilteo, WA, introduces what it calls the first laser marking system kit based on all-digital technology. The company says that anyone can purchase the partially assembled, self-contained kit of components, perform some minor integration, and have a system operating on a marking production line in just a few hours. At the heart of the system is the Synrad DH Series sealed RF-excited carbon dioxide laser marking head, based on digital and fiber optic technology and capable of 125 W output. Synrad says that its high noise immunity makes possible accurate and crisp marking on a variety of materials. Designed for industrial use, the laser can be expected to perform at specification for 35,000 continuous hours, the company says. Because it is sealed, there are no consumable parts and no maintenance is required. When gas runs out, it can be sent to the manufacturer for a refill. Offering a comprehensive choice of focal lengths, the DH Series' beam delivery system utilizes the light, strong beryllium. With the laser vertically mounted, the factory footprint of the DH Series head is just one square foot.

For More Information Circle No. 793

Fiber Optic Spectroradiometers

Ocean Optics, Dunedin, FL, makes available two PC-interface systems that turn the company's high-sensitivity S2000 miniature fiber optic spectrometers into spectroradiometers for the measurement of absolute spectral intensities. The IRRAD2000 is a desktop-PC interface system, the IRRAD2000-PORT a notebook-PC interface system. Both are based on a radiometrically calibrated S2000 spectrometer, preset to a 350-950-nm wavelength range, and configured with a 50-micron entrance slit for performance with resolution of 3 nm FWHM. Both can measure spectral irradiance, radiance, and photopic quantities.

For More Information Circle No. 794

Spill-Proof Honeycomb Optical Top

Technical Manufacturing Corp., Peabody, MA, announces that it is making its CleanTop® II (patent pending) optical tabletop design a standard feature of all its tables. The design involves epoxy-bonding individual non-load-bearing cups under each tapped hole before bonding. Cups are made from chemically resistant nylon-6; a stainless steel (316 alloy) cup is also available. Holes can be tapped and countersunk before adding the cups, allowing the machined top plate to be thoroughly cleaned with open rather than blind holes prior to bonding. CleanTop II insures that liquid spills on the surface are contained and cannot reach the core of the top.

For More Information Circle No. 795

Inexpensive Mirror Mounts

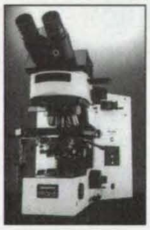
New Focus, Santa Clara, CA, is offering its new general-purpose mirror mounts costing $54, which it says outperform other similarly priced mounts. The mounts have the same high-quality proprietary screws and brass nuts found in the company's standard mounts. New Focus says a high level of stability is attained with a half-inch frame, thicker than any comparable mount. The devices are completely compatible with all standard mounting hardware, and are designed, the company says, for beam steering and pointing applications where cost matters.

For More Information Circle No. 796

Pulsed Laser Mirror Scanner

The new LMS-Q140 laser mirror scanner from Riegl USA, Orlando, FL, is based on the principle of time-of-flight measurement of short IR laser pulses. The company says it provides more accurate measurement to most targets with more measurement points than existing ultrasonic or optical measurement sensors. Range varies as a function of target reflectivity and the atmosphere's particulate density; generally maximum range to an 80-percent reflective target is up to 660 ft. Minimum range is typically 6 ft. Typical absolute measurement accuracy of the sensor is ±0.2 in. (±0.5 cm) and resolution 0.4 in. (1 cm). The measurement rate is 12,000 Hz.

For More Information Circle No. 797



Modular Design for Research Microscope

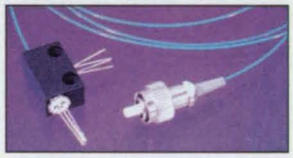
The modular design of the PROVIS (PROfessional VISion) AX70 universal research microscope from Olympus America's Precision Instrument Division, Melville, NY, permits a choice of configurations and varying degrees of automation. Standard transmitted-light illumination is 12V/100W halogen source. The microscope stand allows easy access to the optical path for the attachment of application-specific illumination such as from lasers. The PROVIS AX70 can mount both a video camera and the Olympus PM30 photo system simultaneously, providing precise exposure in all microscopy modes, especially in fluorescence.

For More Information Circle No. 798

High-Resolution Wavelength Meter

The M5300 high-resolution wavelength meter from EXFO Electro-Optics, Vanier, Quebec, Canada, can measure any continuous-wave laser in the 600-nm to 1800-nm wavelength range with an accuracy of ±1 part in ten million. A well-characterized HeNe laser is used as an internal reference. The unit offers a display resolution of 0.0001 nm. Standard GPIB and RS-232 interfaces are available. The M5300 provides an internal attenuator that can be set manually or automatically, the latter useful when scanning a tunable source through its wavelength range. The unit has two laser inputs: a fiber optic assembly can connect to the FC connector on the front panel, or a free-space laser can be directed through a 2-mm aperture on the system's side.

For More Information Circle No. 799



Bidirectional Single-Fiber Modules

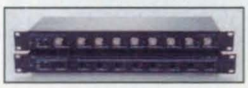
AMP Inc., Harrisburg, PA, announces a new bidirectional single-fiber transceiver for full-duplex communication in both intermediate and long-range telecom-related applications. The modules, equipped with lasers emitting at 1300 nm at one end of the link and at 1550 nm at the other, use wavelength division multiplexing for full-duplex operation without data corruption. The laser and the PIN detector are in the same housing, saving valuable real estate on the PCB. The transceiver supports SDH-SONET, ATM, trunk exchange/local exchange links, and interexchange installations.

For More Information Circle No. 800

Low-Profile Rotary Stage

The new PLR-300 rotary stage from Anorad Corp., Hauppauge, NY, has a height profile of only 32 mm, allowing for a minimal working stack-up height when used with other stages. The company says the low profile is especially beneficial for minimizing causes of system Abbe errors. The stage is powered by two diagonally opposed piezo-ceramic linear motors (PCLMs) that do not generate heat during operation, and a linear/rotary encoder is used to provide positioning precision. Anorad says the stage provides rotation to 360° with an angular resolution of ±0.0005° Positioning accuracy is ±2 microns at a 150-mm radial distance from the center of the axis of rotation.

For More Information Circle No. 801



First Fiber Connection to 5250 Express

Omnitron Systems Technology, Irvine, CA, provides what it calls the first device that allows host systems operating under the new IBM 5250 Express protocol to connect with a fiber optic network. The OmniMux™ 400X connects IBM AS/400 twinax to fiber (or twisted pair) networks, and operates with both the new Express and legacy protocols. The OmniStar™ 400X connects hosts with either protocol in twisted-pair star configurations. The company says the OmniMux 400X allows users to take advantage of the new protocol over extended networks for the first time. The new Express protocol increases data rates from 1 Megabyte per second (MBps) to 2 MBps, and also provides data optimization.

For More Information Circle No. 802

Pulsed Diode-Pumped Solid-State Lasers

Cutting Edge Optronics, Bridgeton, MO, offers 100-mJ and 200-mJ diode-pumped solid-state laser systems for industrial applications. The Nd:YAG ruggedized laser head can be Q-switched acousto-optically or electro-optically, and options include second, third, and fourth harmonics. The complete system includes the head, auxiliary rack with DC power supplies, digital controller/diode driver, auxiliary driver, and recirculating chiller, a quick-disconnect umbilical, and an operating manual. Pulse width for both is 170 microseconds, and beam diameter 3 mm.

For More Information Circle No. 803

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In Situ Interferometric Testing of a Vacuum-Chamber Window

Distortion is measured interferometrically with the help of a collimator.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively simple, direct interferometric technique has been devised for measuring the optical distortion produced by a window in a thermal vacuum chamber. The window of interest can be tested in place, under actual operating conditions. The equipment used in this technique includes a collimator, a laser diode, and a video camera/recorder.

If the window is part of a chamber in which an optical instrument is tested, then the collimator used to test the window is the same one used to test that instrument, and it is installed in the same position and orientation as in testing that instrument. The target holder of the collimator is replaced by an identical holder, on which a laser-diode assembly is mounted in place of the collimation target (see Figure 1). The laser-diode assembly comprises a laser-diode-and-beam-diverger subassembly mounted on a positioning arm, which is attached to a target cell at a spring-loaded pivot point. The laser-diode-and-beam-diverger subassembly can be positioned anywhere in the field of view of

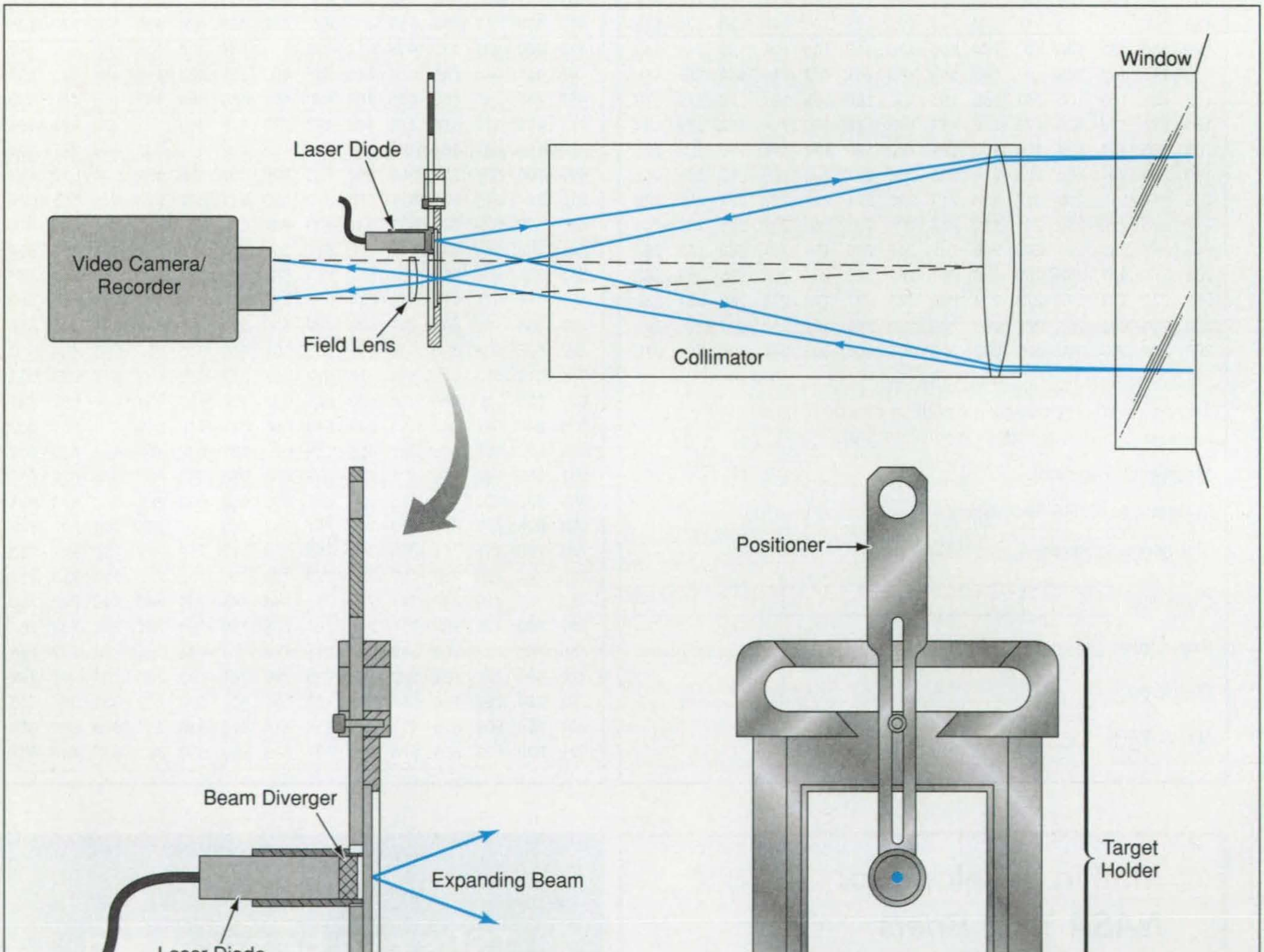


Figure 1. The **Collimator Target Is Replaced** by a laser-diode subassembly. Reflections of the laser light from the surfaces of the window give rise to interference fringes indicative of the quality of the window.

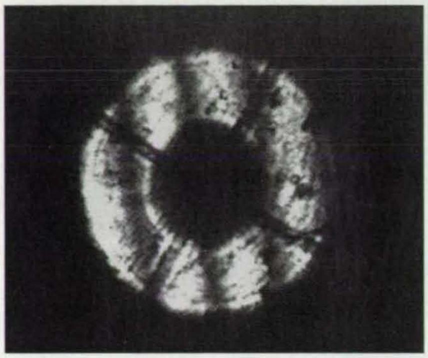


Figure 2. This **Interferogram** was recorded during operation of the thermal vacuum chamber at a temperature of –5 °C.

the collimator to accommodate misalignment between the optical axes of the collimator and window.

The laser beam is expanded, then collimated, then reflected from both surfaces of the window. The reflected light travels back through the collimator, which focuses this light. Provided that the wedge in the window is not too large (3 to 7 interference fringes over the working aperture would be ideal), the focused reflected light forms interference fringes of the Fizeau type; these fringes indicate directly the optical quality of the window. The interference fringes can be recorded by use of the video camera/recorder (see Figure 2). It might be necessary to use a field lens to match pupils to eliminate vignetting and enable sharp focus of the collimator pupil.

This work was done by Lawrence J. Steimle and David I. Brown 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,* ***or circle no. 109*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19895

Oscillating-Flow Heat-Transfer and Pressure-Drop Test Rig

Test specimens are plugs of material representative of regenerator matrices of Stirling engines.

Lewis Research Center, Cleveland, Ohio

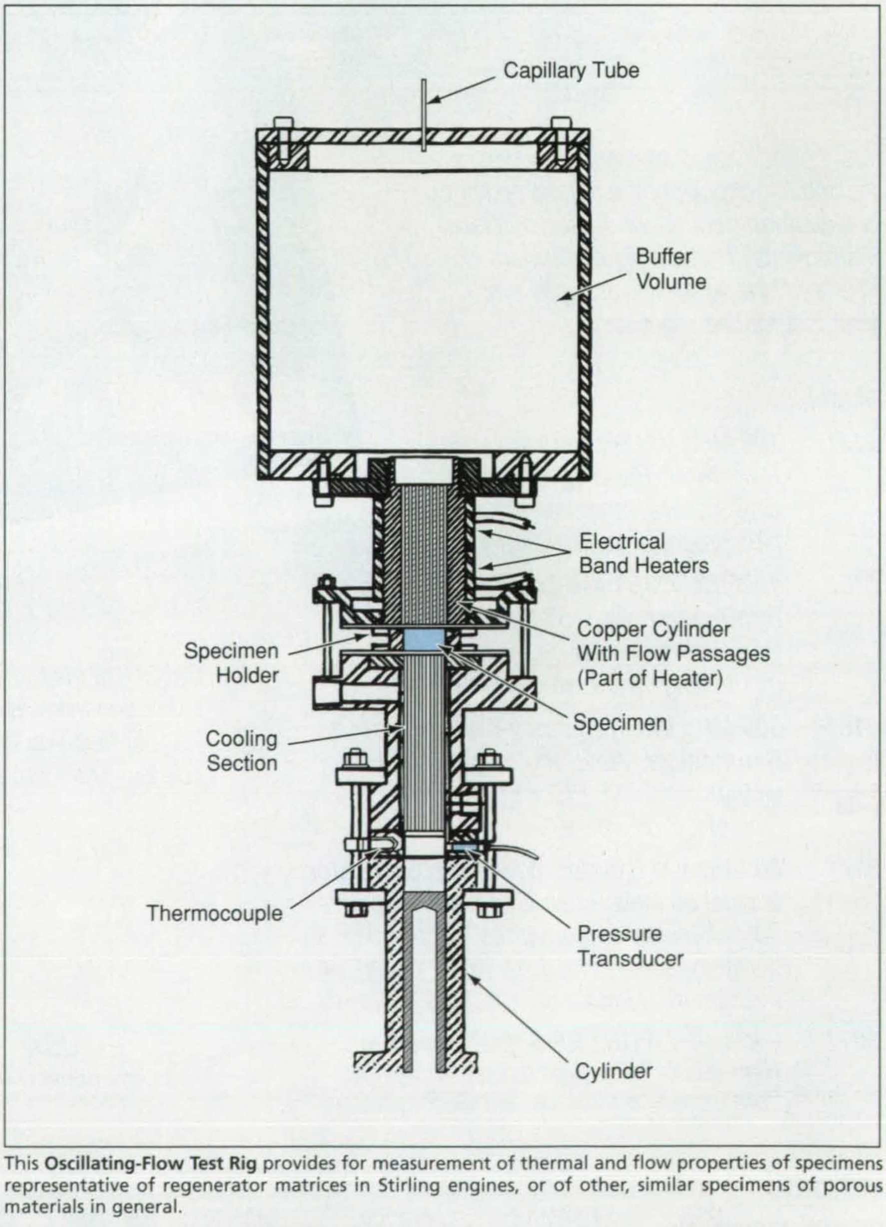
The figure illustrates an apparatus for measuring heat-transfer and pressure-drop characteristics of porous plug specimens in oscillating flows. The apparatus is built around an oscillating-flow test rig that was originally designed for pressure-drop (but not heat-transfer) measurements and has since been modified and refined. The flows and specimens are chosen to be representative of those encountered in the regenerators of Stirling engines.

The apparatus includes an assembly of a piston cylinder, cooling section, specimen holder, and heating section aligned sequentially from bottom to top along a vertical flow path. The foregoing assembly is contained in a pressure vessel to enable testing at specified elevated pressures. The oscillating flow is generated by the piston, which fits closely in the cylinder and is driven by a variable-stroke, variable-frequency linear motor.

The bottom end of the heating section opens to the top of the specimen holder, while the top end of the heater opens to a relatively large, fixed, thermally insulated buffer volume. A capillary tube vents the buffer volume to the surrounding space within the pressure vessel.

The heating section comprises a copper cylinder with drilled flow passages and with electrical band heaters clamped to its outer surface. The electrical power to the heaters is regulated by a commercial temperature controller. The cooling section is a shell-and-tube heat exchanger, with circulating water at controlled temperature serving as the coolant.

Five fine-wire thermocouples are installed on each face of a specimen. The specimen with thermocouples



This **Oscillating-Flow Test Rig** provides for measurement of thermal and flow properties of specimens representative of regenerator matrices in Stirling engines, or of other, similar specimens of porous materials in general.

attached is sandwiched between flow-diffuser disks. The sandwich is installed in the specimen holder.

Because of the large volume and other aspects of the design, the pressure swing in the piston cylinder is attributable mostly to frictional pressure drop in the specimen and in the heating and cooling sections, rather than to compression effects. Therefore, the mass flow rate is very nearly sinusoidal and spatially uniform in the specimen and in the heating and cooling sections.

In its heat-transfer mode, the apparatus is used to measure the net thermal-energy flux, which is the quantity of "bottom-line" importance in a Stirling engine. During operation, the piston is actuated, while the heating section is maintained at a temperature about 200 °C above that of the cooling section, giving rise to a temperature gradient in the specimen. The resulting axial conduction and imperfect heat transfer give rise to a net thermal flux along the specimen; this flux is ultimately rejected to the cooler, where it is measured. Static-conduction losses through cylinder walls and flanges and piston work due to pressure drop also contribute to cooler heat rejection, but these quantities can be calibrated out, so that it is possible to infer the thermal performance of the specimen in isolation.

Specimens tested thus far have been made of woven metal screens and metal felts, with a wide range of porosities, all representative of Stirling-engine regenerator matrices. Experiments on these specimens have yielded generic correlations for friction factors, Nusselt numbers, axial-conductivity-enhancement ratios, and overall-heat-flux ratios.

This work was done by Diane M. Chapman of **Lewis Research Center** *and D. Gedeon of Gedeon Associates and J. G. Wood of Wood Experimental. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 130*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16448.

Mass Analyzer With Rotating Electric Fields

Orthogonal dipole electric fields would disperse incident ions according to their charge-to-mass ratio, analogous to making Lissajous figures with ions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A device for measuring the distribution of masses in an atmosphere or plasma exploits the electrostatic deflection of ions in a rotating magnetic field. A magnetic field is not required. The device is simple to construct, can be made small, and is amenable to micromachining techniques such as LIGA (Lithographie-Abformung und Galvanoformung), or equivalent.

This so-called rotating-field (*rf*) analyzer transmits ions of a particular charge-to-mass ratio. One computes masses from this ratio by either knowing the charge from a separate measurement or making the usual assumption that each ion carries only one or a few units of charge. The device (see figure) consist of a rectangular parallelepiped chamber with four conducting, insulated walls to which the *rf* voltages are applied, an entrance aperture, and a detector face. Dimensions are $x_0 \times y_0 \times z_0$ with the Cartesian origin at the center of the ion-entrance aperture. Ions enter the device at a particular velocity $\mathbf{v}$, polar angle θ, and azimuthal angle ϕ [where $\mathbf{v} = \hat{\mathbf{x}}\sin\theta\cos\phi + \hat{\mathbf{y}}\sin\theta\sin\phi + \hat{\mathbf{z}}\cos\theta$]. Uniorm, sinusoidally-oscillating orthogonal electric fields E_x and E_y are established in the chamber by applying corresponding voltages V_x and V_y to the electrodes (omitted from the figure for clarity). The electric fields or applied voltages are made to oscillate at the same frequency f, and 90° out of phase with each other, so that the resultant electric field rotates about the $\hat{\mathbf{z}}$ direction with frequency f. A straightforward analysis shows that, for homogeneous electric fields close to the axis, the $x(T)$, $y(T)$ position of an ion between the plates is simply given by

$$\frac{x(T)}{\lambda_x} = \cos\omega t_0 - \cos\omega(T + t_0) - \omega\sin\omega t_0 \qquad (1a)$$

$$\frac{y(T)}{\lambda_x} = \sin\omega t_0 - \sin\omega(T + t_0) - \omega\cos\omega t_0 \qquad (1b)$$

Here, $\omega = 2\pi f$ is the angular frequency, T is the time the ion spends in the dipole fields, and t_0 is the time of arrival of the ion at the entrance aperture relative to the phase of the rf field. The assumption of zero velocity perpendicular to the axis has been made for simplicity. The quantities

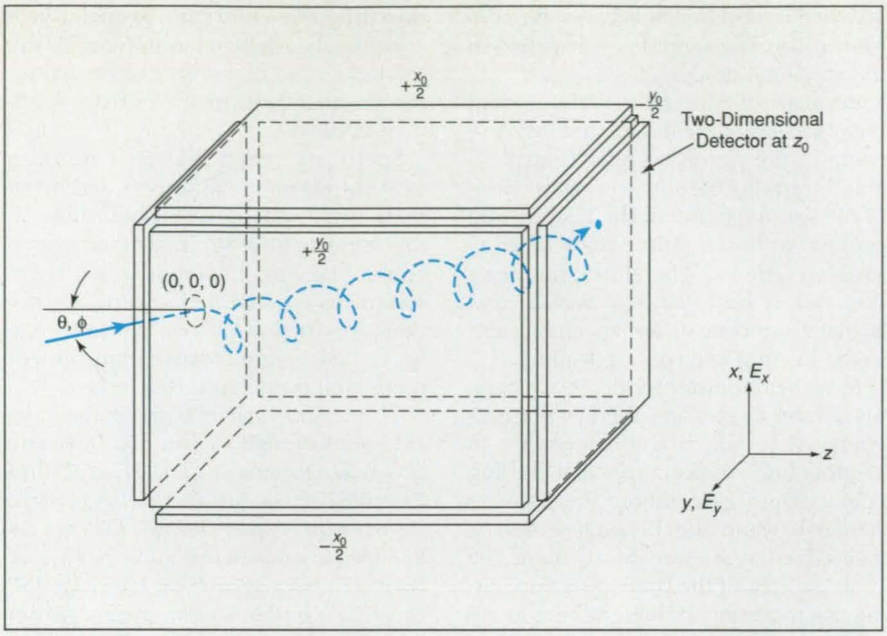
$$\lambda_x = \frac{e}{m}\left(\frac{V_x}{\omega^2 x_0}\right) \text{ and } \lambda_x = \frac{e}{m}\left(\frac{V_y}{\omega^2 y_0}\right)$$

are scaling parameters, which describe the amplitude of ion motion between the plates. This amplitude is seen to be linearly proportional to the charge-to-mass (e/m), electric fields $(Vx/x_0, Vy/y_0)$, and inversely proportional to ω^2. To see how the output pattern at the detector plane $z = z_0$ looks, one would first define the incident particle velocity, then "tune" the rf angular frequency so that $\omega T = 2\pi$ for that velocity. In this case, one can obtain the simple expression

$$\frac{x^2(T)}{\lambda_x^2} + \frac{y^2(T)}{\lambda_y^2} = 1$$

Hence, the locus of points at $z = z_0$ is a circle for each e/m. This is similar to the familiar Lissajous figures one makes with electrons and an oscilloscope. The figure could be detected by an area detector, such as a microchannel plate or a charge-coupled device. The resolution of the device, or separation between adjacent e/m, will depend on the input-aperture diameter, angular width of the incident beam, and homogeneity of the fields. Some of these effects can be obtained by taking suitable differentials of Eqs. 1a and 1b.

To confirm the behavior in Eqs. 1a and 1b, computer simulations of this device were carried out using a three-dimensional, non-space-charge limited fields-and-trajectories code. The device was also tested in the laboratory using a cell of dimensions 2 mm × 2 mm × 20 mm. Mass spectra were obtained from a commercial ion source. Since the input energies of the ions from the source were equal, but the input velocities could not be made equal, each ion was detected by "tuning" ω to its particular velocity, then detecting its transmitted current. One could also use the device as a velocity selector by detecting only those ions with a specific **z**-component of velocity given by $v \cos\theta = z_0/T$. For this, one would pulse the ions into the cell, then gate the detector "on," after the interval T. Suggestions along these lines were reported earlier in, "Ballistic Mass and Velocity Analyzer" *NASA Tech Briefs* (NPO-19235), Vol. 20, No. 6, (June 1996) page 57.



Ions Would Travel Along Spiral Trajectories under the influence of a rotating electric field until they struck a two-dimensional detector in the plane $z = z_0$.

This work was done by Steven J. Smith and Ara Chutjian 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,* ***or circle no. 153*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Automated Window Inspection Device

Both surface and subsurface flaws can be identified and located reproducibly.

John F. Kennedy Space Center, Florida

The Automated Window Inspection Device (AWID) is a prototype apparatus for computer-controlled, noncontact inspection of windows, with reproducible positioning and electronic recording of data on the locations, sizes, and depths of flaws. The AWID was developed to accelerate and facilitate (1) postflight inspections of the windows on the space shuttle for damage by micrometeorites and (2) the recording, analysis, and retrieval of records of such inspections. The AWID could also be adapted to industrial inspection of window glass prior to cutting, and to inspection of windows on aircraft and land vehicles.

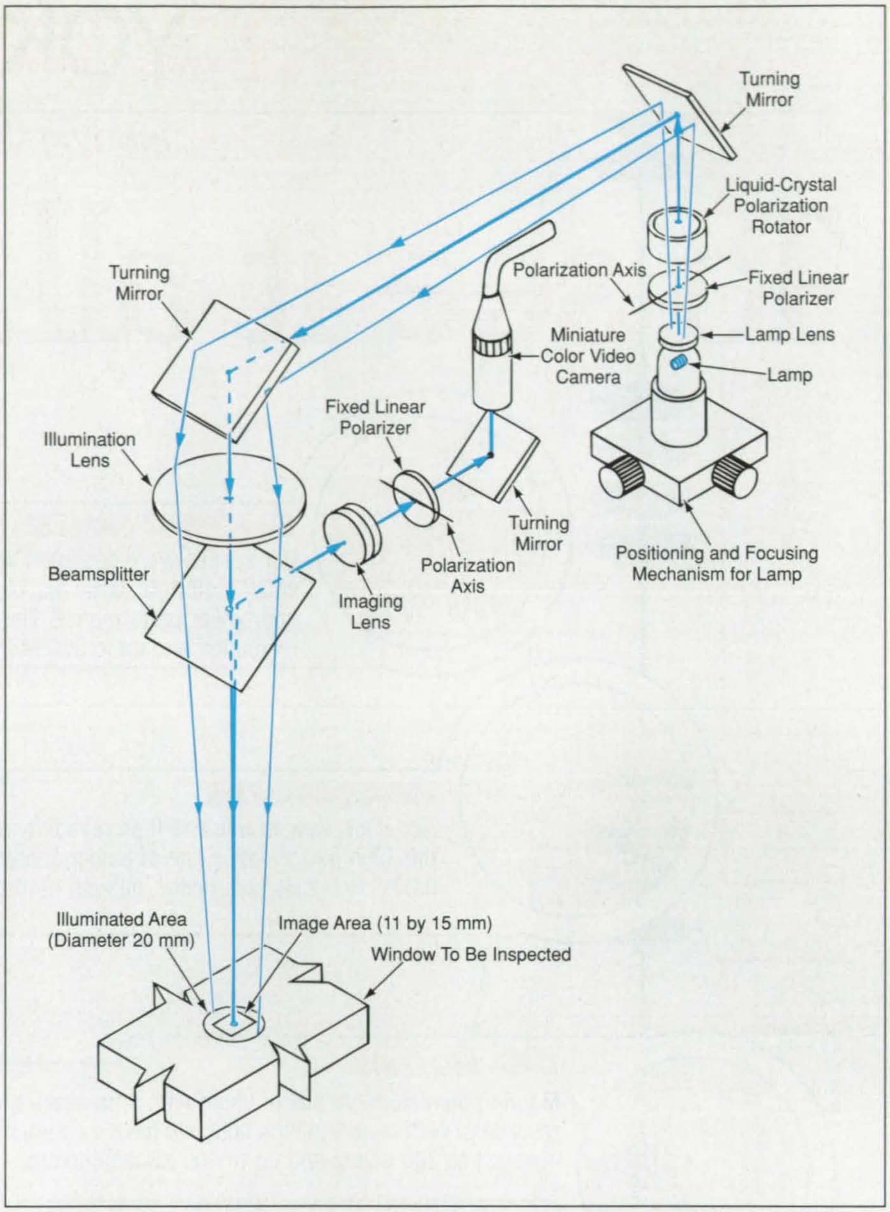
The AWID includes a scanner housing on a two-dimensional (x–y) translation mechanism on a portable frame that mates with posts on the window frame for proper location with respect to the window to be inspected. The translation mechanism comprises x and y drives, each actuated by a stepping motor under computer control for automated or manual scanning. The scanner housing contains two optical inspection instruments; a polariscope for locating both surface and subsurface flaws, and a refocus microscope with focus depth adjustable by use of a third (z-axis) stepping motor for measuring the depths of selected flaws.

The polariscope can reveal otherwise invisible subsurface damage ("bruises") via the effects of subsurface stresses on polarized light. The polariscope includes an illumination and an imaging module (see figure). A lamp in the illumination module consumes a power of 3.8 W and features a nearly-square-appearing tungsten filament. A lamp lens of 6-mm diameter and 6-mm focal length projects an image of the filament onto an illumination lens. The image of the filament fills the aperture of the illumination lens, providing nearly uniform illumination across the entire field. The illumination lens projects a magnified image (about 20-mm diameter) of the lamp lens onto the window.

The polariscope exploits the approximately 4 percent of the illumination that is reflected from each surface of the window. By use of a beam splitter and an imaging lens, light from an 11-by-15-mm portion of the 20-mm-diameter illuminated area is focused into a miniature color video camera. On its way to the camera, the light passes through a fixed linear polarizer. As explained below, the polariscope can operate alternately in a surface-damage-detection mode and a subsurface-damage-detection mode.

In addition to passing through the lamp lens, light from the lamp passes through a fixed linear polarizer and a liquid-crystal variable polarization rotator. The polarization axes of the two linear polarizers are orthogonal. In the surface-damage-detection mode, a square wave with a frequency of 2 kHz and an amplitude between 2 and 3 volts is applied to the polarization rotator, causing the plane of polarization of the illuminating light to be turned about 90° and thus lie approximately parallel to the polarization axis of the polarizer in front of the camera. As a result, an image of surface flaws is formed in the camera in reflected parallel-polarized light, in the same manner as in the case of ordinary unpolarized light.

For operation in the subsurface-damage-detection mode, no voltage is applied to the polarization rotator, causing the plane of polarization of the illuminating light to remain perpendicular to the polarization axis of the polarizer in front of the camera. In this mode, the illumination reflected (without change of polarization) from the front surface is polarized perpendicularly to the axis of polarization of the polarizer in front of the camera and is thus prevented from reaching the camera. However, the stress field in the interior of the window causes the polarization of light reflected from the rear surface to rotate by an amount that depends on wavelength. As a result, any subsurface damage is seen as a colored image on a darker background. The characteristic time for switching between surface and subsurface polarization modes is 30 to 50 ms.



The **Polariscope in the AWID** includes a liquid-crystal polarization rotator that enables operation in two modes: (1) illumination and imaging polarizations parallel for detecting surface flaws, and (2) illumination and imaging polarizations orthogonal for detecting subsurface flaws.

After a scan has been performed to locate surface and subsurface flaws in x and y, the refocus microscope is used to locate flaws in z. The microscope is mounted in the scanner housing next to the polariscope and is accurately positioned in x and y over each flaw to be inspected. The refocus microscope has an "extend-retract" feature to prevent any interference with the polariscope during x–y scans. The microscope is equipped with miniature strain gauges, which act as limit switches to prevent damage in collisions between the microscope and other objects near or on the window undergoing inspection.

Two desktop computers are used for control, analysis, and operator interface. Dedicated image-processing circuit boards relieve the computers of much of the analysis effort.

This work was done by Matthew J. Verdier and Frederick W. Adams of **Kennedy Space Center** *and Stuart M. Gleman, Stephen W. Thayer, Carl G. Hallberg, Joseph E. Kachnic, Curtis M. Lampkin, and Terry D. Greenfield of I-NET. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 157*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Thermographic Detection of Defects in Refractory Composites

Thresholds of detectability have been determined.

Lewis Research Center, Cleveland, Ohio

Significant effort and resources are being expended to develop ceramic-matrix composite (CMC), metal-matrix composite (MMC), and polymer-matrix composite (PMC) materials for high-temperature engine components and other parts in advanced aircraft. The development of composite materials is also being pursued actively in the automobile and sporting-equipment industries, among others. A portion of the development effort involves the assessment of nondestructive-evaluation (NDE) techniques for detecting flaws in these materials. Recent advancements in infrared-camera technology and computer power have made thermographic (infrared) imaging systems worth reconsideration as reliable tools for NDE of these materials. Thermography offers the advantages of real-time inspection, no contact with samples,

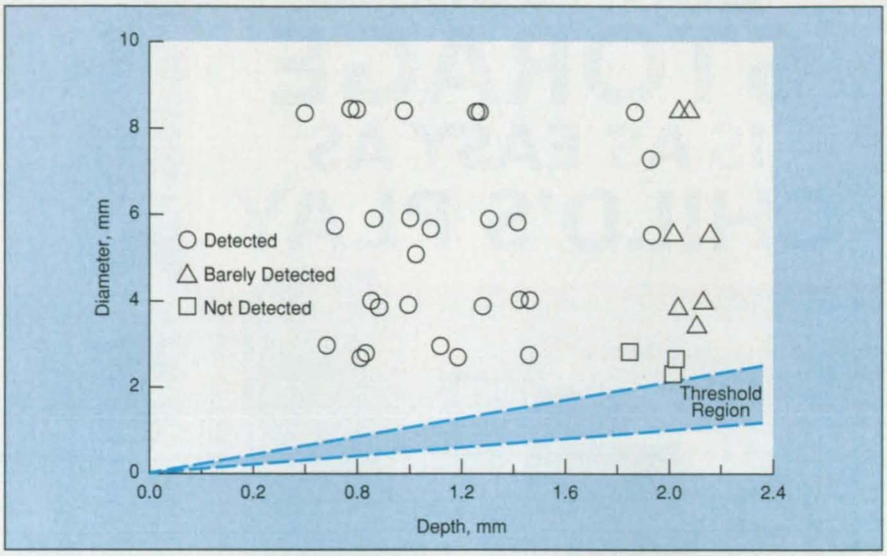

Figure 1. An **Empirical Rule for the Threshold of Detectability** of defects in SiC/SiC is determined by plotting a distribution of defects and indications regarding detectability by the thermographic technique used in the experiments.

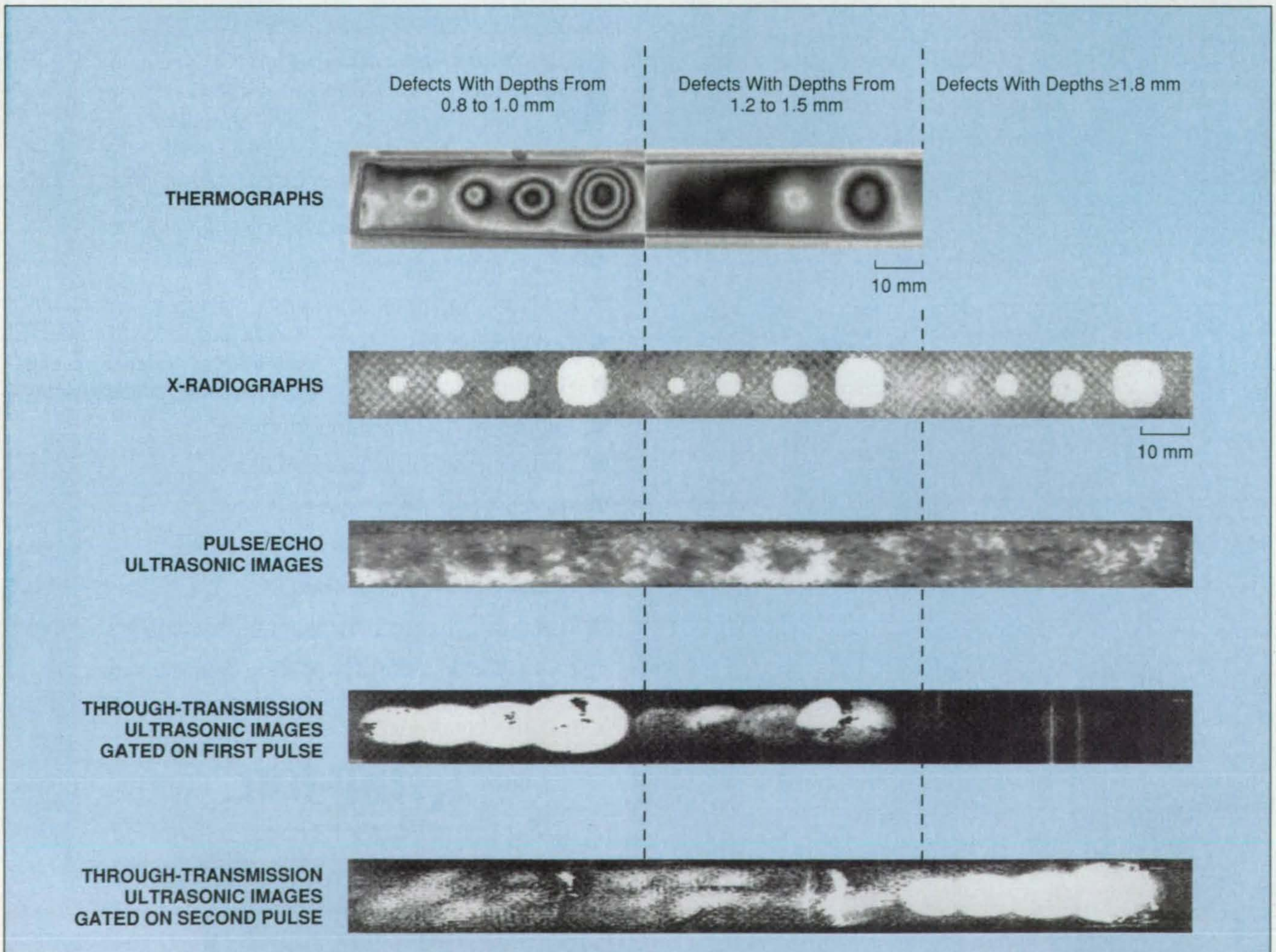

Figure 2. **Images of SiC/SiC Specimens With Defects**, made by several different NDE techniques, show different capabilities for revealing the defects. The through-transmission ultrasonic images have been distorted by graphical manipulation.

nonionizing radiation, capability for inspection of samples with complex shapes, variable sizes of fields of view, and portability.

An experimental study sponsored by NASA Lewis Research Center was performed to evaluate the capability afforded by a thermographic imaging technique for detection of defects in four composite materials of interest as high-temperature structural materials. The materials studied were two CMCs, one MMC, and one PMC; artificial defects in the form of flat-bottom holes with diameters from 1 to 13 mm and depths from 0.1 to 2.5 mm into specimens (2 to 3 mm thick) of these materials. In the thermographic imaging technique used, the source of heat was a pair of xenon flash lamps that faced the same side of the specimen as that observed by an infrared camera.

In the experiments, limits of detectability based on the depths and diameters of the holes were determined for each specimen material. For a SiC/SiC CMC, it was found that defects with depths $\leq$1.8 mm and diameters $\geq$2.6 mm will probably be detected (see Figure 1) by the technique used in these experiments. Similarly, it was found that for a composite of SiC fibers in a calcia/alumina/silica matrix (SiC/CAS) defects with depths $\leq$1.8 mm and diameters $\geq$1.6 mm will probably be detected; for a MMC of SiC/Ti, defects with depths $\leq$1.6 mm and diameters $\geq$3.2 mm will probably be detected; and for a PMC of graphite/polyimide, defects with depths $\leq$1.8 mm and diameters of about 3 to 12 mm will probably be detected. Depth appears to be the limiting variable with regard to detectability in the PMC.

As part of the study, thermographic images and observations about detectability were compared with results from ultrasonic and x-radiographic imaging to highlight the relative strengths and weaknesses of each imaging technique as applied to the composite materials studied. For example, Figure 2 shows thermographic images along with film x-radiographic and ultrasonic images for SiC/SiC specimens. The x-radiographs clearly reveal all defects. The ultrasonic pulse/echo image gives very diffuse indications of most defects because of the porosity (about 15 percent) of SiC/SiC. The ultrasonic through-transmission image clearly shows all defects at shallow and intermediate depths.

Overall, this study has yielded baseline results that can be expected to enable material developers and component designers to determine whether the thermographic technique used can reveal "critical" defects. The technique is applicable to inspection of composite-material structures in any industry. Examples of materials and structures amenable to such inspection include tires, composite hulls of boats, composite frames of bicycles, and multilayer thick tapes.

This work was done by Don J. Roth of **Lewis Research Center**, *James R. Bodis of Cleveland State University, and Chip Bishop of Bales Scientific, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 180*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Testing Corrosion Prevention in Reinforced Concrete

John F. Kennedy Space Center, Florida

An accelerated-testing method has been developed for evaluating the effectiveness of various measures taken to prevent the corrosion of steel reinforcing bars ("rebars") cast into concrete. Such measures can include chemical admixtures incorporated into the concrete, coatings, penetrants, modified concretes, new reinforcing materials, and corrosion-inhibiting chemicals that migrate after being applied. The method is an improvement of standard G 109-92 of the American Society for Testing and Materials (ASTM). In preparation for testing, concrete blocks are cast with rebars inside, along with any appropriate corrosion inhibitor(s). Holes are drilled into the blocks for measurement of electrical potentials at interior locations; other holes are drilled to promote intrusion of saltwater. During exposure of a block to a saltwater or other corrosive environment, electrical potentials are measured at rebars as well as in holes. Corrosion currents are also measured, and polarization resistances are determined. Optionally, potentials can be applied to accelerate corrosion. At the end of a test, the blocks are broken for visual examination of the rebars.

This work was done by Rupert U. Lee of **Kennedy Space Center** *and Joseph J. Curran of Dynacs Engineering Co., Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 122*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
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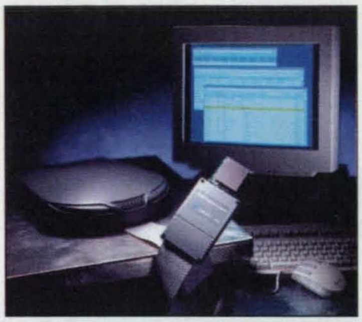
For More Information Circle No. 516

Special Coverage: Test Tools

B-Tree Systems, Minnetonka, MN, has introduced the Validor™ SC **test and verification system**, a fully automated, non-intrusive environment that enables PC and PC component manufacturers to test and verify product compatibility with existing PC software. The system is hardware- and operating-system independent.

The system consists of a test management environment in which test scripts are created and executed, and a target interface subsystem which provides non-intrusive stimulation and monitoring of the unit under test. It provides keyboard and mouse inputs to a software application running on the unit under test, capturing resulting screen outputs, and comparing the outputs with golden reference screens stored in memory.

For More Information Circle No. 740



CodeTEST™-ACT (Advanced Coverage Tools) **software test and analysis tools** from Applied Microsystems Corp., Redmond, WA, meets structural testing standards for life-critical applications mandated by the Federal Aviation Administration (FAA). The suite of tools collects live, in-circuit program measurements, analyzes test history, and generates reports documenting the process and outcome.

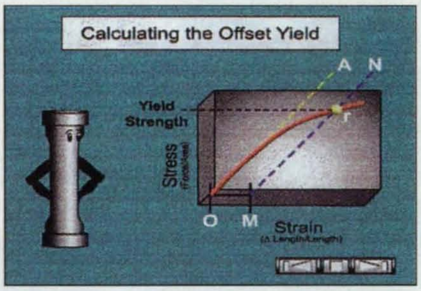
The suite can monitor up to 32,000 C-language functions while measuring performance, test coverage, and memory allocation simultaneously. Software modules are shared network licenses and are available on Sun OS, Sun Solaris, Hewlett-Packard UX, and Windows 95/NT. Microprocessor probes and other software modules are sold separately.

For More Information Circle No. 735

OMEGA Engineering, Stamford, CT, has introduced the OS520 Series handheld **infrared thermometer** for noncontact temperature measurement applications. Three models cover temperature ranges from -18°C to 870°C. Two laser sighting options are available: a laser dot or laser circle. The single laser dot indicates the center of the field of view, and the laser circle indicates the perimeter of the field of view.

Other features include adjustable emissivity from 0.1 to 1.0, backlit LCD dual display, audible and visible alarm, last temperature recall, and electronic trigger lock. Minimum, maximum, differential, and average temperature monitoring, as well as 1 mV/degree analog output are offered.

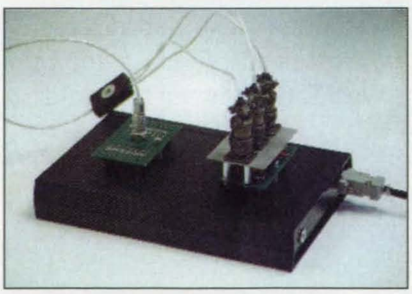
For More Information Circle No. 737



NuVision Partner for Windows 95 **materials testing software** from SATEC Systems, Grove City, PA, performs tensile, compression, flex, bend, shear, and other testing applications. The software also includes an HTML Help system, navigated via Microsoft Internet Explorer, that features animated segments that educate users in aspects of materials testing such as peak load, value at break, linear regression, offset, and tensile strength.

The software can be used to evaluate mechanical properties of composites, plastics, metals, adhesives, ceramics, wire concrete, and other advanced materials. Testing can be performed to ASTM or other industry standards. The Partner Fastener Test Suite is a special package available for conducting tests of threaded fasteners to the ASTM F606 standard.

For More Information Circle No. 745



Sensor Developments, Lake Orion, MI, has introduced the NJACC™ Model 90280 Cable Checker **cable and sensor test system** that evaluates instrumentation cables using plug-in adapter boards that receive connectors with up to 30 pins. Pigtail connections also can be accommodated using a quick-connect wire header adapter. The tester plugs into the serial port of any standard PC.

A Windows-based software program allows the user to check shorted interconnections, incorrect pinouts, cold solder joints, shorts to ground, and actual pin-to-pin resistances from 0 to 1 meg. When a sensor is plugged into the checker, it automatically determines probable wheatstone bridge configurations, individual bridge arm resistances, and location of opens or shorts.

For More Information Circle No. 746

The Model 960 Transient Recorder from RS Technologies, Farmington Hills, MI, is a portable, battery-powered **threaded fastener tester** with two transducer inputs and two angle inputs for measuring fastener torque, angle, and clamp load. It also is used for auditing and certifying or monitoring power tools and hand torque wrenches. It can hold data on up to 500 rundowns.

The unit performs torque versus tension verification testing on fasteners and joints, verifying coating or plating performance. It accepts input from devices with outputs ranging from ±0.5mV/V to ±10V. A real-time torque vs. angle, or torque vs. time graph is displayed simultaneously on the 3 x 5" screen. Statistics for peak data are calculated and displayed.

For More Information Circle No. 738

Special Coverage: Test Tools

The 710 Series of **process calibrators** from Fluke Corp., Everett, WA, includes five handheld, single-function units: the 712/RTD calibrator; 713/30G and 713/100G pressure calibrators; the 714 thermocouple calibrator; and the 715 volt/mA calibrator. The 712 simulates and measures seven types of RTDs with a range from -200°C to 800°C. The 713/30G and 100G measure pressure to 30 psi or 100 psi, respectively, with an accuracy of 0.05% of full scale.

The 714 calibrates nine types of thermocouples, and can measure and simulate temperatures from -200°C to 1800°C, depending on thermocouple type. The 715 measures and sources current to 24 mA with 0.025% accuracy. All units have pushbutton interfaces, EMI shielding, and a 9V alkaline battery.

For More Information Circle No. 739

Cambridge AccuSense, Shirley, MA, offers the Quattro mobile **flow velocity analyzer** that enables designers and thermal and mechanical engineers to obtain accurate snapshots of airflow environment. The unit is density-compensated and provides a true air-velocity reading, corrected for altitudes of up to 10,000 feet. The package consists of a lightweight measurement instrument with four sensor ports, interchangeable AFS airflow sensors, and an optional printer.

Powered by internal rechargeable batteries, the unit provides up to eight hours of continuous data collection and analysis. The system's miniature AFS-30 sensors feature a low-profile probe design of 5.7 mm x 5.8 mm, allowing access to hard-to-reach locations such as printed circuit boards.

For More Information Circle No. 741

Anritsu, Morgan Hill, CA, has introduced MF2412A, MF2413A, and MF2414A **microwave frequency counters** that combine wide frequency range with multi-measurement capability. Covering the 10 Hz to 40 GHz frequency range, the counters measure both pulse and CW signals. The counters incorporate a high-speed sampler and ASIC technology, allowing them to cover the range from audio bandwidth to microwave and millimeter-wave bandwidths.

The MF2412A covers 10 Hz to 20 GHz; the MF2413A has a range from 10 Hz to 27 GHz; and the MF2414A covers 10 Hz to 40 GHz. All units have an acquisition time of 50 ms and measurement time of 0.18 second at 1 Hz resolution. They allow upper and lower frequency limits to be entered for go/no-go testing.

For More Information Circle No. 742

The CT-651 **universal engine tester** from Ono Sokki Technology, Addison, IL, allows RPM measurement to be performed on virtually any engine type or component shaft. A selector switch can be used to specify the type of engine to be measured, and a multiplier circuit reduces the measurement time and achieves accuracies to 0.02% of full scale.

The tester uses a five-digit green LED to display actual RPM being taken, and features a measurement range of 400 to 19,999 RPM. Powered by both AC and DC, it can be used in a lab, on a production line, or during in-vehicle testing. Pulse, analog, and digital outputs are provided as standard to interface to recorders, spectrum analyzers, computers, or other data acquisition systems.

For More Information Circle No. 743

LeCroy, Chestnut Ridge, NY, offers a family of 200 MHz and 400 MHz **digital oscilloscopes** with three types of probes for various applications. Models are available with two or four channels and memory length from 50 to 1,000 Kb/channel. The scopes can view and analyze signals from automotive and medical electronics, power supplies and power devices, and other components.

New specialized probes include six types of high-voltage probes for signals ranging from 600 volts to 40 kV; a current probe with 50 MHz bandwidth; two 10-MHz differential amplifiers; and two 100-MHz differential amplifiers with a choice of probes for inputs. All scopes incorporate a floppy drive, faster processor clock speed, and more RAM than previous versions.

For More Information Circle No. 744

Yankee Environmental Systems, Turners Falls, MA, offers the Model PVH-2020 **virtual hygrometer**, which measures the water vapor content of any gas sample. Control and sensing electronics are contained on an ISA card that plugs into a standard PC slot. The instrument front panel is a LabVIEW® virtual interface that runs in Windows 3.x/95. The front panel includes a graphical strip-chart recorder and automatic datalogging option that stores data in a format compatible with popular spreadsheet programs.

Features include a graphical interface, 20-bit A/D converter, ITS-90 interpolation algorithms for dew point temperature measurement, a two-stage thermoelectric cooler with 60° typical depression, and an alarm relay with two set-point controls. Auxiliary temperature and pressure inputs for reporting humidity measurements in various forms, including wet bulb temperature and parts per million by volume, are included.

For More Information Circle No. 736

Fabricating Diffusion-Cooled Hot-Electron-Bolometer Elements

A key feature is the use of a self-aligned etch mask.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microbridges that constitute the superconducting-transition sensory elements of electron-diffusion-cooled hot-electron bolometers can now be fabricated in increased yield and quality. This improvement is made possible by a fabrication process that notably includes the use of a self-aligned mask during a critical etching step.

Some explanation of the underlying principles is necessary to give meaning to a description of the fabrication process. Electron-diffusion-cooled hot-electron bolometers are undergoing development for use as mixers that could operate at carrier and local-oscillator frequencies in the terahertz range, putting out signals at intermediate frequencies (IFs) in the gigahertz range. The most likely initial applications of such mixers would occur in radio-astronomy receivers. A prototype of the present electron-diffusion-cooled hot-electron bolometers was described in "Diffusion-Cooled Hot-Electron Bolometer Mixer" (NPO-19719), *NASA Tech Briefs*, Vol. 21, No. 1 (January 1997), page 12a.

The microbridge in a device of the present type is made from a film of niobium 10 nm thick. The length and width of the bridge are typically of the order of 100 nm (see Figure 1). The film material and dimensions are chosen to obtain the required superconducting-transition temperature (about 6 K) and to allow electron diffusion to be the dominant cooling mechanism. At the ends of the bridge, the strip of niobium widens into pads that make contact with relatively thick overlying gold pads, which define the length of the bridge and provide both heat sinking and electrical contact to external circuitry.

Like other microelectronic devices, a device of this type must be fabricated in a lithographic process. The need to ensure that the niobium contact pads extend under the full areas of the gold contact pads can give rise to difficulty in lithographic alignment. The present fabrication process (see Figure 2) was developed to solve this alignment problem.

The devices are fabricated, variously, on quartz or silicon wafers, depending upon the circuits in which they are to be used. The wafers are cleaned with organic solvents, then mounted in a vacuum processing chamber on an aluminum disk that keeps them near room temperature during processing. The chamber is evacuated, the substrates are cleaned by an argon-ion beam, then the substrates are coated with niobium 10 nm thick by magnetron sputtering. Then gold is deposited by thermal evaporation to a thickness of 15 nm to prevent oxidation of the niobium during subsequent processing steps.

In the subsequent steps, device features larger than 1 μm are formed by optical lithography, and the smaller ones by electron-beam lithography. Initially, the gold-coated wafers are optically patterned with alignment marks. Then in preparation for electron-beam lithography using a bilayer-stencil technique, the wafers are coated with two layers of poly(methylmethacrylate) of different molecular weights. The bilayer-stencil technique is used because it provides smoother edges for metal lift-off than does a single-layer technique.

The width of the bridge in each device is defined in the first electron-beam-beam-lithography step. After electron-beam exposure and development, gold

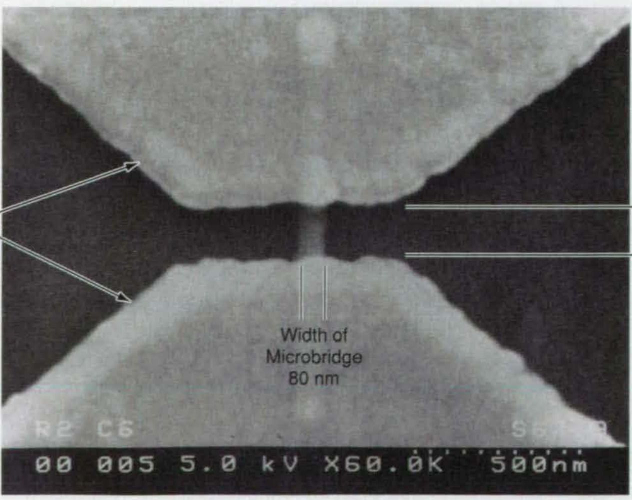


Figure 1. A **Niobium Microbridge** only 160 nm long by 80 nm wide connects broader niobium pads that lie under the gold contact pads.

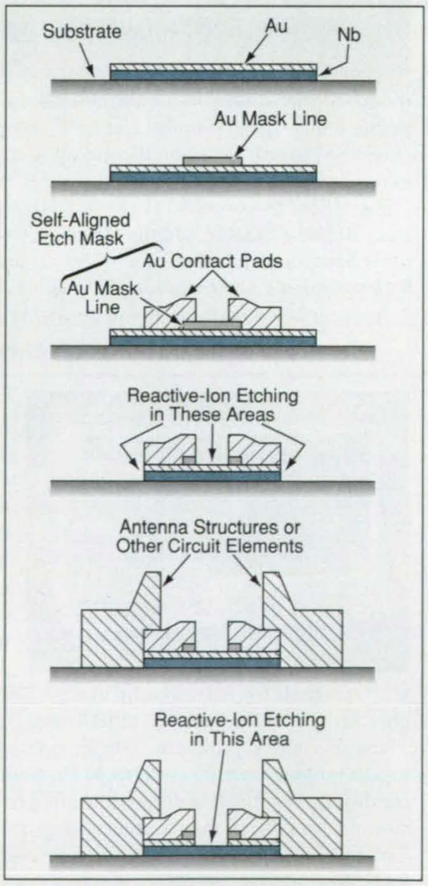


Figure 2. The **Fabrication Process** includes the use of a self-aligned etch mask to solve an alignment problem.

is deposited to a thickness of 25 nm. After lift-off, what remains of this deposit are gold mask lines 50 to 200 nm wide and several microns long.

The width of the bridge is defined in the second electron-beam-lithography step. Two 110-nm-thick gold pads (destined to become the contact pads) separated by a gap 50 to 300 nm long are positioned over the ends of the gold mask line.

The resulting composite of gold pads and the mask line constitutes a self-aligned mask for use in reactive-ion etching to remove the surrounding, unmasked portion of the gold-coated niobium film to form the niobium microbridge while leaving the masked portion of the niobium film intact under the full areas of the gold pads. This etch is performed in a two-step procedure that leaves the niobium microbridge still coated with some gold.

Then by use of a combination of optical and/or electron-beam lithography depending on the specific design, gold antenna structures or other circuit elements are formed in contact with the gold contact pads, and the remaining gold coat on the microbridge is removed by reactive-ion etching. Finally, all devices thus fabricated are separated from each other by dicing the wafers.

Prototype devices for use in quasi-optical receivers for operating frequencies of 1.2 and 2.5 THz have been fabricated by this method. Tests of these devices have shown that they can be fabricated within reasonable tolerances for microbridge lengths and widths as small as 80 nm.

This work was done by Bruce Bumble and Henry LeDuc 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 Circuits category,* ***or circle no. 104*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*
NPO-20023

Hybrid Superconductor/Semiconductor Planar Oscillators

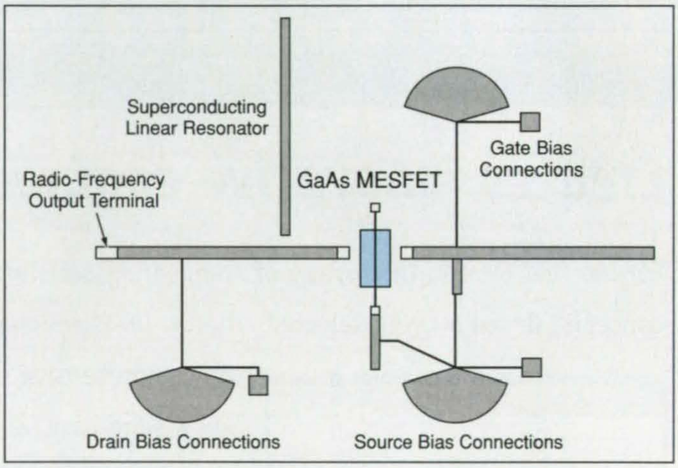
Characteristics include frequency stability, low phase noise, and ability to withstand vibrations.

Lewis Research Center, Cleveland, Ohio

Hybrid high-temperature-superconductor (HTS)/semiconductor planar oscillator circuits that operate at a frequency of 8.4 GHz have been developed. In the original intended application, one of these circuits would serve as a local oscillator in a cryogenic heterodyne receiver in a spaceborne experiment on high-temperature superconductivity. The same attributes that make these circuits attractive for use aboard spacecraft could also make them attractive for use on Earth — especially in applications in which high frequency stability, low phase noise, and ability to withstand vibrations are required.

Like other planar microwave oscillators based on HTS resonators, these oscillators can be made to exhibit frequency stability almost as high as, and phase noise almost as low as, those of quartz-crystal- and dielectric-resonator-stabilized oscillators. An oscillator of the present type includes integrated circuitry that is less complex and more reliable, relative to the circuitry of quartz-crystal- and dielectric-resonator-stabilized oscillators. The resonance quality factor (popularly denoted as Q and defined as the energy stored in electromagnetic field ÷ energy dissipated in one cycle of oscillation) of an HTS resonator of the present type at a temperature of 77 K in the absence of an electrical load is typically about 10^4 — almost equal to the Q of an unloaded dielectric-resonator-stabilized oscillator; in contrast, the Q of an unloaded typical normal-metal resonator is $<10^3$.

The figure illustrates the layout of one of the hybrid HTS/semiconductor oscillators. All of the circuit elements are formed on the surface of a $LaAlO_3$ substrate. The active circuit element is a GaAs metal/semiconductor field-effect transistor (MESFET). The passive HTS circuit elements include the resonator, reactive feedback lines, transmission lines, and dc bias lines; these elements are formed by etching of a deposited HTS film of $YBa_2Cu_3O_{7-\delta}$. The MESFET is electrically connected to the HTS circuit elements by Au wires with a diameter of 0.7 mil (0.18 mm) that are thermosonically bonded in place. Layered Ag/Au contact pads are deposited at the outer ends of the bias lines. Ceramic-chip capacitors and thin-film resistors are thermosonically bonded in place to provide filtering for the bias lines.



A **Hybrid HTS/Semiconductor Oscillator** is implemented as a planar circuit on a dielectric (lanthanum aluminate) substrate. The resonator is 173.5 mils (4.41 mm) long and 6.6 mils (0.17 mm) wide. The bias lines are 1.7 mils (0.04 mm) wide.

At the time of reporting the information for this article, 20 of the oscillators had been fabricated and subjected to a number of tests, including vibration tests and assessments of the effects of variations in the fabrication process. Of the 20 oscillators, 10 were assembled into working units and their performances were measured. At a temperature of 77 K, levels of output power into a 50-Ω load ranged up to 10 dBm. During incorporation into a full cryogenic receiver, output power levels ranged from 0.0 to 3.0 dBm, with less than 50 mW of dissipation.

This work was done by F. A. Miranda, R. R. Romanofsky, and K. B. Bhasin of **Lewis Research Center** *and C. M. Chorey of NYMA, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 108*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*

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Coplanar-Stripline Transition and Band-Stop Filters

Advantages include compactness and suitability for incorporation into monolithic microwave integrated circuits.

Lewis Research Center, Cleveland, Ohio

Three coplanar-stripline circuits have been designed to perform coupling and filtering functions in microwave systems. These circuits could be incorporated into feed networks for microwave antennas, for example. One of the circuits comprises two back-to-back coplanar-strip-to-microstrip transitions. The other two circuits are coplanar-stripline band-stop filters. The principal advantages of these circuits over others designed to perform the same functions are compactness and suitability for integration into monolithic microwave integrated circuits.

"Coplanar stripline" ("CPS") denotes a transmission line that comprises two adjacent conductive strips on one face of a dielectric substrate. "Microstrip" denotes a transmission line that comprises a conductive strip on one face of a dielectric substrate and a patch much broader than the strip (a ground plane) covering all or at least a large portion of the opposite face of the substrate.

The back-to-back CPS-to-microstrip transitions (see Figure 1) serve to couple power from a source to a load; e.g., from a transmitter to an antenna. Proceeding inward from each end of this circuit, one of the conductive strips of the CPS terminates in a radial stub, while the other strip is extended and narrowed to form the microstrip. The radial stub exhibits a resonance, the frequency of which depends on the radius R and angle ϕ; at resonance, there is a radio-frequency short circuit between the strip and the ground plane. The characteristic impedances of the CPS and stripline portions of the circuit are matched by suitable choice of the widths of the conductive strips.

In the CPS portion of the circuit, the electric field is oriented across the gap between the strips and roughly parallel to the faces of the dielectric substrate. In the microstrip portion, the electric field is approximately perpendicular to the faces of the substrate. The angle θ of the edge of the ground plane provides for rotation of the electric field between the CPS and stripline orientations.

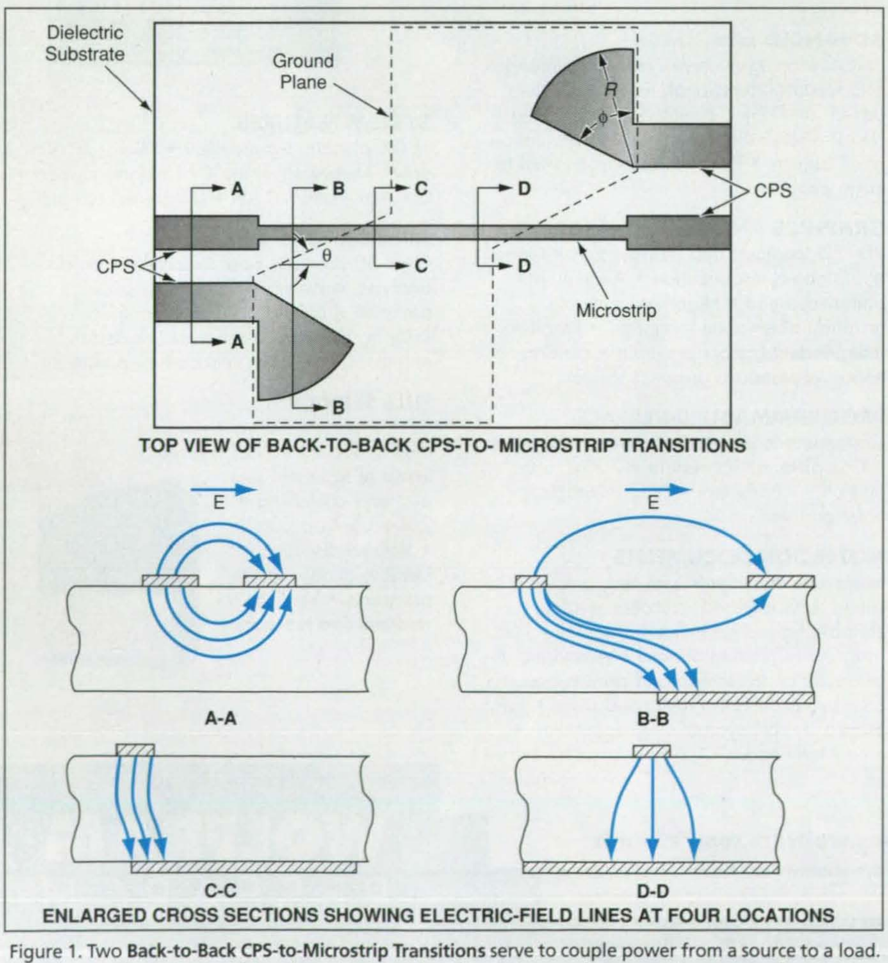

Figure 1. Two **Back-to-Back CPS-to-Microstrip Transitions** serve to couple power from a source to a load. Impedances depend on widths of conductive strips. The resonance frequency depends on R and ϕ.

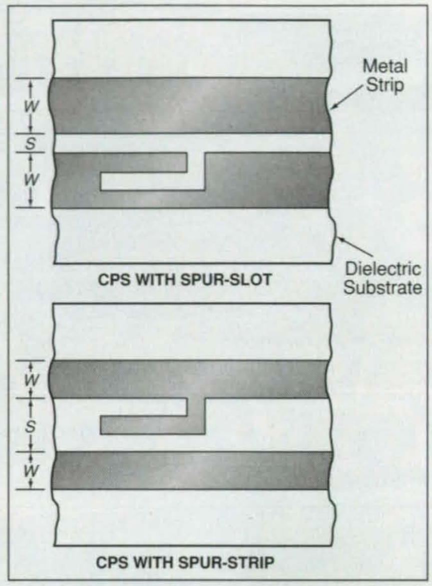

Figure 2. **CPS With a Spur-Slot or a Spur-Strip** acts as a band-stop filter.

The two band-stop filters are of the spur-slot and spur-strip types (see Figure 2). The spur-slot is a resonant structure within one of two strips; it is convenient to use a spur-slot when W is large and S is small. At its resonance, the spur-slot can be modeled as a quarter-wavelength short-circuit stub in series with the transmission line. At resonance, the spur-slot thus prevents the flow of power to the load. The spur-strip is a resonant structure between two strips; it is convenient to use a spur-strip when W is small and S is large. At its resonance, the spur-strip can be modeled as a quarter-wavelength open-circuit stub in parallel with the transmission line. Several spur-slots or spur-strips can be incorporated at intervals of a half wavelength along a transmission line to enhance the band-stop performance.

This work was done by Rainee N. Simons of NYMA, Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 156*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*

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Algorithm Estimates Doppler Shift in a Received DPSK Signal

Processing of delayed and undelayed versions of the signal yields the desired estimate.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm estimates the Doppler frequency shift in a received radio signal with square-wave-pulse binary differential-phase-shift-keyed (DPSK) modulation. [With little modification, the algorithm is also extensible to *M*-ary (where *M* is an integer > 2) DPSK modulation with pulse shapes other than square.] The algorithm was developed especially for use in processing a received K- or K_a-band signal in a ground mobile receiver in a ground-mobile/satellite communication system. There is a need for estimation of, and compensation for, large Doppler frequency shifts in such a receiver. The algorithm implements a feedforward (open-loop) estimation scheme, providing the needed Doppler estimate prior to detection and subsequent processing (see figure) for extraction of data symbols from the modulation.

Older closed-loop schemes for estimating and compensating for Doppler shifts do not work at Doppler shifts greater than fractions of symbol rates, nor do they work in the presence of the deep fading that often occurs in mobile operation. An older open-loop scheme is also limited to small Doppler shifts and depends on symbol synchronization. The present algorithm does not depend on symbol synchronization and performs well even at Doppler shifts well beyond the symbol rate. Furthermore, because it is a feedforward rather than a feedback algorithm, it offers at least the potential for better performance in the presence of fading.

Prior to processing via this algorithm, the input signal is mixed to baseband, then passed through a low-pass filter of cutoff frequency $B/2$ to reduce out-of-band noise. The in-phase (I) and quadrature (Q) components of the resulting input signal $r(t)$ can be represented in complex form as

$$r(t) = s(t)\exp(-j\omega_0 t) + n(t),$$

where t is time; $s(t)$ is the square-wave-pulse-shaped binary data-modulation signal with symbol period T; $n(t)$ is the low-pass-filtered version of the additive white Gaussian noise, with independent I and Q components, that is received along with the signal; and ω_0 denotes the Doppler-frequency shift, which one seeks to estimate, and which is assumed to be constant during the time needed to make the estimate.

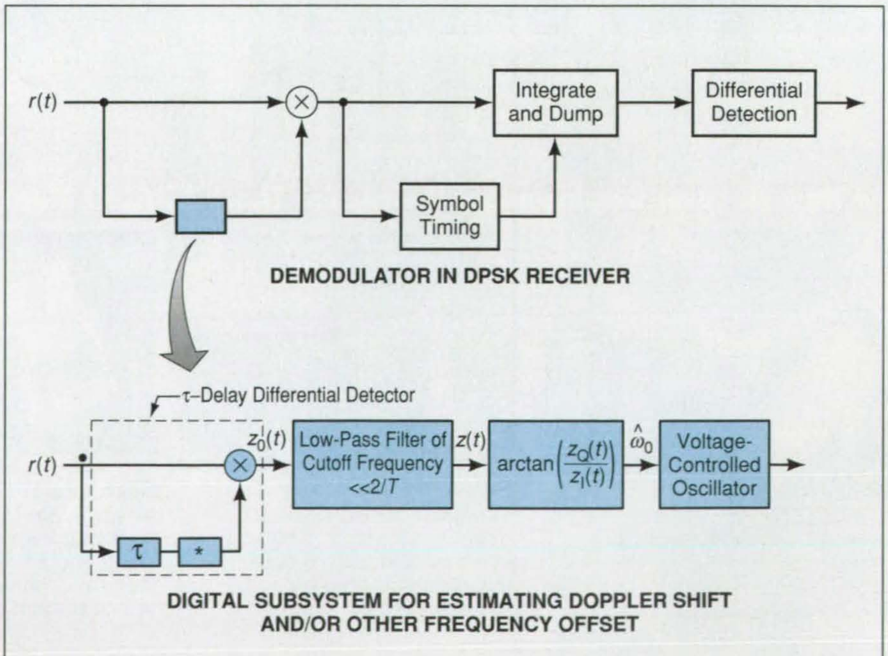
In this algorithm, $r(t)$ is split into two paths, on one of which it is delayed by an interval τ, where $0 \le \tau < T$. The complex conjugate of the delayed signal $r(t-\tau)$ is mixed with the undelayed signal $r(t)$ to obtain $z_0(t)$. The part of the algorithm described thus far can be characterized as implementing a τ-delay differential detector. It can be shown that provided the noise is negligible, one can estimate $\omega_0\tau$ as minus the arctangent of the ratio between the dc (zero-frequency) Q and I components of the output $z_0(t)$ of this detector. To isolate these zero-frequency I and Q components, it is necessary to filter out frequency components at the fundamental and harmonics of the symbol frequency $1/T$; this is accomplished by low-pass-filtering $z_0(t)$ to obtain the complex dc signal $z(t)$. The estimate $\hat{\omega}_0$ of the Doppler shift is then computed from

$$\hat{\omega}_0 = (-1/\tau)\arctan\left[z_Q(t)/z_I(t)\right],$$

where $z_Q(t)$ and $z_I(t)$ denote the Q and I components of $z(t)$. The maximum size of the Doppler shift that can be tracked without incurring the integer-multiple-of-2π phase ambiguity is given by

$$|\hat{\omega}_0|_{max} = \pi/\tau$$

This work was done by Thomas C. Jedrey, Edgar H. Satorius, and Martin J. Agan 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 Systems category,* ***or circle no. 150*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*
NPO-19812



Doppler Estimation and Compensation are performed prior to demodulation and other processing.

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7½ digits

Model 2000

6½ digits

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Specifications

Model	2010	2002	2001	2000
• Resolution	7½ digits	8½ digits	7½ digits	6½ digits
• DC volts	10nV – 1000V	1nV – 1100V	10nV – 1100V	100nV – 1000V
• AC volts	100nV – 750V	100nV – 1100V	100nV – 1100V	100nV – 750V
• Ohms	1μΩ – 120MΩ	100nΩ – 1GΩ	1μΩ – 1GΩ	100μΩ – 120MΩ
• DC amps	10nA – 3A	10pA – 2.1A	10pA – 2.1A	10nA – 3A
• AC amps	1μA – 3A	100pA – 2.1A	100pA – 2.1A	1μA – 3A

For More Information Circle No. 528

ASIC for Viterbi Decoding With $2 \leq K \leq 15$ and $1/2 \geq r \geq 1/6$

Decoding speed exceeds that of older prototypes.

NASA's Jet Propulsion Laboratory, Pasadena, California

An application-specific integrated circuit (ASIC) serves as a building block for a digital system that effects maximum-likelihood decoding of a Viterbi code (a binary convolutional error-correcting code) with a constraint length (K) in the range of 2 through 15 and a rate (r) in the range of 1/2 through 1/6. This ASIC is based on the same architecture as that of two older prototype $K = 15$, $r = 1/6$ Viterbi decoders, the first of which was reported in literature in 1988. These prototypes have functioned successfully in experiments, and their capabilities exceed those of state-of-the-art (K up to 7 and r at 1/2) commercial decoders as of the time of reporting the information for this article, but they have not been put into commercial production, partly because their complexities have given rise to reliability problems. Moreover, these prototypes have been limited to decoding speeds $\leq$ 750 kb/s.

A decoder built from multiple units of the present ASIC is capable of decoding at a speed up to 4.4 Mb/s. Other notable aspects of the decoder and its ASIC building blocks include (1) implementation of a "pipeline" scheme for traceback (reconstruction of the most likely sequence of recent code states); (2) a novel CMOS (complementary metal oxide/ semiconductor) current-logic (CMCL) input/output scheme that affords low switching currents, high immunity to noise, and fast signaling among ASICs; and (3) timing-error-detection circuitry that helps to ensure synchronization of each ASIC with an externally generated clock signal.

In global terms, decoding is performed by a traceback processor that reads a traceback random-access memory (RAM). The decoder contains 64 identical ASICs, each of which (see figure) contains 1/64 of the traceback RAM and 1/64 of other circuits that are called "butterfly processors" because a graphical representation of the arithmetic logic at each node pair has a butterflylike shape. However each ASIC contains a complete traceback processor, so that there is no problem of transferring traceback addresses among ASICs.

Code symbols enter each ASIC at the symbol-input circuit, where they are buffered and preprocessed. The preprocessed code symbols are fed to the butterfly processors, which produce metrics (measures of the likelihoods of candidate paths through sequences of code states). The metrics are fed, variously, back to the butterfly processors in the ASIC or to the butterfly processors in other ASICs. On the basis of comparisons between the metrics of the two alternative path branches that lead into each code state, the butterfly processors generate decision bits, which are transferred to the RAM. Pointers in the RAM-address controller keep track of the reading and writing locations. The traceback controller implements the traceback logic, which reads the RAM and puts out traceback bits to connect to the other ASICs. Data from the traceback controller are transferred to the output controller, which contains last-in/first-out (LIFO) memories. The output controller puts out the decoded data bit.

All registers in the ASIC are loaded initially from a 16-bit bus. The bus controller serves as the interface between the rest of the ASIC and the bus. All ASIC configurations are programmable and are set through this interface.

The ASIC includes metric accumulators (in the butterfly processors), which keep incrementing until they roll over. The metric growth block keeps track of the rate of growth in the metric accumulators to give a measure of how well the decoder is performing. A large metric-growth rate would indicate poor performance; this could occur because of a very low signal-to-noise ratio, or because of lack of synchronization of the decoder operation with the incoming code symbols.

This work was done by Gary R. Burke and William D. Whitaker 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 Systems category,* ***or circle no. 103*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*

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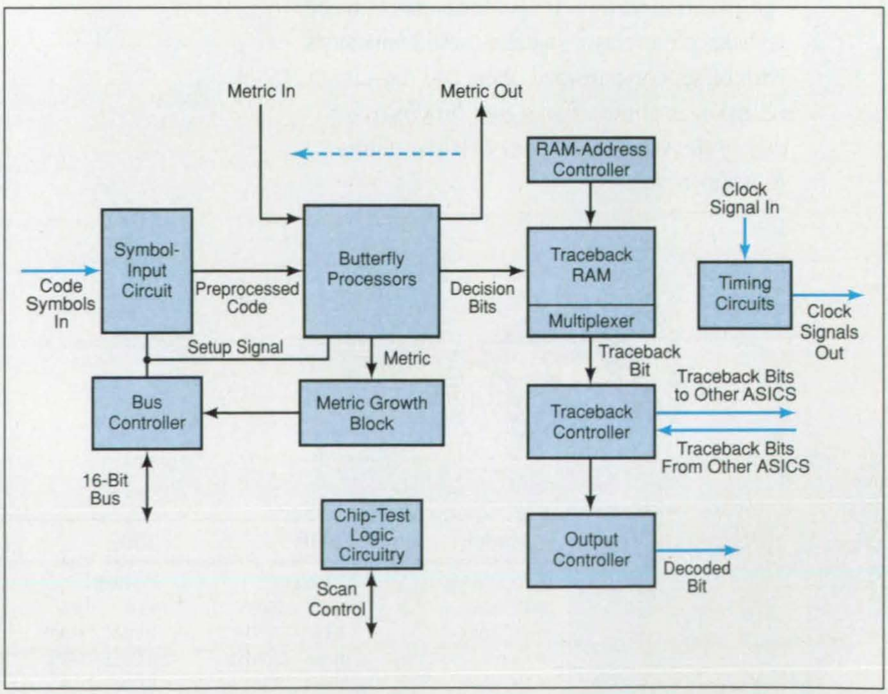
Refer to NPO-19999, volume and number of this NASA Tech Briefs *issue, and the page number.*



This **Simplified Diagram** illustrates the major functional blocks of the ASIC. A complete decoder for a $K = 15$, $r = 1/6$ Viterbi code contains 64 such ASICs.

Signaling-and-Detection Scheme for Beacon Monitoring

The signal level could be 10 dB below that required in a traditional BPSK scheme.

NASA's Jet Propulsion Laboratory, Pasadena, California

A signaling-and-detection scheme has been proposed for use in conjunction with the remote-monitoring concept described in "Beacon Monitoring Would Reduce Interactions With Remote Systems" (NPO-19706), *NASA Tech Briefs*, Vol. 21, No. 5 (May 1997), page 54. To recapitulate: A remote system (a spacecraft in the original intended application) would contain a semiautonomous computer-based monitoring subsystem that would analyze data acquired by onboard instrumentation and would produce a summary assessment of the status of the system. The summary assessment would be represented by one of four messages. To minimize the demand on communication resources and thereby minimize the cost of operation, the subsystem would ordinarily not transmit full telemetric data to a control station (a ground station in the original application). Instead, the subsystem would transmit one of the four messages as a radio beacon signal. Operators on the ground could decide, partly on the basis of the received beacon message, whether and when full telemetric data were needed. Full telemetric data would be transmitted from the remote system to the control station only on command by operators on the ground.

In the proposed scheme, each of the four beacon messages would be represented by a pair of subcarrier tones with unique frequency spacing. These tones would be phase-modulated onto a carrier signal with a modulation angle of 90°. The tones would be detected noncoherently at the control station. At the low data rate inherent in the four beacon messages, this scheme offers adequate performance at a signal level 10 dB below that needed for a bit-based, binary-phase-shift-keying (BPSK) scheme that is used to transmit full telemetric data. This 10-dB performance advantage could be exploited by reducing the transmitted power at the remote station and/or using a smaller antenna to receive the signal at the control station. The larger antenna needed to receive full telemetry could thus be allocated to other tasks until there was a need to receive full telemetric data from the remote system.

The proposed scheme, and two alternative weak-signal-detection techniques that could be used in the scheme, have been tested in a laboratory, but have not yet been tested in an operational system. In both detection techniques, decision statistics are derived from incoherent sums of power spectra and compared with thresholds. In one technique, the frequency drift of the signal is modeled after evaluation of the power spectra; in the second technique, the frequency model is applied before computation of the power spectra.

This work was done by Miles K. Sue, Robert Kahn, Gabor Lanyi, Victor Vilnrotter, Marvin Simon, Ted Peng, John Caraway, and Bruce Crow 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 Systems category,* ***or circle no. 121*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*

NPO-20187

Physical Sciences

Mathematical Model of Pyrolysis of Biomass Particles

The model qualitatively reproduces aspects of pyrolysis seen in experiments.

NASA's Jet Propulsion Laboratory, Pasadena, California

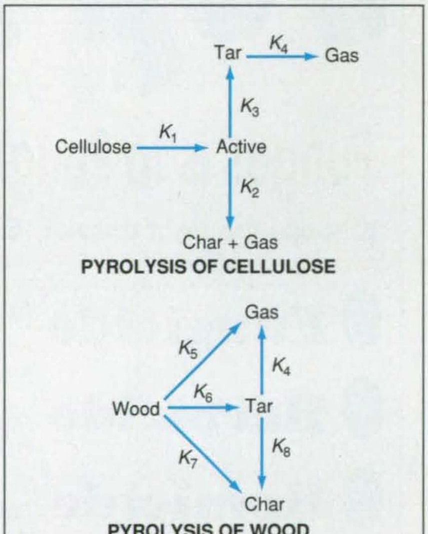
A mathematical model of a special class of solid/fluid chemical reactions has been developed for use in analyzing the pyrolysis of particles of cellulose, wood, and similar biomass materials. Although it involves some simplifying assumptions (as do all models of chemical and physical processes), this model is nevertheless sufficiently detailed to yield spatially and temporally resolved approximations of chemical compositions and temperatures of particles and of liquid and gaseous products as they evolve during the pyrolysis process.

In the model, each particle is assumed to be spherical and porous. The particle is assumed to be chemically reactive, with known volumetric reaction rates for the various chemical species present. It is assumed that the porosity (pore volume ÷ total volume) and the permeability of the particle are large enough to allow for continuous flows of gases. For these and other purposes, the detailed pore structure is not analyzed and instead, only the bulk or "effective" properties associated with porosity are represented. Unlike in some other models, conditions in the environment of the particle are not assumed to be quasi-steady. Conditions at the surface of the particle are allowed to evolve according to the equations of the model and the far-field temperature and pressure.

The model provides for the formation of solid (char), liquid (tar), and gaseous products. Both convection and diffusion of the liquid product(s) are neglected; this assumption is justified, provided that either the viscosity of the liquid substantially exceeds that of the gases or the characteristic reaction time of the liquid is much smaller than its characteristic diffusion and convection times.

The dynamics of flows of gases and of chemical reactions within the particle are represented by coupled equations for conservation of mass, momentum, and energy. For the gaseous chemical species, the equations for conservation of mass include both flow-divergence terms and source terms proportional to the products of partial densities and reaction rates. For the solid and liquid species, only the source terms are included. The reactions are assumed to be irreversible and of first order.

For modeling conservation of energy, all species are assumed to be in local thermal equilibrium in a mixture. The partial internal energy of each chemical species is assumed to be proportional to the its partial density × its specific heat at constant volume × the local temperature. The rate of change of local internal energy is represented by a sum of (1) heat-release rates proportional to the chemical-reaction source terms, (2) conduction proportional to the local gradient of temperature × an effective thermal conductivity according to a mixture-and-porosity-based submodel, and (3) convection of heat via the flow of gaseous species.



A Few Principal Chemical Reactions are included in the model of the pyrolysis of cellulose and wood. The reaction rates are calculated by the Arrhenius equation $K_i = A_i\exp(-E_i/\bar{R}T)$, where K is a reaction rate, A is a rate frequency constant, E is an activation energy, $\bar{R}$ is the universal gas constant, T is the absolute temperature, and the subscript i denotes the ith reaction path or chemical species.

The conservation of momentum for the gas phase is expressed by a single equation for radial flow of a compressible gas mixture through pores, with an effective molecular viscosity proportional to the porosity × the sum of mass-fraction-weighted viscosities of all gas species. The set of equations is completed by an equation of state, based on the perfect gas law, wherein the total local pressure is expressed in terms of the effective local total gas density, porosity, local temperature, and local volume fractions of the gas species.

The model was applied in a parametric study of the effects of initial reactor temperature, heating rate, porosity, and initial particle size on the char yields and conversion times in the pyrolysis of spherical biomass particles in initially quiescent superheated steam. In this study, reaction rates (see figure) were calculated from previously published data on the kinetics of chemical reactions for cellulose and wood. The equations of the model were solved numerically. The solutions qualitatively reproduced aspects of pyrolysis as observed in previous mathematical-modeling and experimental studies.

In particular, the numerical results indicated that one can reduce the production of char by decreasing the initial particle size or by increasing the reactor temperature and heating rate, but that the achievable decrease in the production of char is limited by endothermic reactions, heat capacities, and thermal diffusion. Three pyrolysis regimes were identified: (1) initial heating followed by (2) primary reaction at an effective pyrolysis temperature followed by (3) final heating. The relative durations of the regimes were found to be independent of reactor temperature and to be approximately 1/5, 3/5, and 1/5, respectively, of total conversion time. The results show that neglect of thermal and chemical-species boundary layers outside particles generally leads to overprediction of both pyrolysis rates and tar yields. Comparisons with experimental data revealed that wood-pyrolysis-kinetic data assumed in the study were not accurate.

This work was done by Josette Bellan and Richard S. Miller 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,* ***or circle no. 192*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*
NPO-20070

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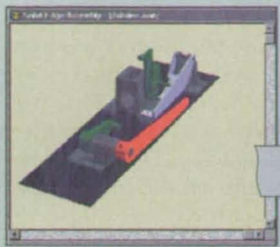

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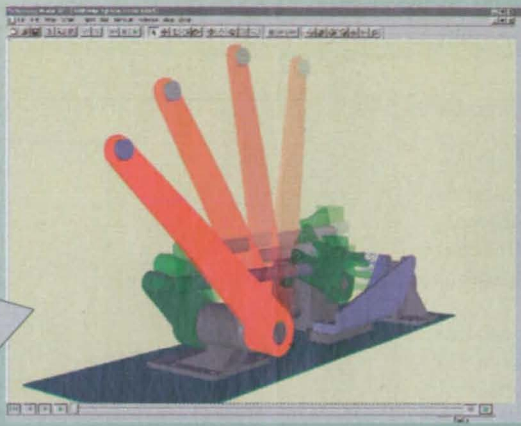

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Modeled by Sean Taffert, Vapor Canada Inc., Quebec, Canada

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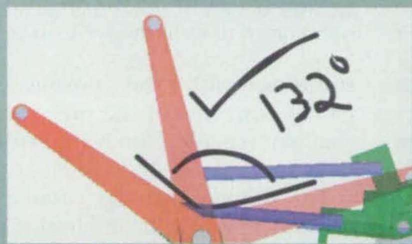

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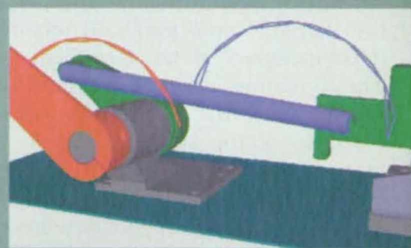
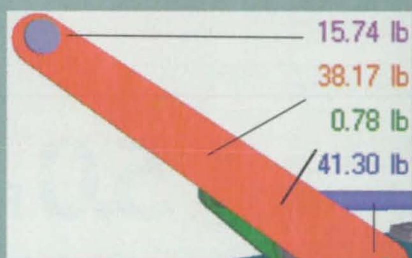


Positional tracks and envelopes



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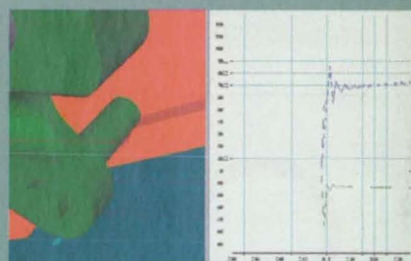

Contact and friction forces

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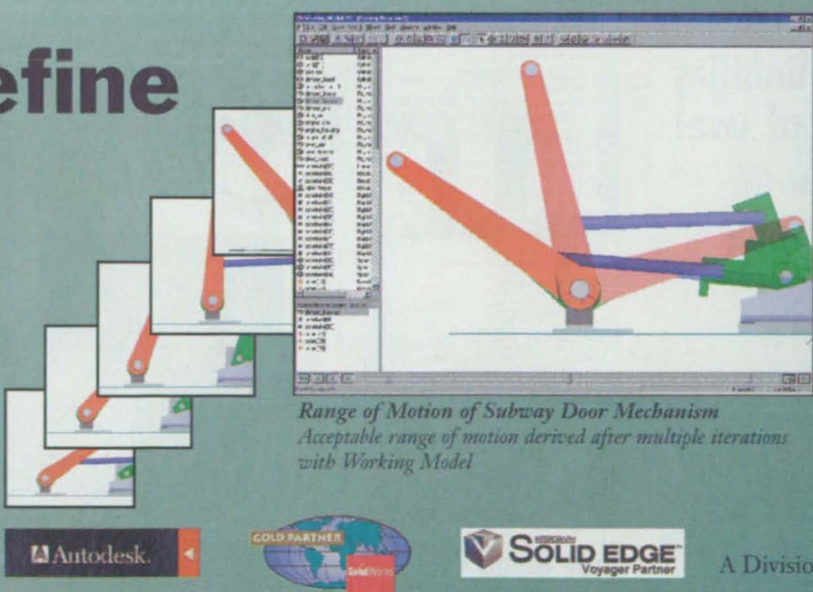

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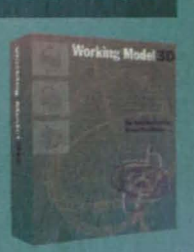

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For More Information Circle No. 523

Generalized Mathematical Model of Pyrolysis of Biomass

This model agrees well with experimental data.

NASA's Jet Propulsion Laboratory, Pasadena, California

A generalized mathematical model has been devised for use in analyzing the pyrolysis of arbitrarily specified (but typical) biomass feedstocks at atmospheric pressure. The model represents both the microparticle (kinetically controlled) and macroparticle (diffusion-limited) types of pyrolysis.

The microparticle portion of the model is based on a superposition of the multistep chemical-reaction kinetics of the primary constituents of biomass; namely, cellulose, hemicellulose, and lignin. The submodel for each primary constituent accounts for decomposition into tar, char, and gas, with secondary decomposition of tar (see Figure 1). The formation of char is represented as taking place via competitive primary reactions of the active feedstock. The macroparticle portion of the model is constructed by coupling the foregoing kinetics, along with appropriate heats of reaction and physical properties of constituents, with the porous-particle model described in the preceding article, "Mathematical Model of Pyrolysis of Biomass Particles" (NPO-20070).

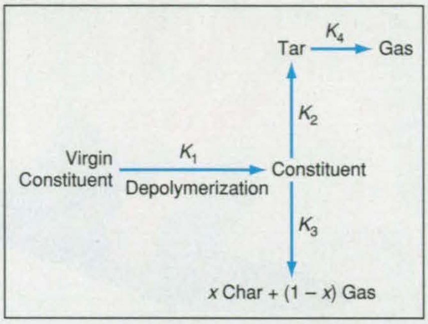


Figure 1. This **Generic Reaction Scheme** represents the pyrolysis of each primary constituent (cellulose, hemicellulose, or lignin). As in the model of the preceding article, each reaction is assumed to be irreversible and of first order, with a rate K_i given by the Arrhenius equation.

The chemical-kinetics parameters in the model were obtained from a combination of previous mathematical-modeling studies and experimental data on the pyrolysis of representative feedstocks (cellulose, lignin, and beech and maple wood). Then the model with the exact same parameters was used to predict selected aspects of the pyrolysis of different feedstocks: The predictions agreed well with data from thermogravimetric-analysis (TGA) and isothermal experiments on the pyrolysis of untreated microparticle bagasse (see Figure 2) and cherry, oak, and pine wood. Considering that the proportions of the three primary constituents vary widely in these feedstocks, the results can be interpreted as signifying that the chemical-kinetics part of the model is unexpectedly robust.

Results obtained with the macroparticle model generally agreed with the experimental data. The small deviations were attributed to differences in particle geometry between simulations and experiment, catalytic effects of min-

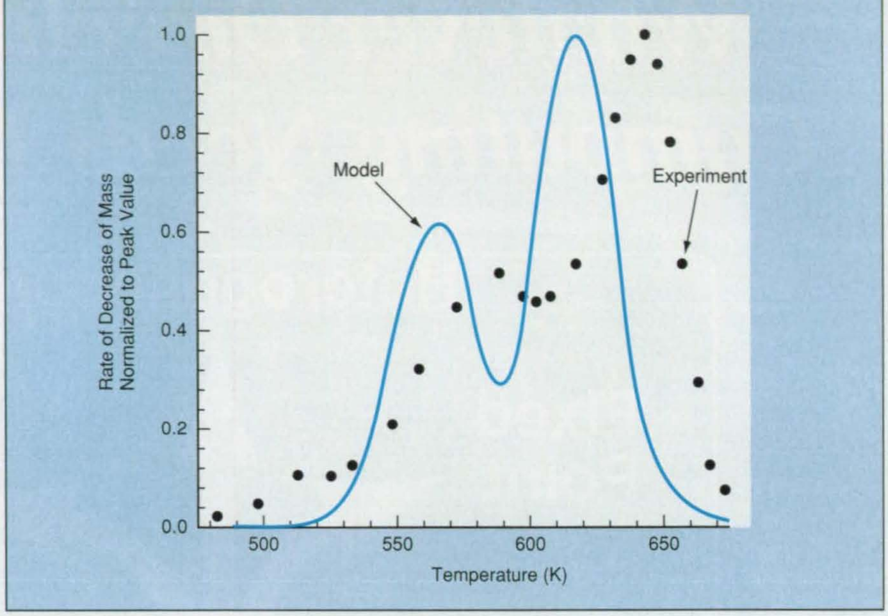


Figure 2. The **Normalized Mall-Loss Rate** of untreated bagasse as a function of temperature under microparticle TGA conditions at a heating rate of 10 K/min as computed by the model is compared here with data from a previous TGA experiment.

eral matter not considered in the model, and differences in properties of various feedstocks.

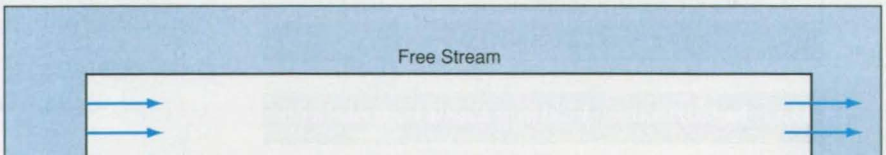
This work was done by Josette Bellan and Richard S. Miller of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 166*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).* *NPO-20068*

Mathematical Model of a Direct-Contact Pyrolysis Reactor

Gross features of pyrolysis phenomena relevant to designing efficient reactors can be analyzed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model has been developed for use in assessing the performances of direct-contact pyrolysis reactors used to convert particles of raw biomass materials (usually small wood chips) into char, tar, and gas. The optimal designs are here considered to be those that maximize the production of



The **Flat-Plate Reactor** and the flow, thermal, and chemical phenomena that take place in the reactor are represented in a simplified geometry in a Cartesian coordinate system.

tar. In such a reactor, the particles are injected along with a flow of a hot feed gas (usually, superheated steam), into a chamber with a heated cylindrical or conical outer wall, are blown along the wall by the flow of gas, and are held against the wall by centrifugal force. Thus, the particles are heated primarily by direct conduction from the wall. Incompletely pyrolyzed particles are collected at the outlet and reinjected at the inlet along with the hot gas and the raw feedstock.

The model features a simplified geometry (see figure) and some simplifying assumptions that, together, make it possible to numerically simulate gross features of flow and pyrolysis phenomena without excessive computation. The reactor wall is represented by a flat plate of finite length heated to a constant temperature T_{wall}. Superheated steam is injected in a turbulent flow at the left end of the wall with average lengthwise speed u_{inflow} and with a temperature T_{inflow}, which is somewhat less than T_{wall}. The particles are assumed to have simple parallelepiped shapes (to represent wood splinters).

The particles are assumed to remain in contact with the wall (with weight substituting for centrifugal force) with their long axes parallel to the flow. Incompletely pyrolyzed particles that leave the wall at the right end are reinjected at the left end. The reactor is represented as operating in a steady state by specifying rates of injection of feedstocks at various stages of pyrolysis (fresh particles and reentrained particles) and associated particle sizes.

The model includes submodels of pyrolysis of particles, turbulent boundary-layer flow, and particle trajectories. The pyrolysis submodel is the one described in the preceding article, "Generalized Mathematical Model of Pyrolysis of Plant Biomass" (NPO-20068), adapted to the present slab geometry. The flow submodel incorporates the long-time-averaged Navier-Stokes equations with a two-equation sub-submodel of turbulence and a no-slip condition on the wall; the flow submodel simulates the development of a turbulent boundary layer, within which the particles quickly become deeply embedded as they are convected downstream. In the particle-trajectory submodel, each particle is represented as moving under the combined influences of the flow (with drag forces represented by a simplified sub-submodel of flow in the immediate vicinity of the particle) and friction with the wall. These submodels are coupled through boundary conditions and conservation laws, and the resulting equations of the overall model are solved numerically.

Calculations were performed for two-dimensional particles of different aspect ratios as well as one-dimensional particles (in the direction perpendicular to the wall), and it was found that the one-dimensional model gives a conservative estimate of both the conversion time and of the amount of tar collected. Directional effects from variations in thermal conductivity and permeability were found to be relatively small. The evolution of pyrolysis was found to be effectively uncoupled from the boundary-layer flow and to be determined primarily by T_{wall}. The foregoing plus other findings suggest that direct-contact reactors offer potential for tar-production efficiencies greater than those of noncontact and semicontact reactors. Tar yields were found to be maximized for small particles and wall temperatures of about 800 K. Ratios between tar-output and feedstock-input rates were found to be independent of injection rates under the conditions studied.

This work was done by Josette Bellan and Richard S. Miller 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,* ***or circle no. 113*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*
NPO-20069

Elevation Corrections for Absolute-Pressure Measurements

Potential applications include process controls and scientific experiments.

Lewis Research Center, Cleveland, Ohio

A method of correcting absolute-air-pressure measurements for small differences in the elevations of pressure taps and pressure transducers has been devised. The variation in air pressure with elevation is well documented; nevertheless, in such disciplines as process control and laboratory experimentation, it has been common practice to account for pressure differences associated only with large differences in elevation along tubes that connect pressure taps to transducers. The emergence of highly accurate multiport pressure-measurement systems, coupled with the need for increasingly accurate pressure measurements, has made it necessary to correct for pressure differences associated with elevation differences as small as a meter or so. The present method can be readily incorporated into future pressure-measurement procedures to provide the necessary corrections; it can also be used to reprocess previous measurements to increase their accuracy.

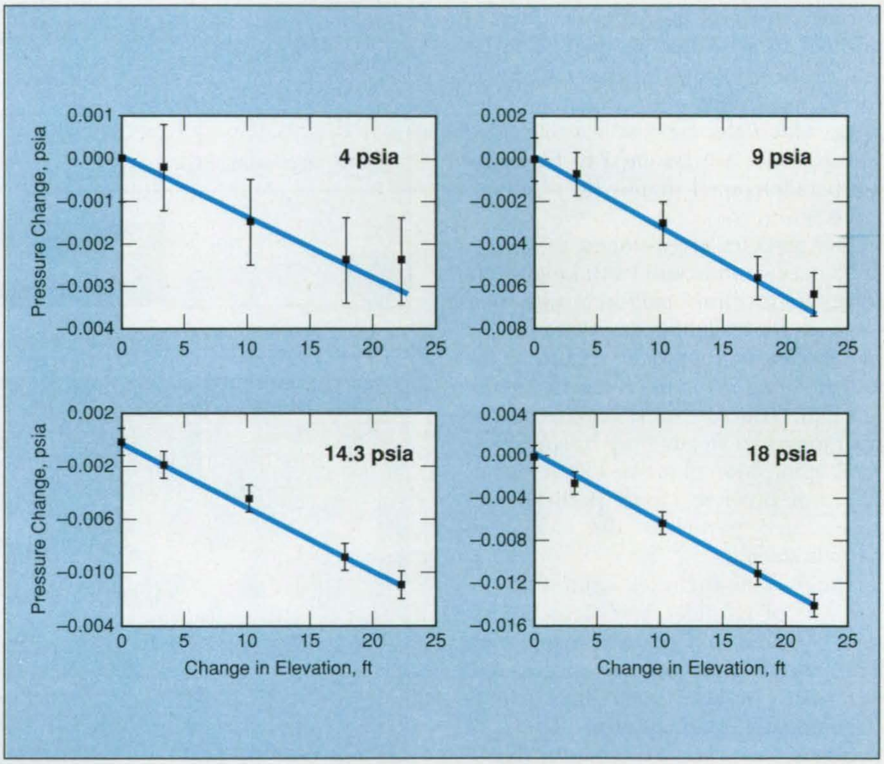
The method is based on the fact that pressure at the bottom of a measurement tube will be higher than the pressure at the top due to weight of the column of air in the tube. It is assumed that the fluid (air) is at a static equilibrium and that the temperature and the gravitational acceleration do not vary significantly over the measured height. The resulting equation for correcting a pressure reading is

$$P = P_0 e^{-\left(g\rho_0/P_0\right)y}$$

where P is the pressure at the pressure tap (the corrected or actual pressure, which one seeks), P_0 is the reading of the pressure transducer, g is the gravitational acceleration, ρ_0 is the known density of air at the known temperature and pressure P_0, and y is the difference in elevation from the transducer to the pressure tap. At 20°C, $g = 9.8$ m/s^2, $\rho_0 = 1.205$ kg/m^3, and $P_0 = 1.01325 \times 10^5$ Pa; therefore,

$$P = P_0 e^{(-1.16546\times10^{-4})y}$$

The method was tested in a series of measurements in air at a temperature of 70 ± 5°F (≈21 ± 3°C) on two commercial pressure gauges at various pressures and elevations. After corrections for biases between the two gauges, the results (see figure) indicate that the predicted and measured variations of pressure with height agree with each other to within 0.001 psi (≈7 Pa).



Calculated and Measured Changes of Pressure agreed with each other within the range of nonrepeatability of the pressure-gauge readings [about 0.001 psi (≈7 Pa)].

This work was done by Joseph W. Panek and Mark R. Sorrells of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 127*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*

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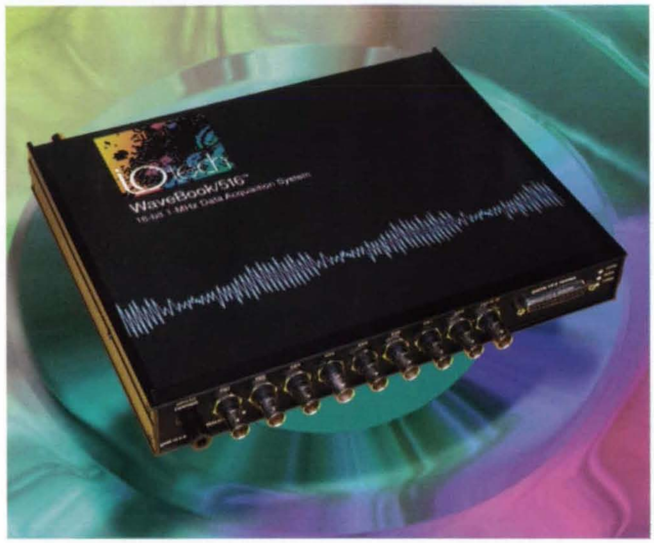

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CIRCLE 404

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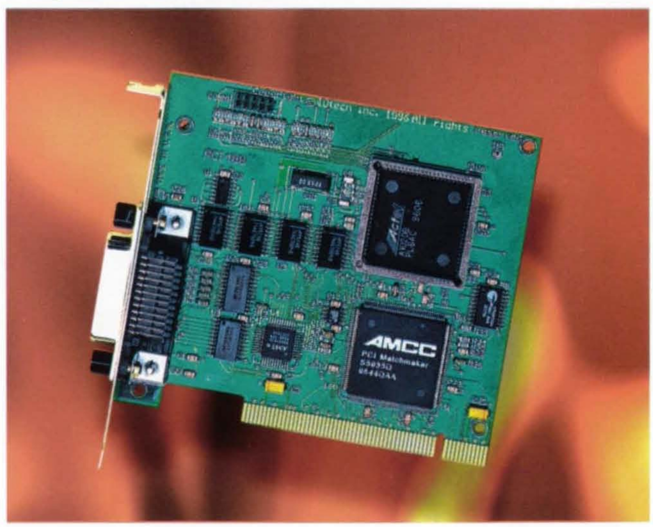

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CIRCLE 405

Materials

High-Performance Thermal Insulation for a Racing Car

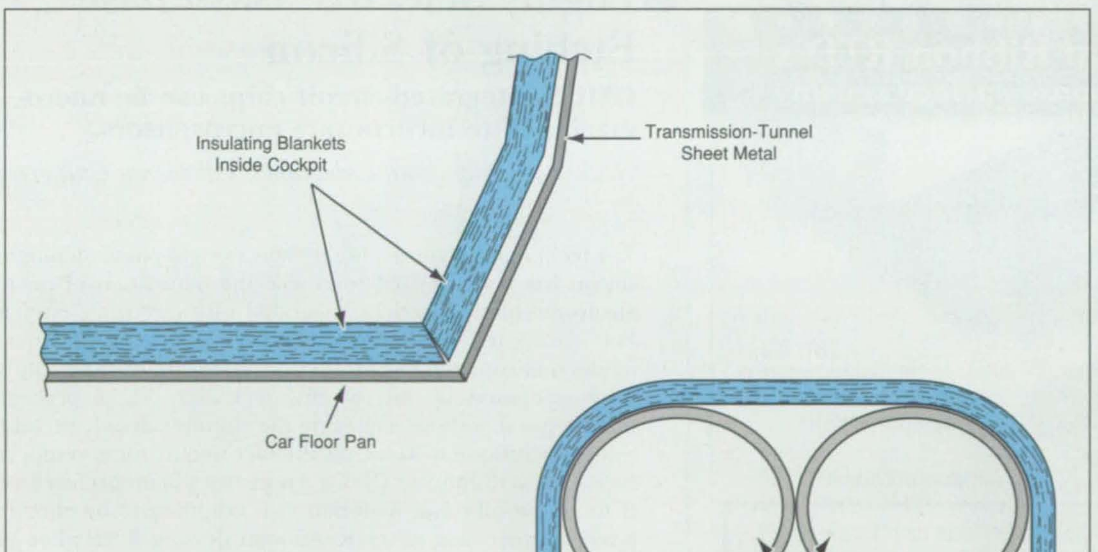
Space-shuttle-type insulating blankets can protect a driver against hotspots.

John F. Kennedy Space Center, Florida

Thermal-insulation blankets developed for use aboard the space shuttle can be adapted to a racing car to protect the driver against excessive cockpit heating. [Also see an earlier article under "Mission Accomplished," *NASA Tech Briefs,* Vol. 20, No. 8 (August 1996) page 20.] Thermal protection for the driver is necessary because, unlike the passenger compartment of a conventional automobile, the cockpit of a racing car is subject to intense heating as a result of unique racing-design features.

In particular, the exhaust pipes are routed so close to the sheet metal of the floor pan and transmission tunnel that a significant portion of the heat radiated by the exhaust system (at a power density of about 12 kW/m²) enters the cockpit, and even at high speed, the airflow is so limited that the cockpit is not cooled to a comfortable or even a safe temperature. Hotspots can develop near the driver's right foot and under the driver's seat. In the absence of thermal protection, a driver can sustain localized second- or third-degree burns. Although a cooling suit can be used to protect the driver, it adds undesired complexity and weight. In addition, a malfunction in the active cooling system could result in active heating of the driver.

Space-shuttle-type insulating blankets offer effective passive thermal protection, without contributing excessively to complexity or weight. The insulating blankets are of three different types: one type for installation on the exhaust and tailpipes, the other two types for installation in the cockpit. The exhaust-system blankets are made partly of a material called "advanced flexible reusable surface insulation" (AFRSI), which comprises a ceramic microfiber core between two glass-fabric face sheets quilted with a ceramic thread. The AFRSI of each blanket is covered with an outer nickel-alloy foil 0.001 in. (25 µm) thick. The foil cover is designed to increase the durability of the blanket, provide some shielding against radiation, and provide for mechanical attachment to enable safety wiring of the blanket to the exhaust-system components. The foil shell is closed along the edge of the blanket by a single fold (followed by rolling) and secured with stainless-steel staples. The single fold is designed to minimize thermal conduction while providing adequate strength. Grommets provide additional reinforcement for the seams and serve as attachment fixtures.



High-Performance Insulating Blankets made of spacecraft-grade materials can be used to prevent excessive transfer of heat from exhaust pipes to the interior of a racing-car cockpit.

The blanket is contoured to the compound curves of the exhaust-system components. The entire blanket is less than 0.5 in. (1.3 cm) thick, yet acts as a highly efficient thermal-radiation shield with low thermal conduction. To prevent overheating of the exhaust and tailpipes, the blanket is installed only over the top of the exhaust system, leaving the bottom exposed to airflow. Because the blanket is made solely of metal, ceramic, and glass, it is nonflammable and does not outgas significantly during use.

The blankets of first cockpit-interior

type are placed under the driver's seat and in floor areas to the left of the seat. Each blanket comprises a (1) a core of low-density, highly resilient glass-microfiber mat between 1 and 2 in. (between 2.5 and 5.1 cm) thick enclosed in (2) a radiation-barrier shell made from layers of an aluminized high-temperature-resistant film and sealed by a high-temperature-resistant adhesive tape, all enclosed in (3) a durable outer shell made of glass cloth impregnated with polytetrafluoroethylene (space-suit material).

The blankets of the second cockpit-interior type are used to insulate the transmission-tunnel/foot-well area. These blankets are made from AFRSI 0.5 in. (1.3 cm) thick, enclosed in glass cloth impregnated with polytetrafluoroethylene. AFRSI was chosen because of its ability to maintain known thickness over a range of compressive loads. The polytetrafluoroethylene-impregnated glass cloth provides durability. The blankets of both cockpit-interior types are designed to be lightweight, to provide maximum thermal insulation, to be nonflammable, and to provide additional protection to the driver in the event of a collision or fire.

This work was done by Bruce V. Lockley of **Kennedy Space Center** *and Martin J. Wilson, Jean M. Charvet, and Suzanne M. Hodge of Boeing. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 111*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11938.

Highly Selective Gas-Phase Etching of Silicon

CMOS integrated-circuit chips can be micromachined to incorporate microsensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique of gentle, highly selective gas-phase etching of silicon has been devised to enable the fabrication of microelectromechanical devices integrated with electronic circuits. For example, newly fabricated complementary metal oxide/semiconductor (CMOS) integrated-circuit chips can be micromachined by use of this technique to incorporate microsensors, without damaging the circuitry already present.

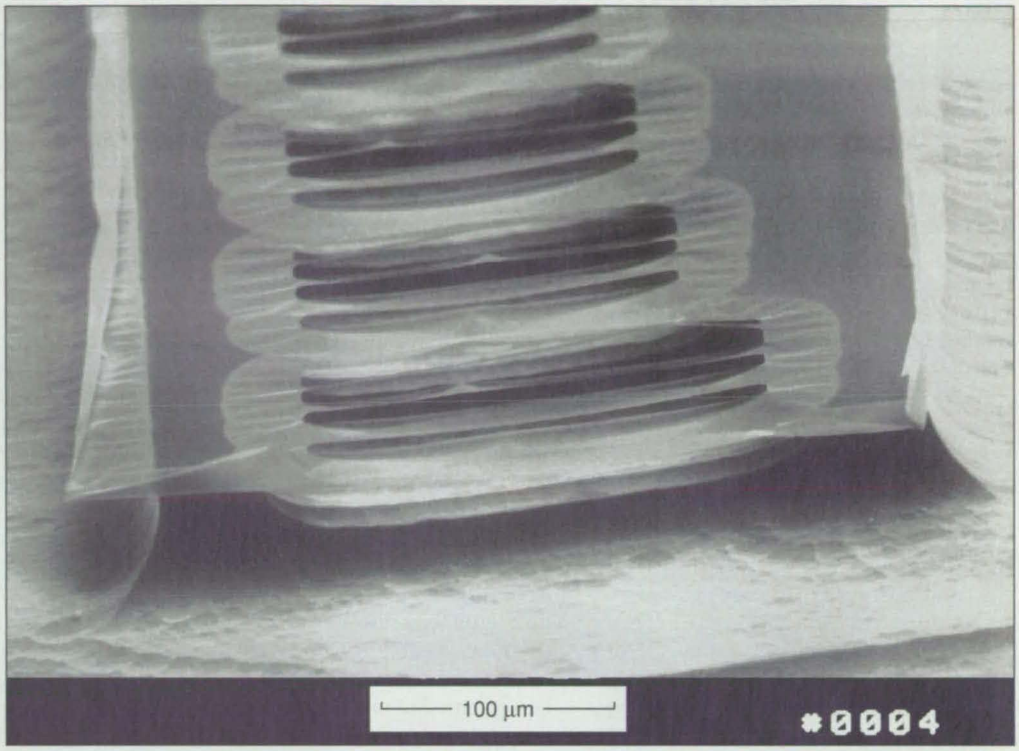
The technique is based on the fact that at room temperature, xenon difluoride (XeF_2) gas etches silicon preferentially to almost all other materials that are likely to be encountered in processing of semiconductor devices. Even when silicon is etched by XeF_2 to a depth of hundreds of microns, there is no appreciable etching of adjacent uncured or cured photoresist, oxide, metal, or polymeric structures with dimensions down to fractions of a micron.

Another notable advantage of gas-phase etching with XeF_2 is that unlike liquid-phase etching, it does not involve hydrodynamic forces that could damage fragile micromechanical structures like those shown in the figure. Still another advantage of etching with XeF_2 is that since it can be done at room temperature, there is no risk of the diffusion that can occur at high temperature, ruining the devices being fabricated.

At room temperature and atmospheric pressure, XeF_2 is a white solid. However, at room temperature, it sublimates at a vapor pressure of several torr (several hundred pascals). Thus, XeF_2 can easily be converted to the gas phase by placing it in a vacuum system of modest capability.

Etching by XeF_2 is performed in a chamber connected by valves to a vacuum pump and to a source of XeF_2. First, the chamber is pumped down to a pressure of a few millitorr (a few tenths of a pascal). Then the valve to the source of XeF_2 is opened and adjusted to maintain the pressure in the source at about 1 torr (≈ 133 Pa), so that XeF_2 gas is released at a suitable rate and concentration. Under these conditions, etching of single-crystal silicon has been observed to proceed at typical rates between 3 and 5 μm/min, and occasionally at rates as high as 10 μm/min. The etch is nearly isotropic and insensitive to the type and concentration of dopant.

This work was done by Michael H. Hecht of Caltech and Kristofer S. Pister and Ezekiel Kruglick of UCLA 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,* ***or circle no. 114*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19902



Microscopic SiO_2 Plates and Beams were fabricated in place on a silicon substrate, then suspended over a pit in the substrate by using XeF_2 gas to etch the silicon out from under them. Aluminum pads are visible at the upper right.

For More Information Circle No. 423

Computer Software

Software for Processing SAR Images of the Polar Oceans

The RADARSAT/ERS-1,2 Geophysical Processor System (RGPS) is an automated system of hardware and software that processes synthetic-aperture-radar (SAR) images of ice and open water in polar oceans to generate higher-level geophysical-data products. Information in such products includes the age and thickness of ice and the onset of melting or freezing. They are all computed by algorithms contained in the RGPS software. In addition to the SAR image data themselves, meteorological fields are used in the analysis of the SAR imagery; therefore, interfaces with external meteorological sources have been established to capture meteorological data. The RGPS is intended to be installed as a subsystem of the Alaska SAR Facility (ASF), though testing of the RGPS had not yet been completed at the time of reporting the information for this article. In operation as subsystem of the ASF, the RGPS would be able to place requests for acquisition of raw SAR data and for preprocessing of those data by other hardware and software, would ingest the preprocessed data, would generate its standard data products routinely, and would deliver these products to an archive for long-term storage and distribution. In addition to the aforementioned geophysical data products generated from SAR imagery, the RGPS would also produce daily surface-pressure, wind, and temperature data on a gridded field.

This program was written by Ronald Kwok, Shirley Pang, Amy Rodgers, and Glenn Cunningham of Caltech for **NASA's Jet Propulsion Laboratory**. *No further documentation is available.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20021.

Software for Tracking the Performance of Other Software

The Flight Software Memory Tracker (FMT) computer program is a collection of utility subprograms developed for use on the ground to track images of the flight software (FSW) in the computers aboard the Cassini spacecraft. [As used here, "images" signifies both (1) the memory load and updatable parameters in the spacecraft computers and (2) logically equivalent representations thereof.] FMT maintains a history of every FSW image aboard the spacecraft ("FSW image" for short), updating the ground copies of the images ("FMT images" for short) whenever the FSW images are updated. When FSW images are updated by uplink commands transmitted to the spacecraft, FMT can translate the commands into update data groups to be appended to FMT images. FMT images can also be updated by readout from spacecraft computer-memory addresses, which readout is performed in addition to normal telemetry downlink. FMT can also generate commands to update both FSW and FMT images at a specified time. The FMT images can be evaluated at any historic time, can be queried for history and statistics, and can be processed to obtain, for example, human-readable values of parameters in engineering units. FMT, which is written in Java, can be ported to computers, with various architectures and operating systems, that are equipped with Java interpreters.

This program was written by Edwin Kan, Allan Wax, and Hal Uffelman 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 Computer Software category,* ***or circle no. 147*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20200

Software for Scheduling Use of Shared Resources

The Quick Utility for Intelligence Planning and Scheduling (QUIPS) computer program automates the scheduling of resources that must be shared among multiple tasks or groups. Designed to aid coordination of military intelligence operations at the division and brigade levels, QUIPS might also prove useful in coordinating other large-scale operations in which resources and tasks are dispersed to various locations. QUIPS generates one primary display to show all resources on a battlefield or other area of interest, the statuses of the resources, and timeliness for their availability. A graphical user interface enables the user to point and click instead of type, thereby reducing the user's workload and increasing efficiency. In the original military application, QUIPS is coupled with the Tactical Movement Analyzer (TMA) and Sensor Placement Analyzer (SPA) programs to create an end-to-end asset-management software module. TMA digests data on roads, rivers, railroads, urban areas, vegetation, and elevation to present a picture that helps a military analyst determine the possibilities for movement by enemy and friendly forces. SPA helps in determining the most effective locations for placing a limited number of sensors, taking account of the area that could be covered by each sensor at a given location, and of effects of weather, terrain, and distance on the propagation of radio signals to and from the sensors.

This work was done by Nora Mainland, Kurt Stadsklev, and Paul Maglio 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 Computer Software category,* ***or circle no. 165*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20207.

Software for Development of Spacecraft-Simulation Programs

DARTS Shell (Dshell) is a multimission spacecraft simulator for the development, integration, and test of flight software and hardware. Dshell reduces the time and cost of developing simulation programs by enabling the development of the software in modular, reusable form and by providing a host of generic capabilities that simplify the development process and enhancing run-time usability. Dshell combines (1) the DARTS program (described in the following article), which is a computational engine that solves equations for the flexible dynamics of both spacecraft and nonspacecraft multibody systems with (2) libraries of mathematical models for such hardware items as actuators, sensors, motors, and encoders into (3) an integrated simulation-environment software system that can be easily config-

ured and interfaced with flight software and hardware according to requirements for various real- and non-real-time simulations. Dshell is portable from desktop computer workstations to real-time, hardware-in-the-loop simulation environments. Dshell is in use by several of NASA's projects, including Cassini, Galileo, Mars Pathfinder, and several projects in the Flight System Testbed at NASA's Jet Propulsion Laboratory.

This program was written by Abhinandan Jain and Jeffrey Biesiadecki 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 Computer Software category,* ***or circle no. 135*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20248

Program for Simulating Dynamics of Multibody Systems

The Dynamics Algorithms for Real-Time Simulation (DARTS) computer program solves the equations of motion of tree-topology, flexible, and/or multibody mechanical systems as diverse as molecules, mechanisms, robots, spacecraft, and ground vehicles. It has proven to be particularly useful for real-time simulation of the dynamics of spacecraft. DARTS enables the use of high-fidelity mathematical models of the dynamics of spacecraft, without sacrificing simulation speed. DARTS is based on state-of-the-art algorithms from the spatial-operator-algebra formulation for multibody dynamics. This formulation, which has been reported in a number of previous issues of *NASA Tech Briefs*, was developed expressly for modeling the dynamic behavior of complex, articulated collections of bodies (principally, multiple-link robot arms) that interact with each other in free space or in contact with other bodies in the environment. Both DARTS and the Dshell software described in the preceding article have been executed on a variety of UNIX and VxWorks platforms.

This program was written by Abhinandan Jain, Guillermo Rodriguez, and Guy K. Man 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 Computer Software category,* ***or circle no. 134*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20168

COSMIC, NASA's Software Technology Transfer Center, has an inventory of over 800 software packages that originally were developed by NASA and its contractors for the U.S. space program. These packages have a wide range of applications other than space exploration and are used by industry, academic institutions, and other government agencies.

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Mechanics

High-Wind Masts for Meteorological Instruments

The masts would be faired to minimize aerodynamic loading of the structures.

John F. Kennedy Space Center, Florida

Rigid, guyed masts of a proposed type for supporting meteorological instruments would be designed to withstand considerably stronger winds than those conventionally used. The proposed fairings would also help minimize perturbations of airflows and thereby minimize the contaminating effects of the masts on measurements taken by instruments mounted on the masts.

The masts would be constructed in modular sections, each 3.3 m long, that could be connected together to achieve the desired overall height. Typically, three sections would be used (see figure) to obtain the standard wind-sensor height of 10 m as specified by the World Meteorological Organization. The base of the mast would be mounted rigidly in the ground.

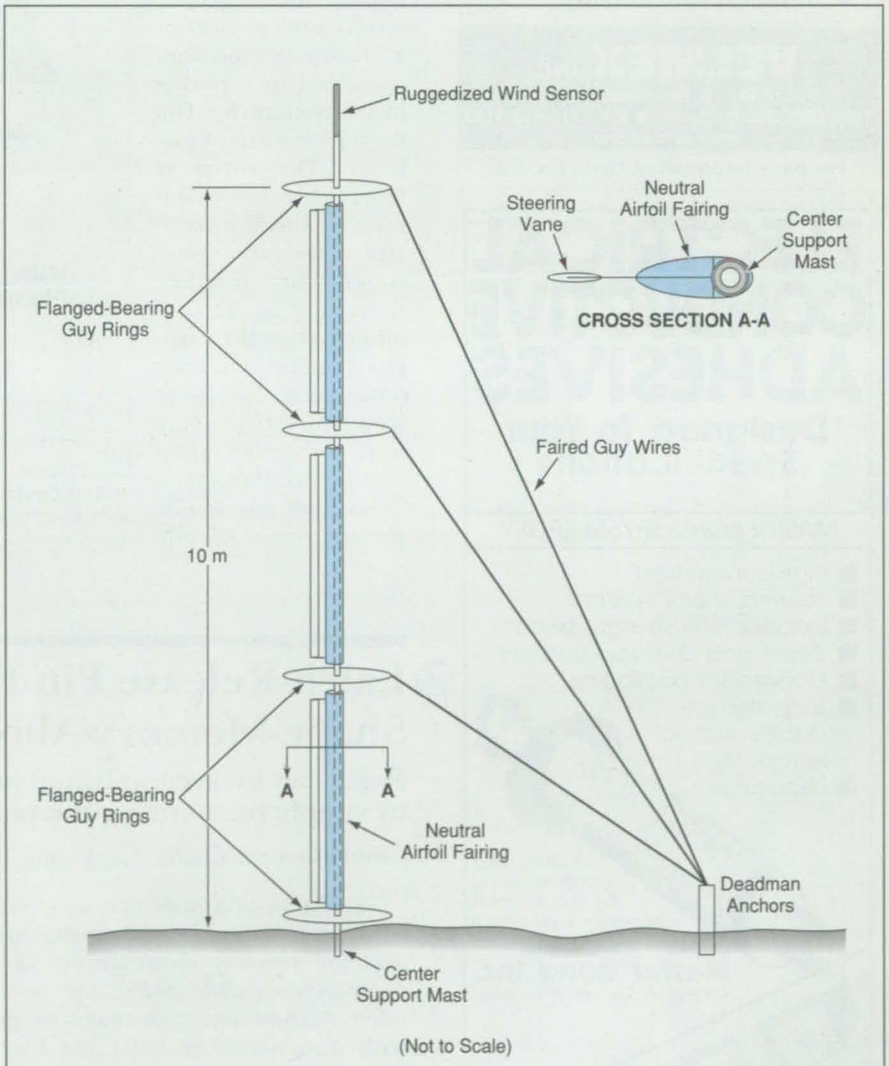
The main structural member in each section of a mast would be a cylindrical tube. The fairing would be a vertically finned, neutral-lift airfoil that would surround the tube. The airfoil would be free to pivot azimuthally around the tube to align itself with the wind as directed by the vertical fin section. The airfoil would pivot on bearings mounted on circular flanges at the ends of the tube. The circular flanges above each section would provide attachment points for guy wires. The flanges at the lower end of the sections could serve as bearing surfaces.

To minimize aerodynamic drag caused by vertical winds acting on the circular flanges, the size and shape of the flanges should be kept to a minimum but consistent with the need to provide clearance between the guy wires and the airfoils. The airfoil ends should be trimmed to eliminate mechanical interference with the flanges or guy wires. If there is a need for further reduction of the wind load on the entire structure, then the guy wires could also be faired with airfoils in a manner similar to that of the sections of the mast.

When a cylinder is faired with a neutral-lift airfoil which is free to pivot with the wind, the effect is equivalent to dividing the drag coefficient, diameter, or length of the cylinder by approximately a factor of 8. Conversely, it could be viewed as reducing the equivalent speed of the wind acting on the cylinder to $8^{-1/2}$ ($\approx 1/2.8$) of its actual value. This approach can result in substantial improvements of non-aerodynamically-faired conventional towers and masts, which can typically withstand winds of no more than about 125 mi/h (56 m/s). Simply by changing the structural members to self-aligning, neutral-lift airfoils, wind loads would be reduced enough to enable the structures to withstand winds up to 350 mi/h (156 m/s).

This work was done by Jan A. Zysko of **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 141*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-6225. Refer to KSC-11741.



This **Aerodynamically Faired Mast** would withstand high winds and introduce minimal perturbations into the flow of air around the meteorological instrument(s) mounted on top.

Self-Contained Impact-Type Damper for Bellows-Type Face Seals

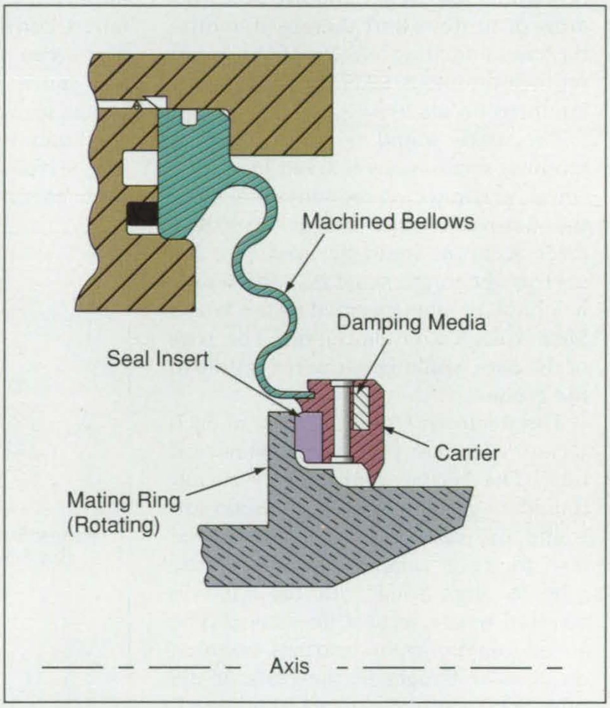
This damper suppresses dynamic instability or chatter due to stick-slip phenomena and fluid vaporization.

Marshall Space Flight Center, Alabama

A self-contained impact-type damper for a bellows-type face seals suppresses dynamic instability or chatter. In current practice, damping in a typical seal is accomplished through rubbing contact between a ground (a stationary member) and a bellows or carrier as the seal translates. Usually, the rubbing contact occurs through a third member. This contact results in the potential for the carrier to seize, with consequent limitation of axial travel. It also makes for a complicated assembly, susceptible to assembly error.

The self-contained impact-type damper (see figure) consists of a damping medium contained in a pocket in an insert carrier. The medium consists of particles. The cavity is filled to less than its full volume with the particles, leaving some room for motion. Damping is accomplished when the particles impinge on each other and the cavity walls, absorbing energy from the carrier when it begins to vibrate.

This work was done by Richard James Kloepfer and Michael Howard Dills of UTC/Pratt & Whitney, Government Engines & Space Propulsion, for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 198*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
MFS-31188



A **Self-Contained Impact-Type Damper** has been incorporated into an advanced bellows-type lift-off face seal in a high-pressure turbopump.

Latch-Release Pin Puller With Shape-Memory-Alloy Actuator

Reset can be accomplished manually or automatically by simply reextending the pin.

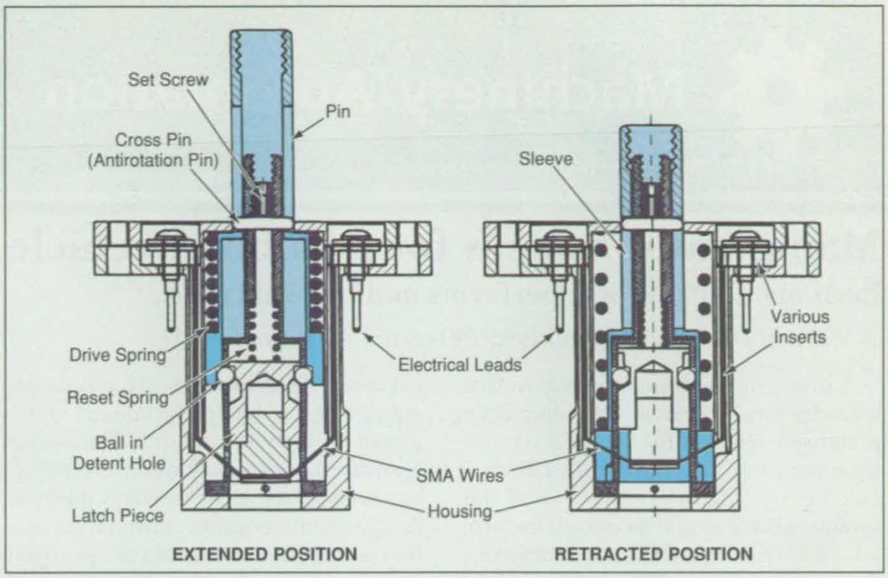
Lewis Research Center, Cleveland, Ohio

The figure illustrates one of several related pin-puller mechanisms that harness the recovery characteristics of a shape-memory alloy (SMA). Like some other SMA-actuated mechanisms described previously in *NASA Tech Briefs*, this pin puller is suitable for use in place of a pyrotechnically actuated pin puller and can be operated under remote control to release a door and/or deploy a stowed object, for example. Unlike pyrotechnically actuated pin pullers, this and other SMA-actuated pin pullers can be reused.

The SMA component in this pin puller serves as a trigger to release potential energy stored in the driver spring. This spring biases the pin toward retraction (downward in the figure). However, under normal (nonactuation) conditions, the pin is set in the extended (uppermost) position and the ball-detent latch prevents retraction.

A component made of an SMA undergoes a pronounced deformation to a "remembered" shape when its temperature rises through a transition value, causing a transformation in its metallurgical structure from a martensitic to an austenitic phase. In this case, the SMA component is a wire, made of a nickel/titanium alloy denoted by the trade "Nitinol," that has been stretched. To initiate retraction of the pin, electric current is made to flow along the wire, thereby heating the wire above its transition temperature and causing it to shrink to its "remembered" (unstretched) length. The shrinkage of the wire pulls the latch piece upward, against the downward bias of the reset spring. As a result, the balls are no longer forced to protrude through the detent holes. Thus, the balls no longer block the retraction of the pin.

Later, the mechanism can be reset by pulling on the pin to extend it. Provided that the SMA wire has cooled enough to recover its stretched length, the mechanism will remain reset because the reset spring biases the latch piece into its lowest position, where it forces the balls to protrude through the detent holes.



In this **SMA-Actuated Pin Puller,** the SMA wire serves as a trigger that releases potential energy stored in the driver spring.

This work was done by Michael Bokaie of TiNi Alloy Co. for **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 167*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16511.

Manipulator System for a Robotic Vehicle

Each manipulator arm performs multiple functions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype manipulator system that includes two different arms has been tentatively selected for use on a semiautonomous robotic vehicle called *Rocky 7* (see figure). [A previous version of this vehicle with a single manipulator arm was described in "High-Performance Robotic Vehicle" (NPO-19921) *NASA Tech Briefs*, Vol. 21, No. 1 (January 1997), page 67.] *Rocky* 7 is the most recent one in a series of such vehicles that are candidates for use in future remotely controlled scientific exploration of the surface of Mars. In comparison with the *Sojourner* vehicle deployed on Mars from the Mars *Pathfinder* spacecraft in July 1997, *Rocky 7* would carry more scientific instrumentation and would function with greater autonomy, mobility, and capability for manipulation. The basic design of *Rocky* 7 and the other vehicles in the series could also be adapted to such terrestrial uses as remote surveillance and/or manipulation in remote and/or hostile environments.

The joints in the two manipulator arms are back-driveable and feature modular, lightweight, high-torque, gearmotor-type actuators, which were described in "Actuators for Rapid Development of Prototypes of Robots" (NPO-20054), *NASA Tech Briefs*, Vol. 21, No. 3 (March 1997), page 94. Both the actuators and the arm segments are hollow; this makes it possible to use the insides of the actuators and arms as optical paths and to hold electrical wires for actuators and for scientific instruments.

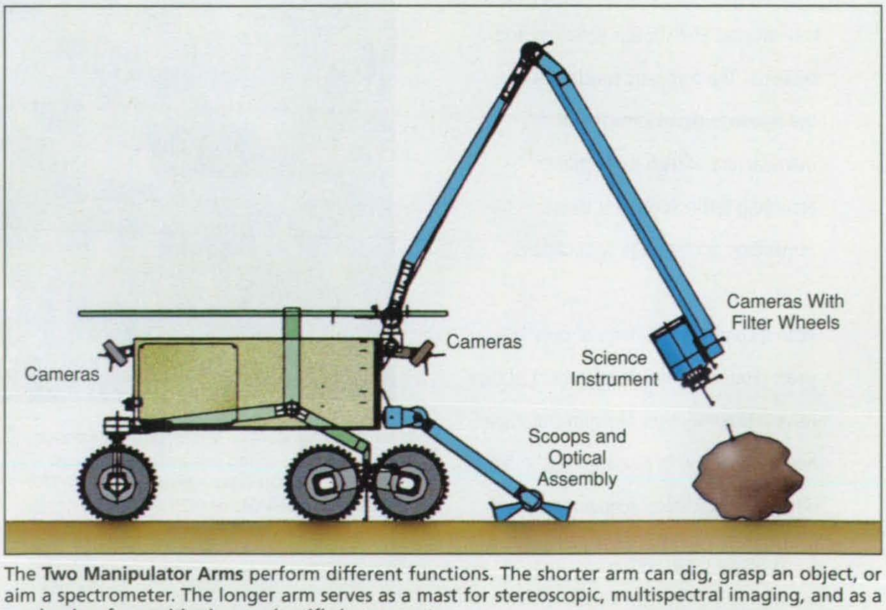
Mounted on the outer end of the shorter arm are two scoops and an optical assembly. The scoops can be used to dig (to a depth of 10 cm), hold, and dump soil samples; they can also be used to grasp an instrument canister; e.g., for burying a seismometer. The total mass of the arm is 0.65 kg. The arm can carry a payload of as much as 1 kg in normal Earth gravity.

The optical assembly includes two mirrors, with a fiber-optic connection along the arm to a spectrometer housed in the vehicle chassis. The optical assembly constitutes the input optical device of the spectrometer, and is aimed by turning the arm. The optical aperture is open only when the scoops are rotated to the back-to-back position. A spectrometer-calibration target can be rotated into or out of the spectrometer field of view by rotating both scoops together through a full circle.

Mounted on the outer end of the longer arm is an integrated sensor package that contains the following: (1) two stereoscopic video cameras with counterrotating filter wheels, and (2) an instrument canister that can be outfitted with either a gimballed close-focus camera, Mössbauer spectrometer, nuclear magnetic resonance spectrometer, or other science instrument. The arm can be extended to a height of 1.4 m above ground; it can be used to rotate the cameras through a complete circle for panoramic imaging of the surrounding terrain, to position the cameras for viewing objects of scientific interest from above, or to position the cameras to inspect the vehicle. The total mass of the longer arm is 0.7 kg. The arm can carry a scientific instrument as massive as 0.5 kg in normal Earth gravity.

Both arms can be stowed compactly, without interfering with the suspension and wheel-drive mechanisms, with a solar photovoltaic panel that supplies the power for the vehicle, or with another stereoscopic camera system that is used to guide the vehicle across the terrain as well as image the activities of the arms. An onboard electronic control system is used to operate both the vehicle drive motors and the actuators in the manipulator arms; this system provides variable-rate motor control, detects errors in joint angles, prevents collisions of the arms with objects in the vicinity, controls contact of mast instruments with the target rock, analyzes images of potential digging areas to prevent futile attempts to dig in rock, and visually verifies successful manipulator operations.

This work was done by Richard Volpe, Timothy Ohm, Richard Petras, Richard Welch, J. (Bob) Balaram, and Robert Ivlev 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,* ***or circle no. 152*** *on the TSP Order card in this issue to receive a copy by mail ($5 charge).*
NPO-20162



The **Two Manipulator Arms** perform different functions. The shorter arm can dig, grasp an object, or aim a spectrometer. The longer arm serves as a mast for stereoscopic, multispectral imaging, and as a mechanism for positioning a scientific instrument.

Software for Planning in a Hierarchical Processing Environment

Mathematical models predict effects of variations in process parameters.

John F. Kennedy Space Center, Florida

Decision-support software based on discrete-event simulation (DES) has been undergoing development for use in planning and scheduling work in the Orbiter Processing Facility (OPF) at Kennedy Space Center. The software is also suitable for adaptation to similar use in other facilities characterized by low-volume processing and by hierarchical processing environments with multiple subfacilities and with dependencies of tasks on resources and on the prior completion of other tasks.

DES is traditionally applied to mass-production manufacturing environments, where processing volumes are large. DES can enhance decision-support systems by providing the means for mathematical modeling of the effects of uncertainties in parameters. In DES, parameters are treated as being variable with probability distributions; this makes it possible to perform computational simulations to quantify the effects of changes in parameters upon critical outputs, before changing the parameters in a real process or system. In mass-production environments, parameters such as queue lengths and throughput rates are relevant, but in the dynamic processing environment of the OPF, different parameters become relevant.

The developmental software system includes subsystems that implement mathematical models for planning the flow of work at two levels: (1) the OPF task level and (2) the interfacility level. These models have been built by use of commercially available DES software.

The model for the OPF task level is a generic, reusable one that simulates a network of tasks. As each simulated task begins, an attempt to obtain the resources necessary to complete the task is made. If the resources cannot be obtained, the task waits. The output information provided by this model includes the amount of time each task waited for resources, amounts of resources utilized, and the total duration (and variance of duration) of a project.

The model for the interfacility level can also be characterized as a launch-processing-simulation model. This model evaluates the number of launches per year, based on expected process durations and numbers of OPF shifts available. Inasmuch as fixed "milestone" dates are available as inputs, a deviation from a planned launch date can be evaluated in the near term. The model can be used to evaluate workers' overtime needed to meet a planned launch date in the near term and the expected number of launches per year in the long term.

This work was done by JoAnn Leotta of **Kennedy Space Center** *and Robert R. Safford and Matt Archer of the University of Central Florida. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mathematics and Information Sciences category,* ***or circle no. 160*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
KSC-11936

Consortium Benchmarking in a Competitive Environment

The best features of proven benchmarking models are combined in an innovative approach.

John F. Kennedy Space Center, Florida

The Kennedy Benchmarking Clearinghouse (KBC) is an organization for implementing an emerging methodology called "consortium benchmarking" in a competitive business environment. The partners in the KBC include NASA Kennedy Space Center and a number of its contractors. Within the KBC, the partners are represented by professionals in quality management and related disciplines.

"Benchmarking," as used here, is a disciplined approach for comparing and measuring your processes against best-in-class organizations (in any industry), identifying the best practices that enable superior performance, and adapting those best practices within your own organization to achieve breakthrough performance improvements. Benchmarking denotes a methodology, based on principles of quality management and process improvement, for developing and using quantitative and qualitative techniques, measures, and criteria for assessing the performances of processes and organizations. This methodology encompasses intra- and/or inter-organizational standardization, as appropriate, to facilitate exchanges and comparisons of performance-assessment information among individuals and organizations, with the ultimate goal of adapting best practices and thereby improving performances.

Consortium benchmarking — benchmarking performed by a group or groups of organizations — is predicated on collaborative, long-term partnerships for sharing the best and most effective practices of all member organizations and of innovative "best-in-class" outside organizations as well. It offers a less-costly alternative to conventional benchmarking because member organizations share the burden of benchmarking studies. Consortium benchmarking is appropriate when any or all of the following conditions occur:

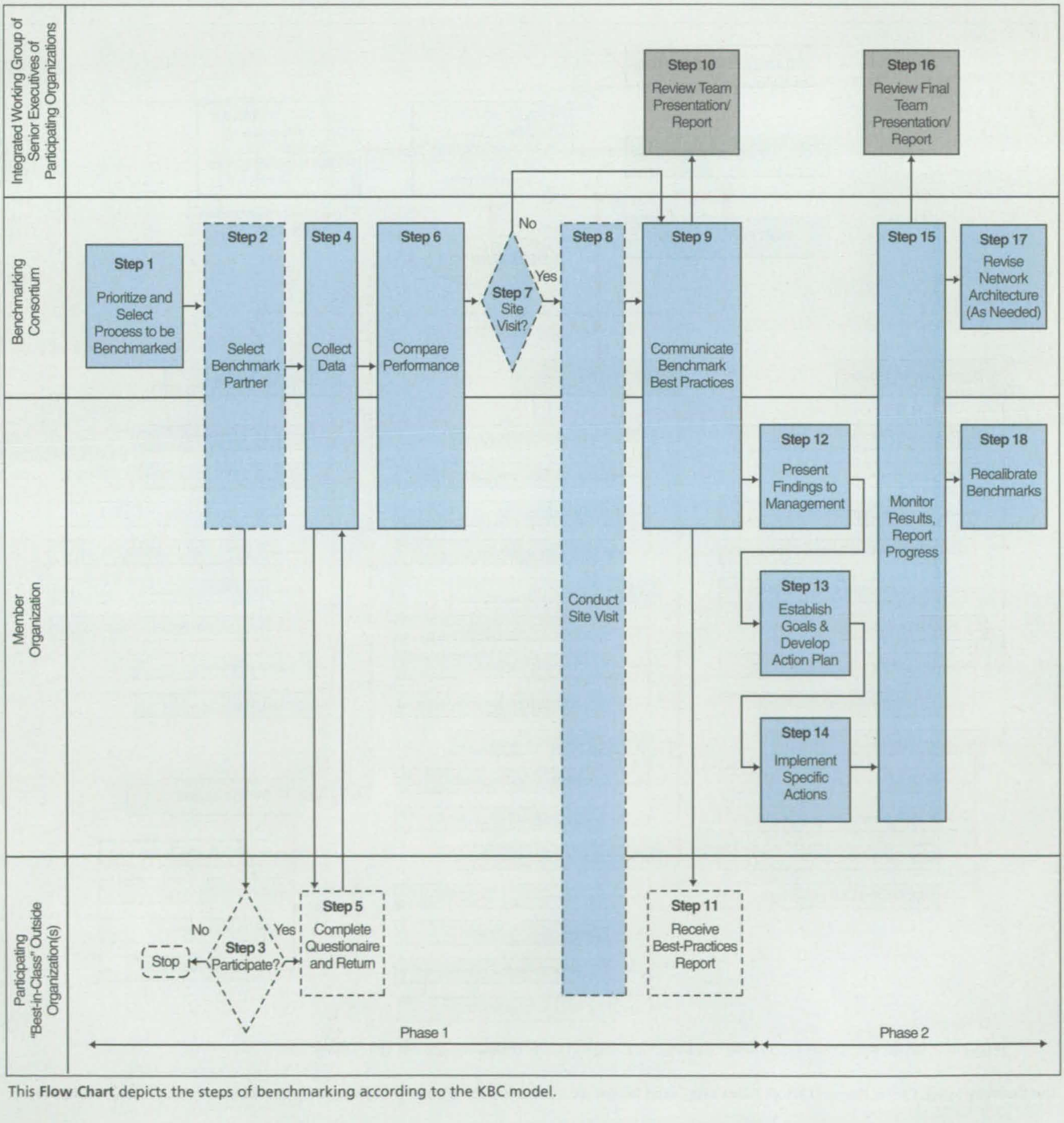
- Partners have limited resources to devote to benchmarking.
- Partners have minimal experience in performing benchmarking studies.
- Partners share a technological culture and language, so that meaningful comparisons can be made quickly and easily.

- Partners share the same measurement system.
- Partners frequently use similar technologies, processes, and systems.
- Partners are located in proximity.
- Partners meet regularly or at least have already established a forum.

The KBC model for consortium benchmarking (see figure) incorporates a vision, a charter, a two-phase methodology, norms, a reporting structure, and a code of conduct. Within the KBC, processes to be examined in benchmarking studies are selected according to a consensus approach that reflects a multiple-organizational determination of needs, priorities, and objectives. The KBC has provided a foundation for continued benchmarking at Kennedy Space Center through the development of common terminology and techniques. In addition to enhancing benchmarking skills among members, the KBC has strengthened an organizational culture that values continual improvement and teamwork to achieve excellence. This unique model for consortium benchmarking is transferable to other organizations interested in accelerating business changes that can lead to large improvements in the performances of products, processes, and services.

This work was done by Tim Barth of **Kennedy Space Center**; *Cathy L. Horton of NASA Headquarters; Darcel E. Drew of the Boeing Co.; Jeannette J. Eads of EG&G Florida, Inc; Nilgun A. Leavitt of Dynacs Engineering Co., Inc.; Sara C. Morrison of United Space Alliance; and Fred A. Lockhart of Lockheed Martin. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mathematics and Information Sciences category,* ***or circle no. 161*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-6225. Refer to KSC-11888.



This **Flow Chart** depicts the steps of benchmarking according to the KBC model.

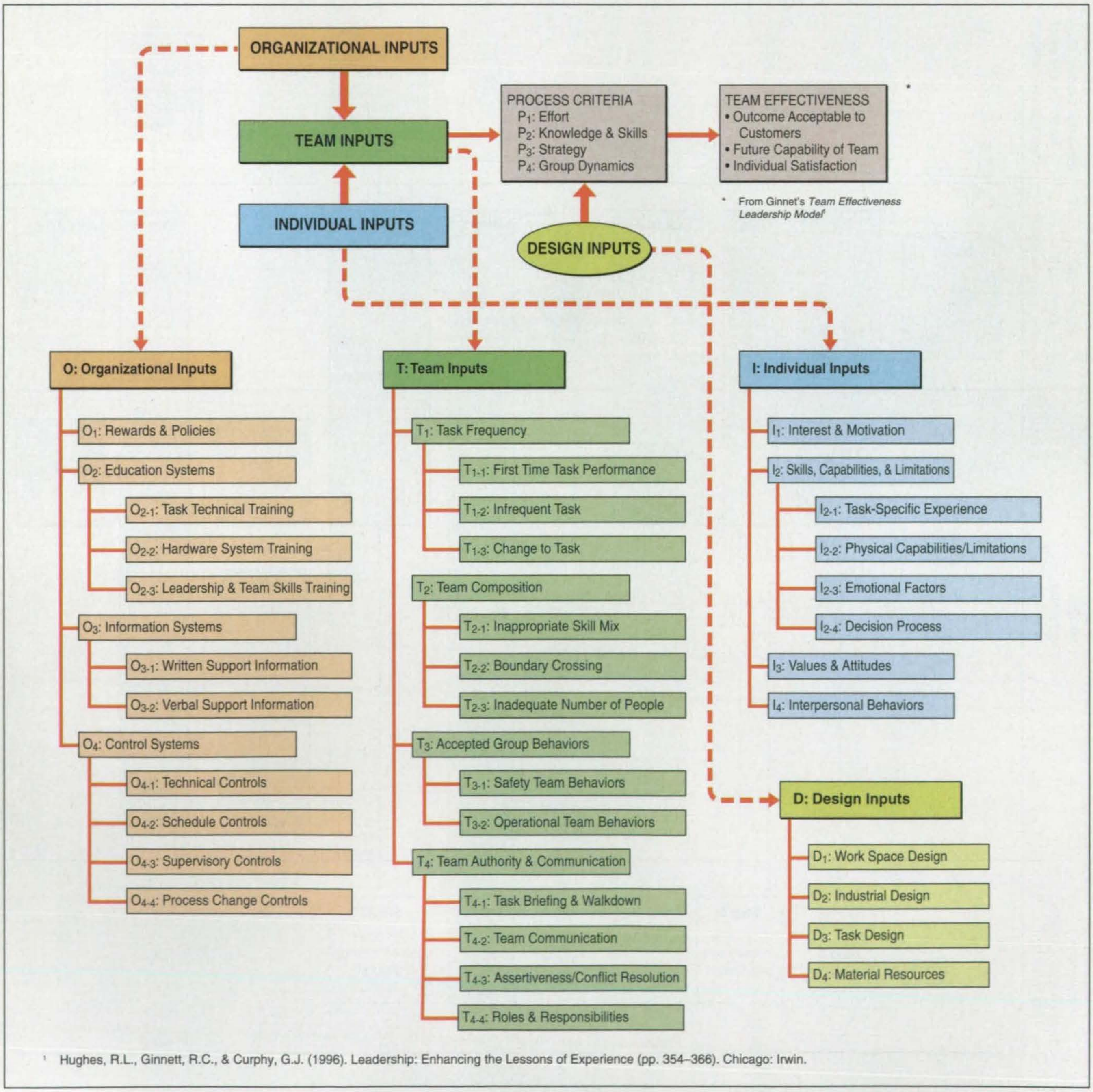
Model for Investigating Human Factors in an Organization

Contributing causes of mishaps can be analyzed in depth.

John F. Kennedy Space Center, Florida

The Kennedy Space Center Human Factors Event Evaluation Model is a model to facilitate long-term gathering and analysis of data to investigate the effects of human factors on the operations of a complex organization. The model was developed specifically for use in comprehensive human-factors-oriented analysis of events, mishaps, and processes in space-shuttle processing at Kennedy Space Center; it can also be adapted to other organizations that function through interactions of human and equipment subsystems. The main purpose of such analysis is to understand root causes of human errors so as to be able to (1) prevent recurrences of previously observed mishaps and (2) recognize the potential for other mishaps that have not yet been observed and take proactive measures to prevent them.

The present model was developed by extension of a more generic model, called the "Team Effectiveness Leadership Model," the purpose of which was to identify system inputs needed to create high-performance work teams. The present model goes beyond the traditional approach of narrow focus on operators and tasks, providing for more in-depth analysis of causes and effects. Thus, for example, the model makes it possible to investigate the degrees to which such factors as teaming, leadership, and cultural norms could con-



1 Hughes, R.L., Ginnett, R.C., & Curphy, G.J. (1996). Leadership: Enhancing the Lessons of Experience (pp. 354–366). Chicago: Irwin.

The **Kennedy Space Center Human Factors Event Evaluation Model** serves as a tool for acquiring and analyzing data on events that involve human errors.

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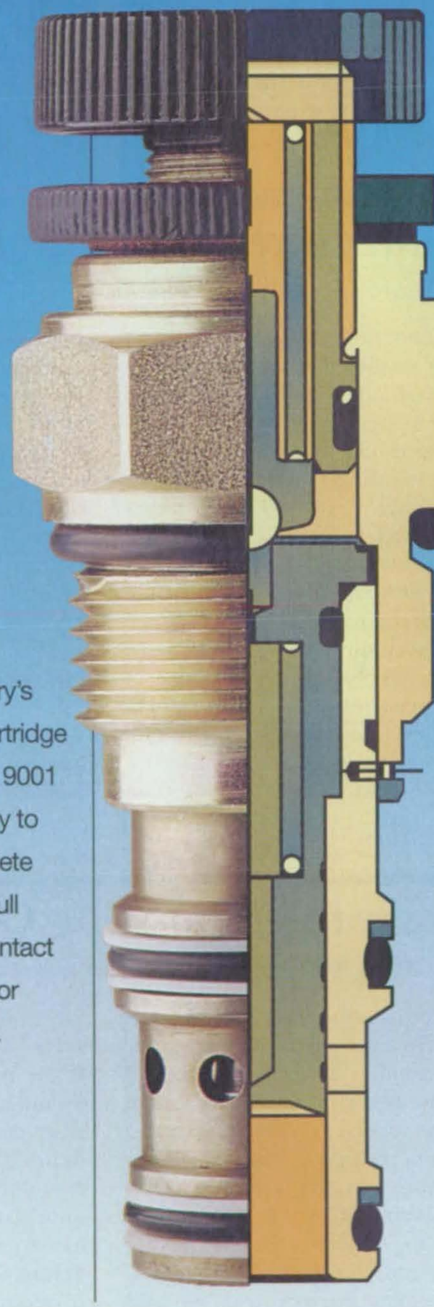

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For More Information Circle No. 570

tribute to errors by well-intentioned, well-trained, experienced technicians.

The model serves as a tool to ensure that appropriate questions are asked during investigations of errors, to provide a data base containing standardized representations of events (incidents, mishaps, close calls), and to provide quantitative information as to why errors occur. The questions and the inputs to the model (that is, the answers to the questions) are divided into categories and subcategories. The main categories (see figure) are organizational inputs, team inputs, individual inputs, and design inputs. Subcategories can be added or modified, as needed, to adapt the model to applications other than space-shuttle processing at Kennedy Space Center. To ensure consistency among users, each category is delineated by narrative definitions and examples of probing questions.

Two particularly notable examples of subcategories are those pertaining to written and verbal support information. These subcategories encompass such things as specifications, company directives, and government documentation.

In applying the model to a given event, an investigative team works from top to bottom and from left to right while reviewing each category. If a category is applicable, a cause code and a brief description of the event are entered into a comprehensive data base of events. Once trends have been identified through analysis of multiple events, sources of data can be investigated to review specific problem sources. For example, if there appears to be a tendency for errors to arise in or from the verbal transmission of information, tape recordings of verbal exchanges can be audited in an attempt to identify sources of error.

This work was done by Patrick A. Simpkins, Tim S. Barth, and Jim Medina of **Kennedy Space Center** *and Donna M. Blankmann-Alexander, Mark J. Nappi, and John W. Jamba of United Space Alliance. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mathematics and Information Sciences category,* ***or circle no. 162*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
KSC-11975

Work-Measurement and Methods-Analysis Studies of the OPF

John F. Kennedy Space Center, Florida

Two reports describe early phases of continuing studies directed toward the selection and adaptation of industrial work-measurement and methods-analysis procedures for application to the Orbiter Processing Facility (OPF) at Kennedy Space Center. These studies were prompted by a need to increase efficiency, effectiveness, and productivity in the face of budget reductions. In the work-measurement study, (1) candidate work-measurement techniques were selected on the basis of feasibility, (2) similar space-shuttle-processing tasks were grouped into clusters, (3) the candidate techniques were used to measure the times of tasks in the clusters, then (4) the technique that scored highest according to weighted quantitative criteria developed for each cluster was selected as the "best" technique for the cluster. The methods-analysis study included an ergonomic review of tools, direct observation of tasks, and examination of work instructions. Several areas for improvements in work methods were identified. A methodology for selecting cost-effective methods-analysis techniques in the OPF environment was developed.

This work was done by Amanda Mitskevich and Tim S. Barth of **Kennedy Space Center**; *Robert R. Safford, Julia Pet-Edwards, William Swart, and Kay Stanney of the University of Central Florida; and Susan Murray of Texas A&M University. To obtain copies of the reports, "A Procedure for Adaptation of Work Measurement Procedures To The Space Shuttle Ground Processing Environment" and "A Procedure for Adaptation of Industrial Methods Analysis Procedures To Space Shuttle Ground Processing At The Kennedy Space Center," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mathematics and Information Sciences category,* ***or circle no. 163*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
KSC-11934

Software for Improving Operational Processes

John F. Kennedy Space Center, Florida

The Schedule and Cost Risk Analysis Modeling System (SCRAM) computer program identifies important sources of schedule and cost risks in an operational process. The related Process Analysis and Improvement Support System (PASS) program assists in the overall analysis and improvement of an operational process, with emphasis on identifying and eliminating causes of anomalies. SCRAM enables the construction and analysis of realistic mathematical models of schedule variables (e.g., durations of tasks) and of constraints imposed by limitations on resources. SCRAM utilizes input information in the form of historical delay data and schedule information for a process in question to derive measures of importance of classes of delays. PASS includes (1) a process-analysis module, which performs schedule and cost analyses of delays, using criticalities defined by the analyst instead of resource constraints, to identify the most important kinds of anomalies; (2) a root-cause module, which provides for quantitative and qualitative analyses of causes of anomalies; and (3) a process-improvement-evaluation module, in which the language of representation of cause-and-effect relationships from the root-cause module is used in accounting for process-improvement alternatives and criteria for making decisions.

This work was done by Robert Fung and Max Henrion of Lumina Decision Systems for **Kennedy Space Center.** *No further documentation is available.*

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

Max Henrion
Lumina Decision Systems
59 North Santa Cruz Ave.
Suite Q
Los Gatos, CA 95030

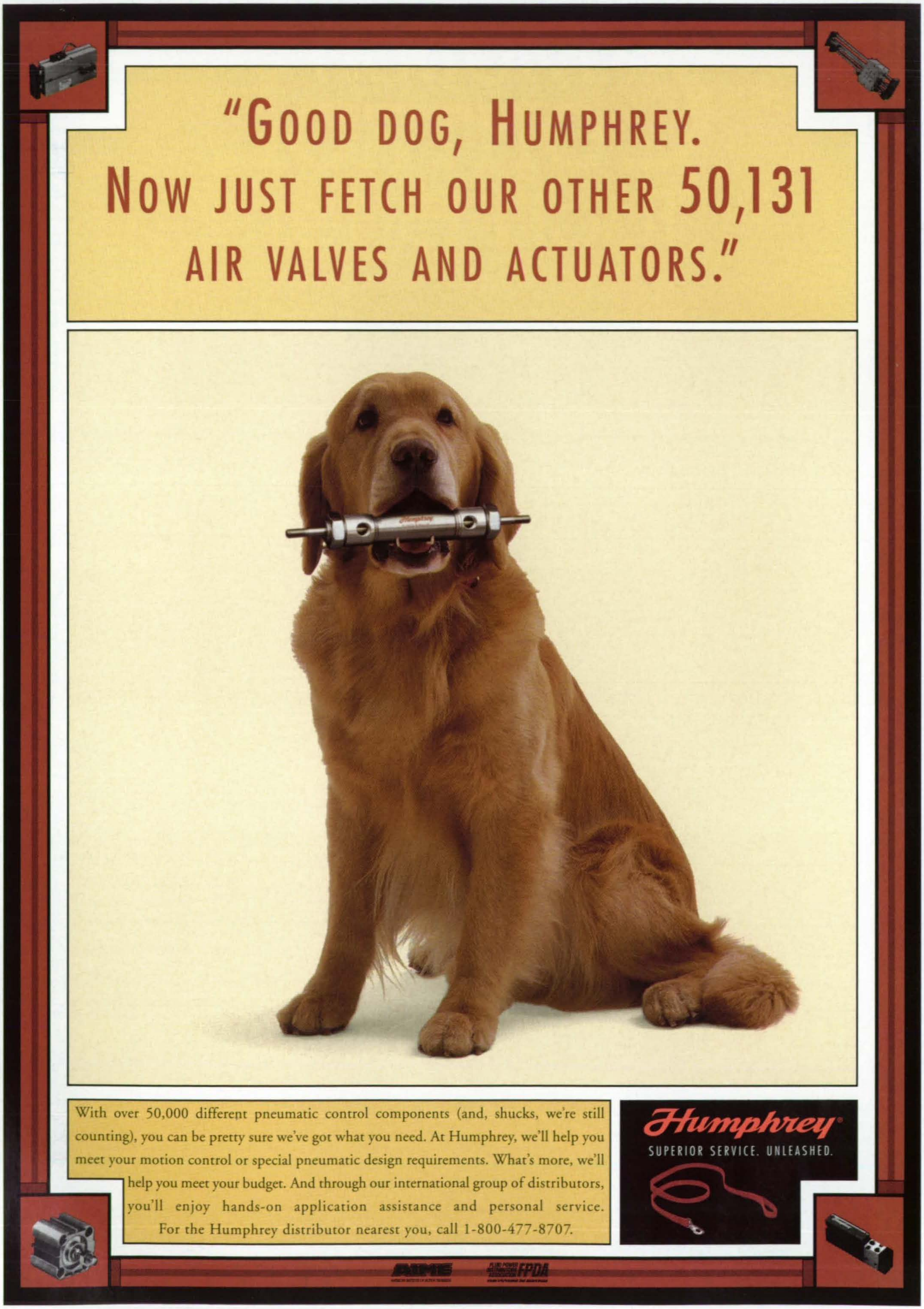
Refer to KSC-11914/15, volume and number of this NASA Tech Briefs *issue, and the page number.*

February 1998

Motion Control Tech Briefs

Large Gimbal Mount for Focal-Plane Testing

Microstepper with 50-nm Resolution



For More Information Circle No. 480

Motion CONTROL Tech Briefs

Motion Control Tech Briefs Supplement to *NASA Tech Briefs* February 1998 Issue Published by Associated Business Publications

MOTION CONTROL TECH BRIEFS

DEPARTMENTS

On the cover:

Newport Corp.'s motorized gimbal mount for positioning large, heavy optics. See the brief beginning on page 2b.

Photo courtesy Newport Corp.

For More Information Circle No. 481

Large Gimbal Mount Enables Focal-Plane Testing

A motorized gimbal mount has been developed to scan and position large, heavy optics (up to 17" in diameter) with high angular resolution (0.0001°).

Newport Corporation, Irvine, California

The latest missile guidance and tracking guidance systems deliver unprecedented performance, in terms of range, precision, and the ability to function in very unfavorable atmospheric conditions. These systems rely on a new generation of high-resolution, multifunction focal plane arrays to image visible and IR radiation. In testing these arrays, the focused light from a blackbody source must be sequentially directed onto each individual pixel using all-reflective optics. Accomplishing this requires panning and tilting a 17"-diameter mirror at a resolution of 0.0001° under programmable, motorized control. This brief describes a novel, 2-axis gimbal mount that was designed to successfully meet this and other demanding specifications.

How did these specifications arise? Focusing the blackbody radiation onto individual micron-sized pixels dictates the use of large (12"), high-numerical-aperture optics. However, since the mirror must steer the 12"-diameter blackbody "beam" through as much as 90°, it must have a clear aperture of 17". Illuminating individual pixels at a distance of 2 feet translates into an angular resolution of 0.0001° (0.36"). Holding these specifications in actual operation also requires the mirror to be very rigid, meaning it is thick and very heavy. In addition, this application requires moving the mirror under vacuum at speeds of up to 50°/second.

Figure 1 shows the assembled gimbal mount. The first step in development was designing the passive components—the primary bracket (or cradle mount) and the mounting ring. This involved a tradeoff to provide the nec essary rigidity at a reasonable mass. Using 5/8"-thick 6061T-6 aluminum alloy proved to be the optimum way to meet these goals.

In addition to static rigidity, trial designs were also analyzed and optimized for dynamic behavior, *i.e.* resonances. Successfully rotating the gimbal at constant velocity means avoiding low-frequency flexure modes. Fortunately, the design team had extensive experience using finite element analysis (FEA) to address the same issues in the design of vibration isolation systems. Table 1 shows the success of this optimization: the first resonance of the assembled gimbal does not occur until 63 Hz.

With a mounted optic, the entire gimbal assembly can weigh more than 250 lb. This was obviously a major factor influencing the choice of bearings and rotation stages. For example, the shaft on each side of the mounting ring was mated to the main bracket using *two* sets of angular contact bearings. To support operation in a cryochamber, these bearings include Teflon spacers and a special lubricant to provide vacuum compatibility (to 10^{-6} torr).

Vibrational Mode	Resonant Freq. (Hz)
1	63
2	150
3	162
4	212
5	283

Table 1. **Vibrational Modes and Resonant Frequencies** of the assembled gimbal mount.

Automated motion is enabled by the use of motorized rotation stages. The mounting ring (elevation) is driven by a Newport RTM160CC rotation stage. The entire gimbal is rotated azimuthally by a Newport RTM350CC stage. Both stages are equipped with brush DC motors to provide the smoothest possible motion.

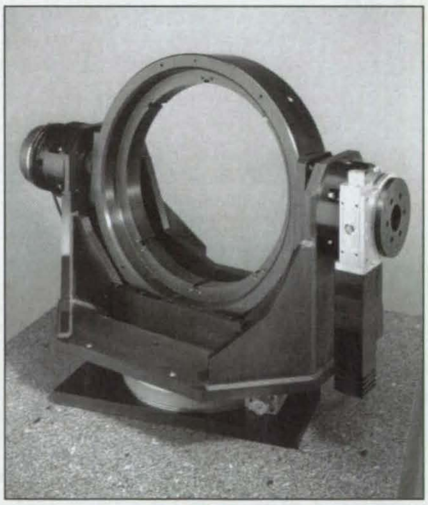


Figure 1. The 17" **Gimbal Mount,** including its rotation stages.

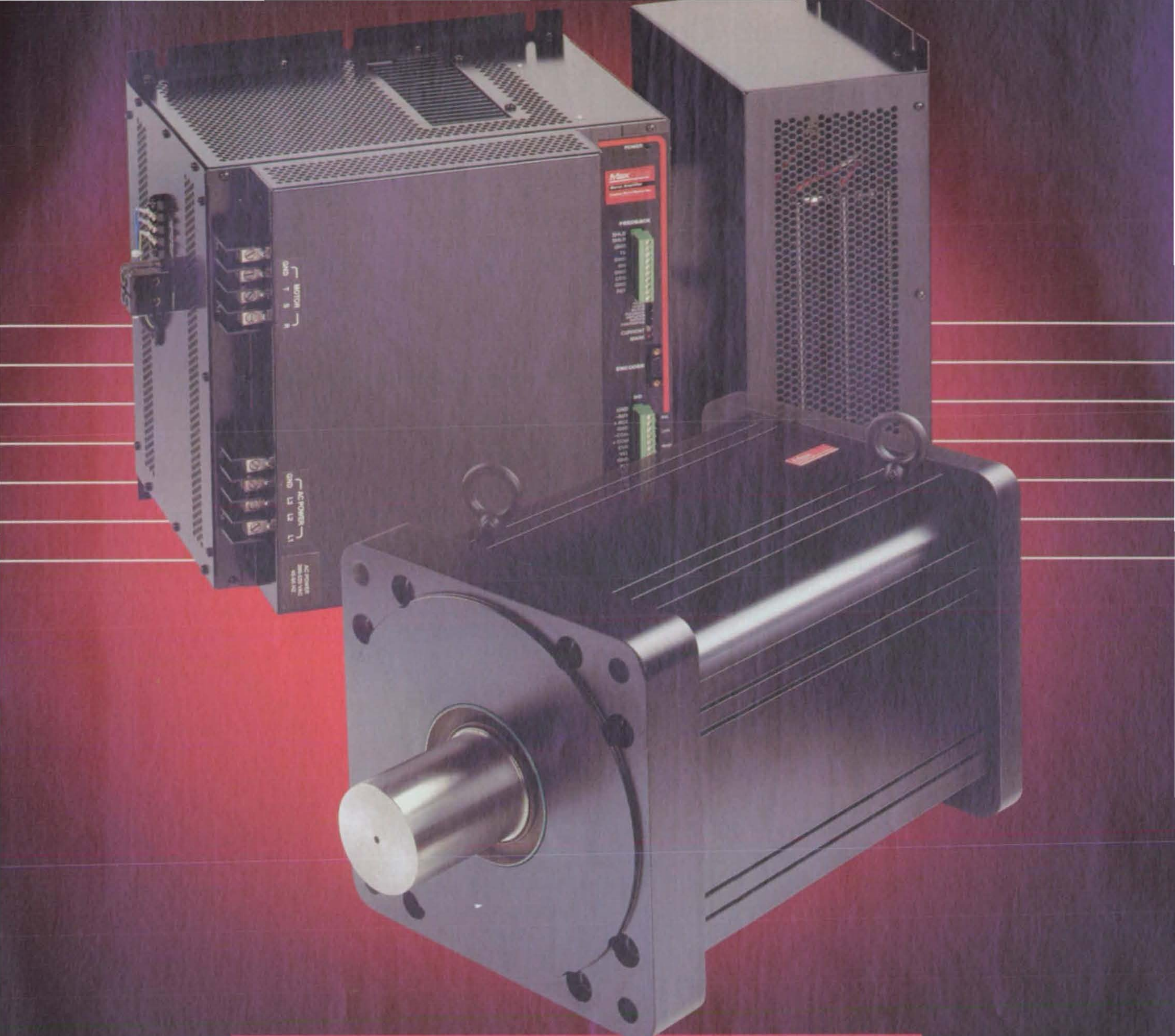
The required 0.0001° resolution is ten times higher than the normal, closed-loop operation of these motorized rotation stages. Therefore Heidenhain RD optical encoders were integrated to directly measure the rotation of the gimbal axes, thus providing feedback signals to the system controller.

Verifying the performance of this high-resolution gimbal mount is an important step in production, and represents something of a challenge in and of itself. To perform the test, the output of a Newport LAE 500 laser diode autocollimator is reflected off the surface of a plane mirror at the gimbal point (the point in space at which the two rotation axes intersect). This instrument can measure beam deviations as small as 0.2", which corresponds to a gimbal motion of 0.1" (0.00003°).

Since their successful development, these gimbal mounts have found several other important uses. For example, their high load-bearing capability has proven to be an asset in the testing of a missile guidance system. In this case, the missile's entire detection system is mounted on the gimbal to test its tracking accuracy over a long line of sight. The gimbal's high resolution is also proving useful for steering large laser beams. In one experiment it has been used to evaluate the practicality of disabling satellites and incoming missiles with ground-based lasers.

To summarize, a difficult set of design goals for a large, two-axis rotation mount was met by bringing together several different disciplines. These included finite element design and analysis, precision machining and assembly of the subcomponents, the availability of high-performance rotation stages to drive the motion, and the ability to measure/calibrate the performance. The successful design not only meets the high-resolution needs of the original application, but is now benefiting other uses as well.

This work was done by a team led by Beda Espinoza, Lee Green, and Warren Booth at **Newport Corp.**, *Irvine, CA. For more information, contact Booth at (714) 253-1670; fax (714) 253-1841; E-mail: wbooth@newport.com.*



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For More Information Circle No. 482

Antiovershoot Position Control for Motors Run at Full Speed

Innovative position controller allows the desired position damping to be reached while the motor is running at full speed.

Marshall Space Flight Center, Alabama

An improved motor controller provides a circuit that will allow a motor to run at full speed while traveling from point A to point B, and still be able to obtain the desired damping coefficient when reaching point B. Previously, a motor would overshoot its desired stopping point when running at full speed, especially in high-inertia systems. Some form of rate feedback, or lead compensation, was required to stabilize a position loop, but the motor would not run at full speed while traveling from point A to point B.

The innovators recognized this problem while working on the Electromechanical Actuator Advanced Development Program at Marshall Space Flight Center. Consequently, they developed a nonlinear motor controller that will allow the motor to obtain both the desired motor speed rate and the desired damping coefficient when reaching point B.

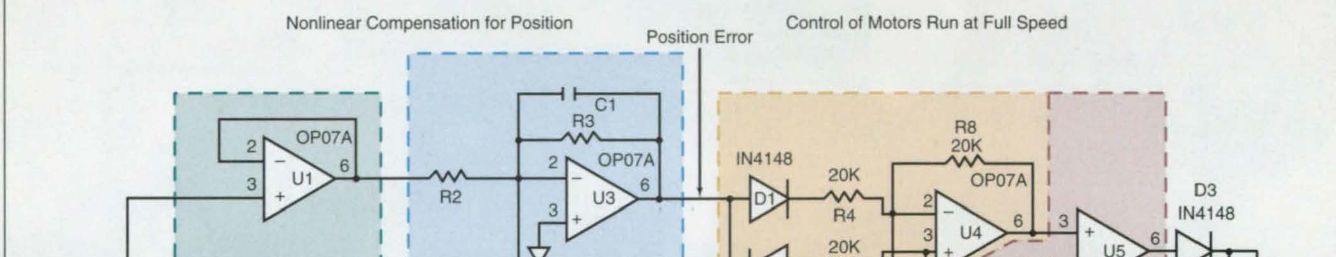
This motor controller concentrates on the position error of the system. Buffers are used to tie in the position command and position feedback points of the system with a high impedance input. An adder circuit simply adds the position command to the negative position feedback. The output of the adder circuit is a signal proportional to the position error.

Depending on the amplitude of the position error, the controller will take the rate feedback of the system out of the system control loop, or it will sum it into the system control loop. If the position error is too large in the comparator block, the rate feedback will be removed from the control loop. If the position error is too small, the rate feedback will be added to the system control loop. In order to achieve this, the position error is fed into a minus absolute-value circuit. This will allow the invention to work whether the position error sign is plus or minus.

The minus absolute value of the position error is then compared, using the circuit in the comparator block, to a user definable set point. This set point allows the user to select at what point the rate will be summed into the system control loop. By selecting the set point, the user determines how long the motor can run at full speed as the position mechanism travels from a given point to another commanded point. Also, by selecting the set point, the user determines when the rate will be summed into the system controller to add damping to the system control loop.

A discrete signal from the comparator block toggles between a plus and minus voltage. The diode and resistor condition the output signal of the comparator block so that it will only go from zero to a plus voltage. This signal then controls the analog switch, which actually does the switching in and out of the rate feedback to the system controller.

The end result is a circuit that allows the motor to run at full speed until the final position gets close, as defined by the user. The rate feedback is then summed into the system controller to achieve the desired damping for the position loop.



The **Improved Motor Controller** allows a motor to run at full speed until the final position gets close.

This work was done by David E. Howard and Justino Montenegro of **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category,* ***or circle no. 185*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31182.

All-Terrain Vehicle With Self-Righting and Pose Control

Wheels driven by gearmotors are mounted on pivoting struts.

NASA's Jet Propulsion Laboratory, Pasadena, California

A small prototype robotic all-terrain vehicle features a unique drive and suspension system that affords capabilities for self righting, pose control, and enhanced maneuverability for passing over obstacles. The vehicle is designed for exploration of planets and asteroids, and could just as well be used on Earth to carry scientific instruments to remote, hostile, or otherwise inaccessible locations on the ground. The drive and suspension system enable the vehicle to perform such diverse maneuvers as flipping itself over, traveling normal side up or upside down, orienting the main vehicle body in a specified direction in all three dimensions, or setting the main vehicle body down onto the ground, to name a few. Another maneuver enables the vehicle to overcome a common weakness of traditional all-terrain vehicles — a limitation on traction and drive force that makes it difficult or impossible to push wheels over some obstacles: This vehicle can simply lift a wheel onto the top of an obstacle.

The basic mode of operation of the vehicle can be characterized as four-wheel drive with skid steering. Each wheel is driven individually by a dedicated gearmotor. Each wheel and its gearmotor are mounted at the free end of a strut that pivots about a lateral axis through the center of gravity of the vehicle (see figure). Through pulleys or other mechanism attached to their wheels, both gearmotors on each side of the vehicle drive a single idler disk or pulley that turns about the pivot axis.

The design of the pivot assembly is crucial to the unique capabilities of this system. The idler pulley and the pivot disks of the struts are made of suitably chosen materials and spring-loaded together along the pivot axis in such a way as to resist turning with a static frictional torque T; in other words, it is necessary to apply a torque of T to rotate the idler pulley or either strut with respect to each other or the vehicle body.

During ordinary backward or forward motion along the ground, both wheels are turned in unison by their gearmotors, and the belt couplings make the idler pulley turn along with the wheels. In this operational mode, each gearmotor contributes a torque $T/2$ so that together, both gearmotors provide torque T to overcome the locking friction on the idler pulley. Each strut remains locked at its preset angle because the torque $T/2$ supplied by its

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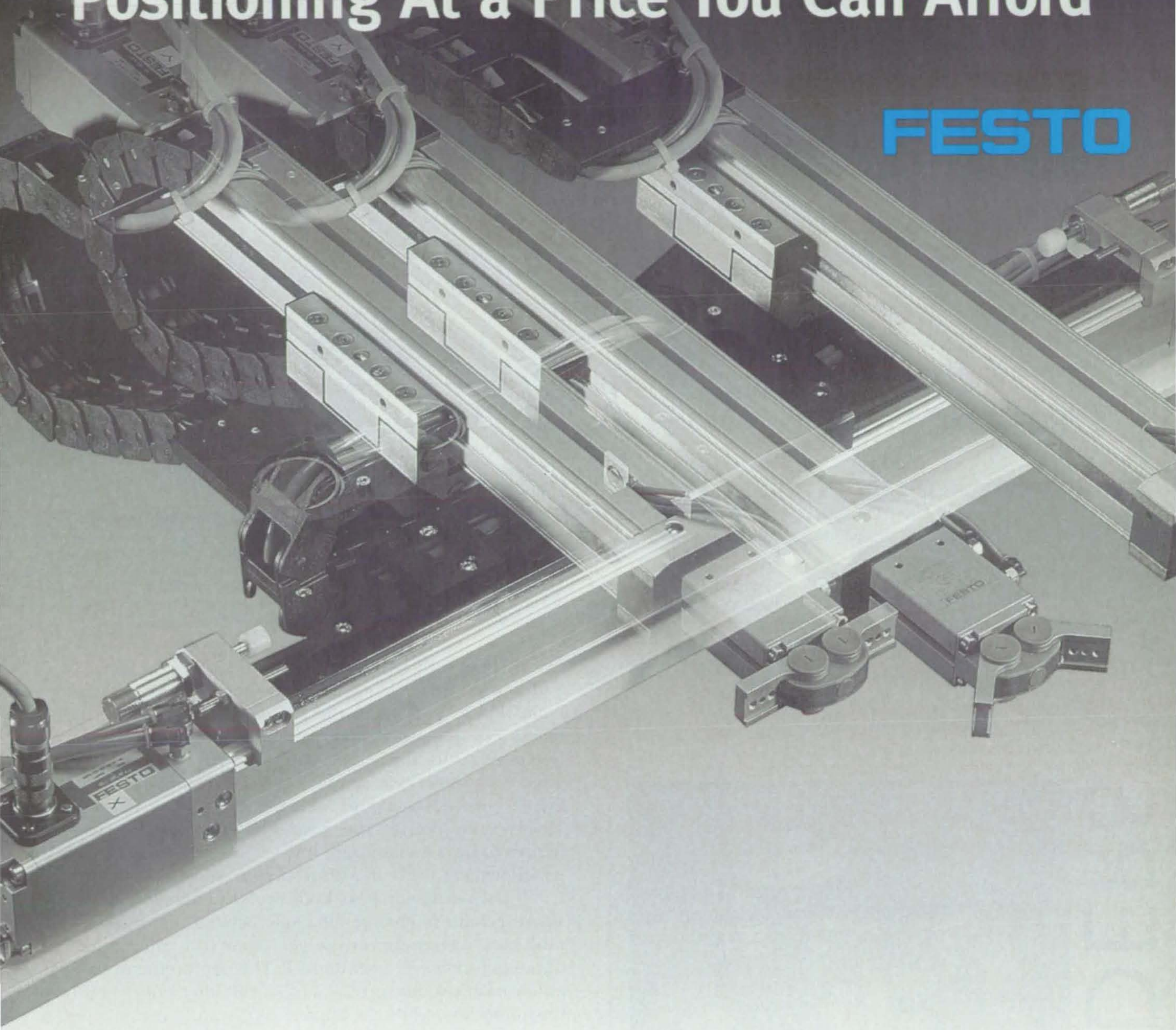

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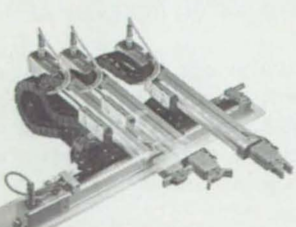

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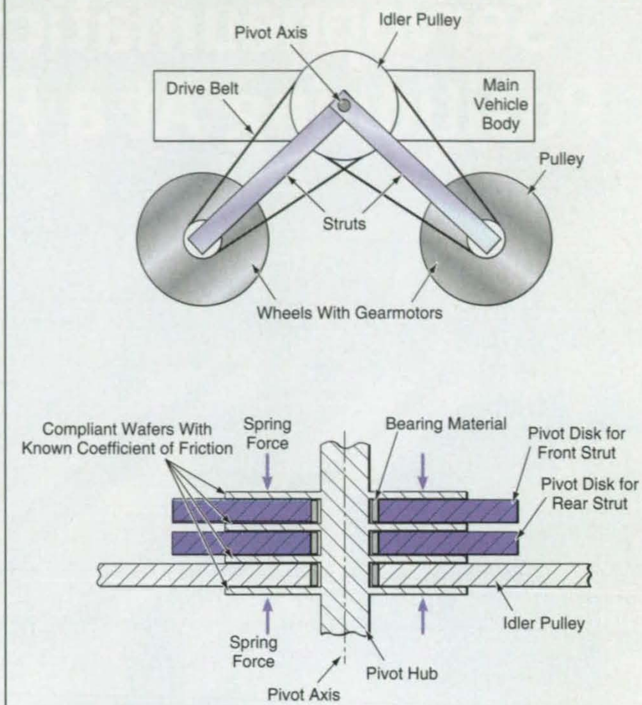

ENLARGED CROSS SECTION IN PLANE OF PIVOT AXIS

Each Wheel Is Driven by a dedicated gearmotor and is coupled to the idler pulley. The pivot assembly imposes a constant frictional torque T, so that it is possible to (a) turn both wheels in unison while both struts remain locked, (b) pivot one strut, or (c) pivot both struts in opposite directions by energizing the gearmotors to apply various combinations of torques $T/2$ or T.

motor is not sufficient to overcome its locking friction T.

If it is desired to change the angle between one strut and the main vehicle body, then the gearmotor on that strut only is energized. In general, a gearmotor acts as a brake when not energized. Since the gearmotor on the other strut is not energized and since it is coupled to the idler pulley, a torque greater than T would be needed to turn the idler pulley. However, as soon as the gearmotor on the strut that one desires to turn is energized, it develops enough torque (T) to begin pivoting the strut with respect to the vehicle body.

It is also possible to pivot both struts simultaneously in opposite directions to change the angle between them. To accomplish this, one energizes the gearmotors to apply equal and opposite torques of magnitude T: The net torque on the idler pulley balances out to zero, so that the idler pulley and body remain locked, while the applied torques are just sufficient to turn the struts against locking friction. If it is desired to pivot the struts through unequal angles, then the gearmotor speeds are adjusted accordingly.

The prototype vehicle has performed successfully in tests. Current and future work is focused on designing a simple hub mechanism, which is not sensitive to dust or other contamination, and on active control techniques to allow autonomous planetary rovers to take advantage of the flexibility of the mechanism.

This work was done by Brian H. Wilcox and Annette K. Nasif 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,* ***or circle no. 186*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Refer to NPO-20057, volume and number of this NASA Tech Briefs *issue, and the page number.*

Multimedia Operator Interface for a Health-Care Robot

The robot can be controlled by patients with some disabilities.

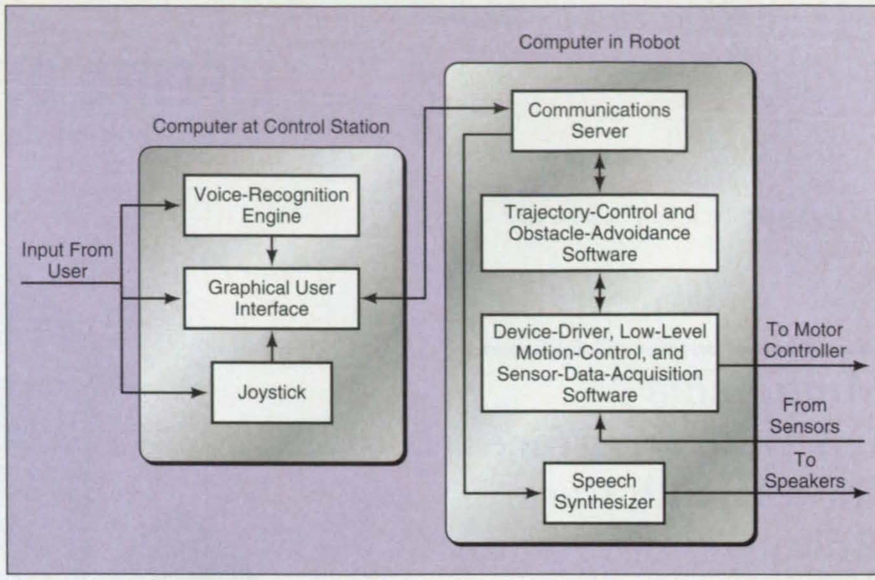
NASA's Jet Propulsion Laboratory, Pasadena, California

An operator interface is undergoing development along with other subsystems of a robot that would assist in caring for elderly and disabled patients. This development has been initiated in anticipation of an increasing need for long-term care, in both home and hospital environments, with decreasing ratios of medical personnel to patients. Robots of the type envisioned would be controllable by both medical personnel and patients with some disabilities. Typically, the robots would be used to perform routine, mostly nonmedical tasks like delivering food and retrieving articles of clothing or other objects for patients.

The prototype robot includes a battery-powered mobile platform equipped with a color camera mounted on a pan-and-tilt head, and an array of ultrasound, infrared, and contact sensors for autonomous navigation. A fully developed robot would also include a manipulator arm. Some control functions are performed by a computer mounted on the platform; other control functions are performed by a computer at a control station, where the operator interface resides (see figure). In a fully developed robotic system of this type, the control station could be located at a patient's bedside or in a nurse's office, for example.

To accommodate the needs of patients and medical personnel and the limitations on dexterity of some patients in a variety of situations, the operator interface accepts inputs and generates outputs in a variety of media. In particular, it provides an integrated combination of voice, video, and computer graphical inputs and outputs, plus mouse and joystick inputs. The voice mode is the main command mode and is included primarily because many elderly and disabled patients would find it difficult or impossible to use the mouse and/or keyboard. The voice mode is implemented by a voice-recognition engine running commercial speech-recognition software that listens for voice input from the operator and seeks to match the operator's utterances with each of fourteen commands (e.g., stop, turn left, move forward) stored in active voice menus. When the robot receives and interprets a voice command, a speech synthesizer in the robot restates the command for confirmation.

The operator interface includes a graphical user interface that can present visual feedback in the forms of images from the video camera on the robot, images from a remote video camera (e.g., during a video conference with a physician), a graphical display of the robot on a map of the environment, or a graphical display of sonar readings of distances and directions from the robot to nearby objects. The data-entry portion of the graphical user interface includes interactive displays for using the mouse to select the voice mode, to set translational and rotational speeds of the robot, or to select the joystick to control motion. The mouse can be used to stop all motions of the robot in an emergency. The mouse can also be used to move a cursor to a target position indicated on the map graphical display and to command the robot to move to that position; when the mouse button is clicked at the target position, the robot moves toward the target, automatically avoiding obstacles along the way.



The **Operator Interface** resides in a computer at a control station that communicates with a computer in the robot.

This work was done by Paolo Fiorini, Homayoun Seraji, and Khaled Ali of Caltech and K. G. Engelhardt of KG Robotics 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 Systems category,* ***or circle no. 187*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20072

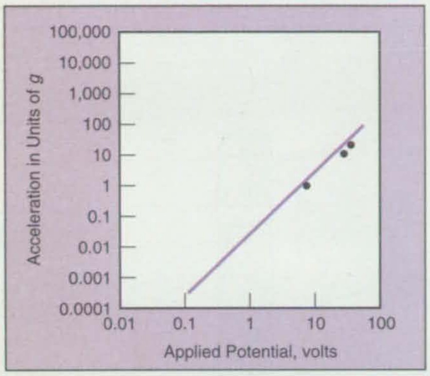
Protecting a Micromachined Accelerometer During Handling

The proof mass is clamped electrostatically.

NASA's Jet Propulsion Laboratory, Pasadena, California

A highly sensitive micromachined accelerometer that is intended to be exposed to very small accelerations during operation incorporates features for protection against much larger accelerations during handling and transport. More specifically, the accelerometer is designed to measure acceleration as small as 10^{-8} × that of normal Earth gravitation (g), yet can withstand accelerations as large as 200 g when the protective function is activated.

The accelerometer is made from four bulk micromachined silicon dice. Two of the dice are made into a square proof mass 1 cm² in area and 0.8 mm thick supported by eight folded cantilever springs, each spring being 1 cm long, 100 μm wide, and 25 μm thick. Another die contains four quadrature electrodes, plus a tip electrode that is placed near an electrode on the proof mass. The displacement of the proof mass is inferred from measurement of the quantum-mechanical-tunneling electron current between the tip electrode and an electrode on the proof mass; this tunneling-tip aspect of the design is similar to that of a scanning tunneling microscope and offers the advantage of high sensitivity (displacements as small as 10^{-3} Å can be measured). The remaining die, called



The **Acceleration That the Accelerometer Can Withstand** increases with the clamping force, which is proportional to the square of the applied potential.

the "force plate," contains a single electrode that is used to control the position of the proof mass.

The spring-and-mass and tip-electrode structures are delicate; this is an unavoidable aspect of the design necessary for achieving the required sensitivity, but it makes these structures vulnerable to damage in the presence of large accelerations. Accordingly, during handling and transport, the single control electrode on the force plate is also used to clamp the proof mass away from the tip electrode and against the force plate. This clamping is effected by applying sufficient electrostatic potential (see figure) between the control electrode and an electrode on the proof mass to pull the proof mass into contact with the force plate. An oxide layer on the surface of the force plate prevents undesired electrical contact between the control and proof-mass electrodes.

This work was done by Frank T. Hartley of Caltech and Paul M. Zavracky of Northeastern University 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,* ***or circle no. 188*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-19813

Passive Magnetic Bearings With Ferrofluid Stabilization

Sizes, weights, and power consumptions can be reduced.

Lewis Research Center, Cleveland, Ohio

Permanent-magnet rotary bearings with ferrofluid stabilization in the axial degree of freedom are undergoing development. These bearings are totally passive, yet stable in all degrees of freedom. In contrast, previously developed electromagnet and permanent-magnet bearings all exhibit instability in at least one degree of freedom, giving rise to the need for active electronic feedback and power-control circuitry. By making active control unnecessary, ferrofluid stabilization can enable reductions in the overall sizes, weights, and power consumptions of machines that contain permanent-magnet bearings. Unlike passive magnetic bearings based on superconductivity, which are

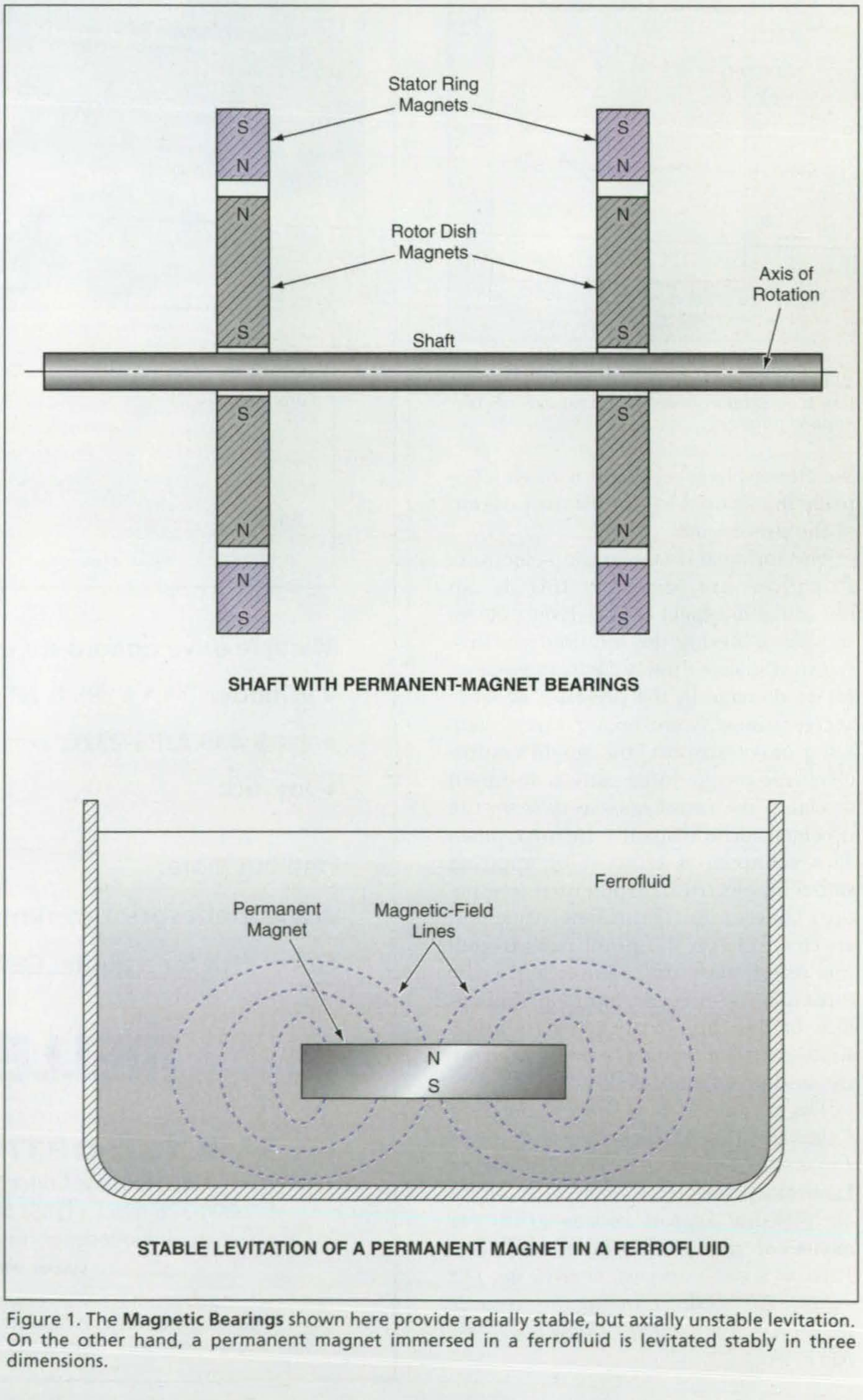


Figure 1. The **Magnetic Bearings** shown here provide radially stable, but axially unstable levitation. On the other hand, a permanent magnet immersed in a ferrofluid is levitated stably in three dimensions.

restricted to operating temperatures far below room temperature, the developmental bearings are designed to function at temperatures from 0 to 50 °C.

Figure 1 contains a simplified drawing of a shaft with typical conventional permanent magnet bearings near both ends. The repulsion between like magnetic poles of the rotor and stator portions of each bearing give rise to a magnetic levitation that is stable in the radial degree of freedom but unstable in the axial degree of freedom.

Figure 1 also depicts an elementary ferrofluid stabilizer comprising a permanent magnet immersed in ferrofluid in a container. In the absence of externally applied force, the magnet seeks an equilibrium position that is approximately central in the body of ferrofluid. When the magnet is displaced from the equilibrium position, there arises a restoring force that, if not resisted, pushes the magnet back toward the equilibrium position; that is, the levitation is stable. However, in the configuration depicted here, the restoring force, and thus the load capacity, is too small to be useful. To obtain enough restoring force and load capacity for use in stabilizing a magnetic bearing along a specified axis, it is necessary to confine the ferrofluid in a restricted cavity and optimize the permanent-magnet geometry to increase the restoring force along that axis.

Figure 2 illustrates one of many possible configurations of a shaft equipped with magnetic bearings and with ferrofluid stabilizers designed to generate enough axial restoring force to counteract the axial instability of the magnetic bearings. A prototype of this configuration has been tested and found to be stable. The tests also revealed that magnetic bearings may be useful, to some extent, as vibration isolators.

This work was done by Eliseo DiRusso of **Lewis Research Center** *and Ralph Jansen of Ohio Aerospace Institute. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category,* ***or circle no. 189*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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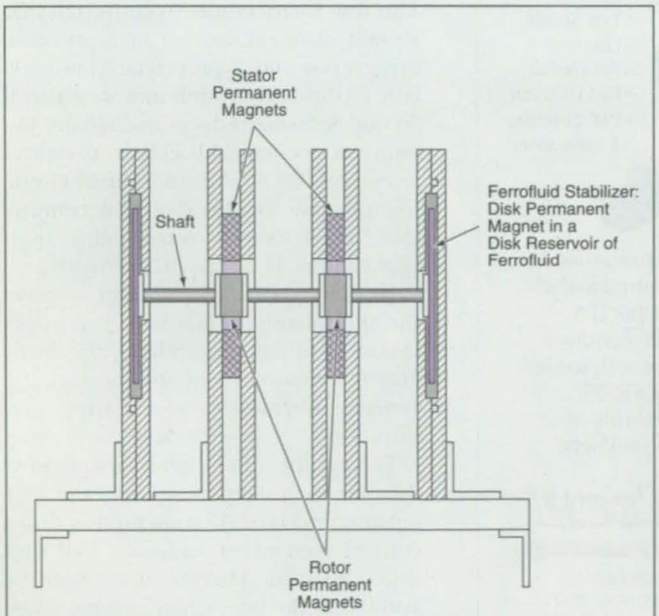


Figure 2. A **Shaft With Magnetic Bearings and Ferrofluid Stabilizers** is levitated stably in all degrees of freedom.

Precision Actuator Positions Laser Grating

A microstepper with 50-nanometer resolution enables tuning of a narrow-linewidth diode laser.

Applied Precision Inc., Issaquah, Washington

The tunable external cavity diode laser is an important new tool used to evaluate and test the latest fiber-optic components and building blocks of modern telecommunications systems. A key factor enabling operation of this type of laser is the ability to angle-tune the wavelength-dependent key component (a diffraction grating) in the cavity with extreme precision and repeatability. When Hewlett Packard wanted to develop a laser with enhanced wavelength performance, their design required a linear actuator with 100-nm resolution over a travel range of several millimeters. This brief tells how a custom microstepper system was developed to meet the needs of this demanding application.

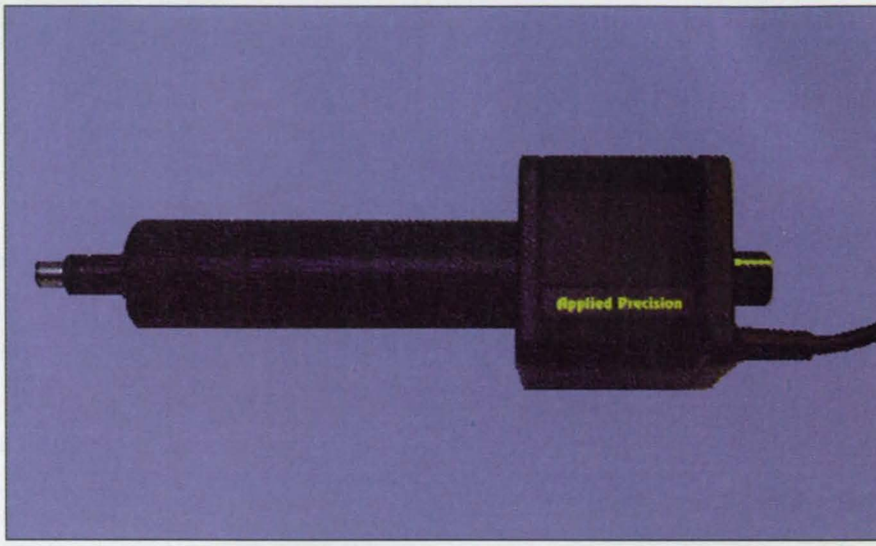


Figure 1. **The Nanomover Micropositioning System.**

The diffraction grating is rotated by pushing on the end of a spring-loaded grating arm, which is several centimeters in length. The target was to tune the laser output with a wavelength resolution of 100 MHz, which translated into a positional resolution of 100 nm or better. Piezoelectric actuators were rejected for this application because they do not provide the necessary range of motion (several mm). DC-motorized actuators did not offer the necessary holding stability—the actuator is never truly stationary but is always oscillating around the target encoder position. Furthermore, they require the use of an encoder, which would add cost and complexity to the laser. On the other hand, a microstepping system offered the potential for high resolution over a long travel range, as well as excellent repeatability without an encoder.

The starting point for the OEM design was a micropositioner called the Nanomover®. This was developed by Applied Precision several years ago, initially for integration into test instrumentation for the semiconductor industry, and later as a stand-alone micropositioner. The Nanomover uses a conventional stepper motor in a microstepping mode, with a minimum microstep size of 0.036°. This fine rotary motion is converted into 25 mm of linear motion by a precision drive screw and a proprietary low-backlash linkage. The minimum step size is 50 nm. Software reduces the 500-nm lost motion (mechanical backlash) to deliver a repeatability specification of ±100 nm. Because power-down does not compromise this long-term repeatability, most applications do not need an encoder.

Modifying this basic design to meet the special requirements of this application required customizing the three major components of this positioning system: mechanics, electronics, and software.

Two significant mechanical issues were the operating temperature and the grating arm interface. A stepper motor draws current even when stationary and thus generates heat. Thermal drifts must be avoided in the laser cavity as these could compromise cavity/wavelength stability and wavelength calibration. For this reason, Hewlett Packard heats the entire laser cavity and stabilizes it at 55 °C. Our life tests showed that the original lubricant would lose its lubricity at these temperatures. A custom synthetic oil was formulated to eliminate this problem.

The interface between the positioner tip and pivot arm also required special consideration. As shown schematically in Figure 2, the positioner contacts a tungsten carbide tooling ball mounted in the grating arm. As with many motorized devices, the tip of this positioner rotates as it translates. This is not an issue in most applications. In this case, however, the tooling ball gradually translates across the surface of the rotating positioner tip as the grating arm moves. This required that the face of the positioner tip be truly perpendicular to the direction of travel. In addition, a testing protocol was designed which would not create even minute scratches or surface blemishes in the tip face, which could introduce errors into the motion-to-wavelength transfer function. During testing, the tip is protected with a small tungsten carbide plate, which has been lapped flat. This rotates with the tip, so that any wear scratches are produced on it instead of the tip.

The major electronic issues were related to voltage and systems integration. Since size was an issue, the design team initially integrated both the control and drive electronics on a single board, conforming to the Hewlett Packard template. These electronics had been redesigned to operate using the ±19V available in the laser. To further reduce cost, Applied Precision now simply licenses a surface-mount implementation of this circuit to Hewlett Packard for direct in-house automated fabrication.

Finally, the control electronics are based on a Z8 processor. This control system was originally designed to run in an ISA bus environment executing commands from a standard library set. To work in the Hewlett Packard laser meant designing a new register-level interface to work with their HPIB bus. Obviously, an entirely new command set had to be created to support this environment.

To summarize, as with any OEM motion control application, this work involved meeting two equally important goals: first, to provide the necessary performance, and second, to configure the system in such a way that it could be seamlessly integrated into the final product.

This work was done by a group led by Ron Seubert and Steven Reese at **Applied Precision Inc.,** *Issaquah, WA. For information on this technology, contact Rick Loya at (425) 557-1000, ext. 4083; fax (425) 557-1055; e-mail: rloya@api.com.*

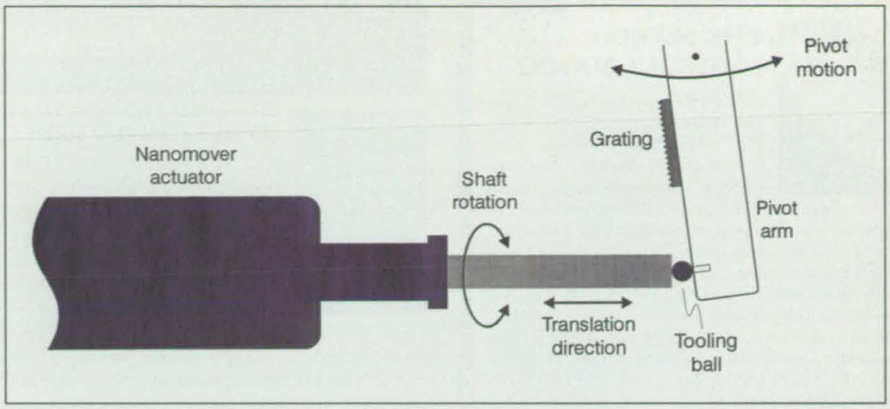


Figure 2. As the grating arm moves, the **Tooling Ball Contact** moves across the rotating tip of the actuator.

1998 MOTION CONTROL CATALOG

Galil's 1998 catalog is 128 pages with specs for ISA, PC/104, VME, and standalone motion controllers with RS-232. Features include: "Mix-and-match" steppers and servos on 1 through 8 axes, memory for application programs, uncommitted I/O, linear and circular interpolation, gearing and Ecam. Also, software for servo tuning and interface to AutoCAD, G-codes and Visual Basic. DOS, Win 3.1, 95 and NT. Catalog includes 28-page technical reference about motion control systems. Galil Motion Control, 203 Ravendale Drive, Mountain View, CA 94043; (650) 967-1700; 800-377-6329; fax (650) 967-1751; web site: www.galilmc.com

Galil Motion Control

For More Information Circle No. 695

SMALL-FRAME BLDC MOTORS

Describes API Portescap's small-frame, high-speed brushless DC motors in sizes 5 to 15. Ideal for a variety of applications, including industrial, commercial, medical, and aerospace, these motors feature unique threaded bodies to accept gearheads and/or flanges. These motors are equipped with Hall-effect sensors and are capable of 75,000+ RPM. API Portescap, 110 Westtown Road, West Chester, PA 19382; 800-566-5274 or (610) 692-2700; fax (610) 696-4598; URL: www.apiportescap.com

API Portescap

For More Information Circle No. 696

DIGITAL SERVO DRIVERS

Three new series of digital brushless drives feature three levels of performance: Digital Servo Drives for torque and velocity control; Intelligent Servo Drives for economical positioning; and Centennial Digital Drives for positioning with advanced features such as dynamic adaptive compensation. All drives can be networked (SERCOS or CAN), provide continuous current to 30 A RMS, and are UL and CE compliant. API Controls Inc., 45 Hazelwood Drive, Amherst, NY 14228-2096; 800-566-5274 or (716) 691-9100; fax (716) 691-9181; URL: www.apicontrols.com

API Controls Inc.

For More Information Circle No. 697

CUSTOM PRECISION POTENTIOMETERS

FREE, all-new Betatronix Custom Precision Potentiometers Catalog provides background on the company's industry-leading design and manufacturing capabilities. Betatronix has manufactured conductive plastic and wirewound potentiometers for 30 years. Catalog covers linear and rotary motion, aerospace and missile, outer space, and robotics and animatronics applications; full-color photos and mechanical parameters of all-inclusive product line are featured. Betatronix, Inc., 110 Nicon Court, Hauppauge, NY 11788; Tel: 516-582-6740; Fax: 516-582-6038; www.betatronix.com

Betatronix, Inc.

For More Information Circle No. 698

New Products

Miniature Dovetail Slides

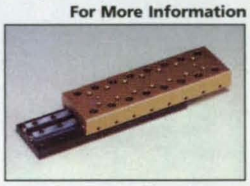
M & M Precision Systems Corp., Dayton, OH, announces the addition of the Model MSP and MSM miniature dovetail slides to its line of motion positioning products. Designed for applications with limited space, the slides were developed, the company says, to meet the need for a small, lightweight, sturdy positioner that had greater rigidity than ball bearing slides. M & M calls the MSP and MSM the smallest cast-iron dovetail slides available as a standard catalog item. They are available in single- or multiaxis configurations, with or without drive screws and optional locking devices. They come in five travel lengths ranging from 10 to 50 mm and five load capacities from 17.5 to 40 kg.

For More Information Circle No. 753

Modular Translation Stages

New Focus, Santa Clara, CA, introduces a new family of ball bearing translation stages. The company says the unique modular design of these linear stages is based on an interlocking track design for which a patent is pending. New Focus says that with the twist of a single screw the stages can be easily reconfigured to meet particular customer needs. The company also points to the stages' low profile, small footprint, and compatibility with standard actuators.

For More Information Circle No. 756



Aluminum Crossed Roller Tables

Del-Tron Precision Inc., Bethel, CT, says its Gold Motion Series crossed roller slide tables offer low-cost and lightweight aluminum body construction to support heavy loads and precision linear motion. More than 25 standard sizes are available. Load capacities range from 44-924 kg, and travels from 1-9 in. Straight line accuracy is 0.0001 in./in. of travel, and positional repeatability is 0.0001 in. For applications where particulate contamination caused by corrosion must be reduced, Del-Tron offers Gold Motion tables equipped with corrosion-resistant stainless steel crossed roller linear bearings.

For More Information Circle No. 759

High-Load-Carrying Linear Stage

Northern Magnetics, Santa Clarita, CA, offers a crossed roller positioning stage that it says provides short strokes up to 12 in., high accuracy, and speed for high-productivity applications. The company puts the load-carrying capacity of the new stage at approximately twice that of comparably sized ball bearing stages. The compact linear motion stages feature brushless linear motors, glass scale linear encoders, crossed roller bearings, and optional way covers. Standard on the stages are optical limit switches and shock absorbers. Also available are an optional cable carrier and user-specified controller and amplifier.

For More Information Circle No. 761

Rotary Stepper Motor

Haydon Switch and Instrument (HSI), Waterbury, CT, expands its line of rotary stepper motors to include one that has 15° per step and is 46 mm in diameter. HSI says the motor incorporates a design that utilizes an enlarged rotor in combination with low-inductance coils for superior dynamic performance. Producing up to 18 oz. of holding torque, they are available with bronze sleeve bearings or ball bearings. Standard coil configurations include 5-V or 12-V bipolar or unipolar windings. Custom configurations are also available. HSI says typical applications include medical equipment and analytical instrumentation.

For More Information Circle No. 755

Motion Control Design Software

Kollmorgen Motion Technologies, Radford, VA, releases new software that it says simplifies servo system sizing and selection. Windows™-based MOTIONEERING™ enables the motion control designer to choose an application, define a motion profile, and select the optimum servomotor, amplifier, and power supply. Its comprehensive database of motor types includes DC servo, brushless servo, direct drive linear, direct drive rotary, and vector AC. Application mechanisms that can be selected include leadscrew, rack and pinion, and direct drive rotary and linear devices. Product selection includes more than 300 systems.

For More Information Circle No. 757

Linear Motion Sliders/Thrusters

Promec, Willimantic, CT, says that its sliders and thrusters provide as standard several features that other manufacturers offer only as options. They are equipped with four precision adjustable hard stops, rather than the usual two. They have permanently lubricated linear ball bearings and steel endplates, rather than the composite bearings and aluminum endplates typically used by other manufacturers, Promec says.

For More Information Circle No. 760

Cantilever Slides

PHD Inc., Fort Wayne, IN, says that its newly redesigned Series SA and SB cantilever slides are small in size, but rugged enough to handle high-impact loads, and versatile enough to be used as slides for carrying loads for a wide variety of applications. They are available in five sizes from 8-mm bore to 32-mm bore; travel lengths range from 1/2 in. to 3 in. Designed for pneumatic use only, they have a maximum working pressure rating of 150 psi. They incorporate fluoropolymer composite bearings for dynamic side loads up to 75 lb.

For More Information Circle No. 764

Diagnosing Helicopter Gearboxes Using Connectionist Networks

Concepts of dynamical modeling, fuzzy systems, and neural networks are brought to bear.

Lewis Research Center, Cleveland, Ohio

A method of automated diagnosis of helicopter gearboxes involves processing of selected features of digitized outputs of vibration sensors via structure-based connectionist networks (SBCNs), which are mathematical constructs that incorporate elements from the disciplines of dynamical modeling, fuzzy systems, and neural networks. Like vibration-analysis gear-diagnostic methods that have been reported previously in *NASA Tech Briefs,* the SBCN method offers a partial solution to the basic problem of using pattern-classification techniques to extract indications of specific faulty gearbox components from the outputs of accelerometers mounted at several locations on a gearbox.

In the traditional approach to diagnosis by analysis of vibrations, one relies on a combination of (1) human expertise regarding abnormal features of vibration signals and (2) information on the proximity of each vibration sensor to each component that could be faulty. The traditional approach entails difficulty in processing large numbers of both normal and abnormal signal features and in identifying abnormal features in signals contaminated with noise. The SBCN approach offers greater potential capability for coping with noise and multiple features.

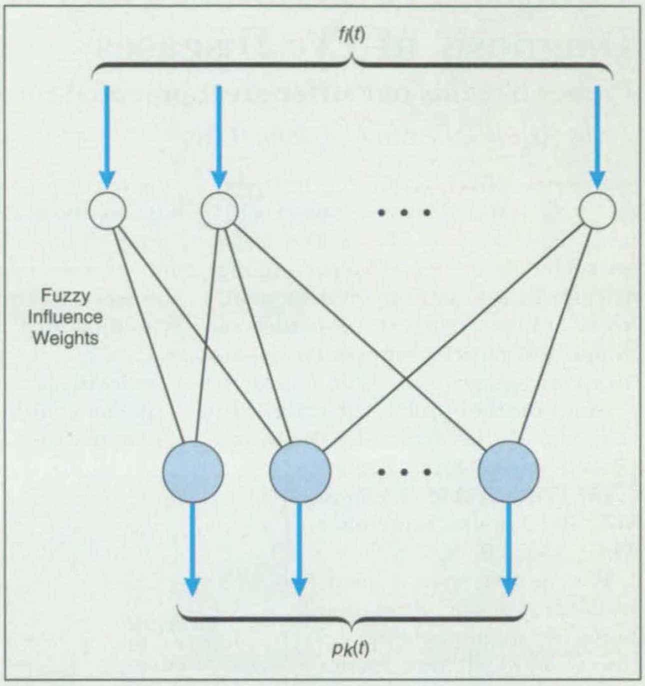
In its graphical representation (see figure), an SBCN is reminiscent of a simple artificial neural network. Vibration signals to be processed in the SBCN are preprocessed via the Single Category-Based Classifier (SCBC) algorithm, which classifies signal features by comparing their values with corresponding values recorded during normal operation in the absence of faults. Some features are flagged on the basis of their degrees of abnormality. The flagged features are fed as inputs to the SBCN.

The flagged features propagate through the SBCN similarly to the way in which they would propagate through a corresponding neural network. The responses of the SBCN are given by

$$p_k(t)=\sum_{i=1}^{n} f_i(t)\,w_{ik}$$

where $p_k(t)$ is a measure of the time-dependent index that the kth gearbox component is faulty, $f_i(t)$ is a value representative of the time-dependent flagged vibration-signal features from the ith accelerometer, and w_{ik} is a connection weight. As they would in a neural network, the connection weights embody the ranges of flagged feature values associated with various specific faults.

Unlike in a neural network, the connection weights are not established by supervised training on comprehensive sets of measurement data associated with known faults. Instead, each w_{ik} is based on the lower and upper bounds of fuzzy influences between the ith accelerometer and the kth component. The "structure-based" aspect of the SBCN arises as follows: The need for supervised training is eliminated by using knowledge of the dynamics of the gearbox structure to account for the effects of the proximity of the components and the accelerometers on the features of the vibration signals. In principle, this would involve the use of the dynamics to predict the effects of propagation of vibrations through the structure and the resulting attenuation of the flagged signal features at every frequency of interest. In practice, exact mathematical modeling of the dynamics is impossible; instead, one uses a simplified lumped-mass mathematical model to approximate root-mean-square (rms) attenuation values that are used as average attenuation levels applicable to all frequencies. The rms values are used to assign structural influences, which are then represented by fuzzy variables.



A Structure-Based Connectionist Network resembles a simple artificial neural network, but its connection weights are obtained in a different way.

The structural-influence fuzzy variables embody knowledge of the structure only. It is necessary to also assign featural-influence fuzzy variables, which embody knowledge of the effects of component failures on flagged signal features. Inasmuch as vibration-signal features are usually obtained at frequencies related to rotational frequencies of individual components, the effects of component faults on the features can be determined readily and used to calculate the featural-influence fuzzy variables. The structural- and featural-influence fuzzy variables are then incorporated as connection weights in the SBCN.

This work was done by Vinay B. Jammu and Kourosh Danai of The University of Massachusetts and David G. Lewicki of the Propulsion Directorate of the U.S. Army Research Laboratory for **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mathematics and Information Sciences category,* ***or circle no. 129*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Compact, Noncontact Fiber-Optic Probe for Diagnosis of Eye Diseases

Probes like this one offer great potential for research and diagnosis.

Lewis Research Center, Cleveland, Ohio

A compact fiber-optic probe has been found to be useful for noncontact diagnosis of interior parts of eyes. The probe was originally developed for performing dynamic-light-scattering measurements to determine transport properties of submicron particles suspended in fluids in microgravity, and is an improved version of the probes described in "Dynamic Light Scattering With Improved Fiber-Optic Probes (LEW-15461)" *NASA Tech Briefs,* Vol. 19, No. 9 (September 1995), page 86.

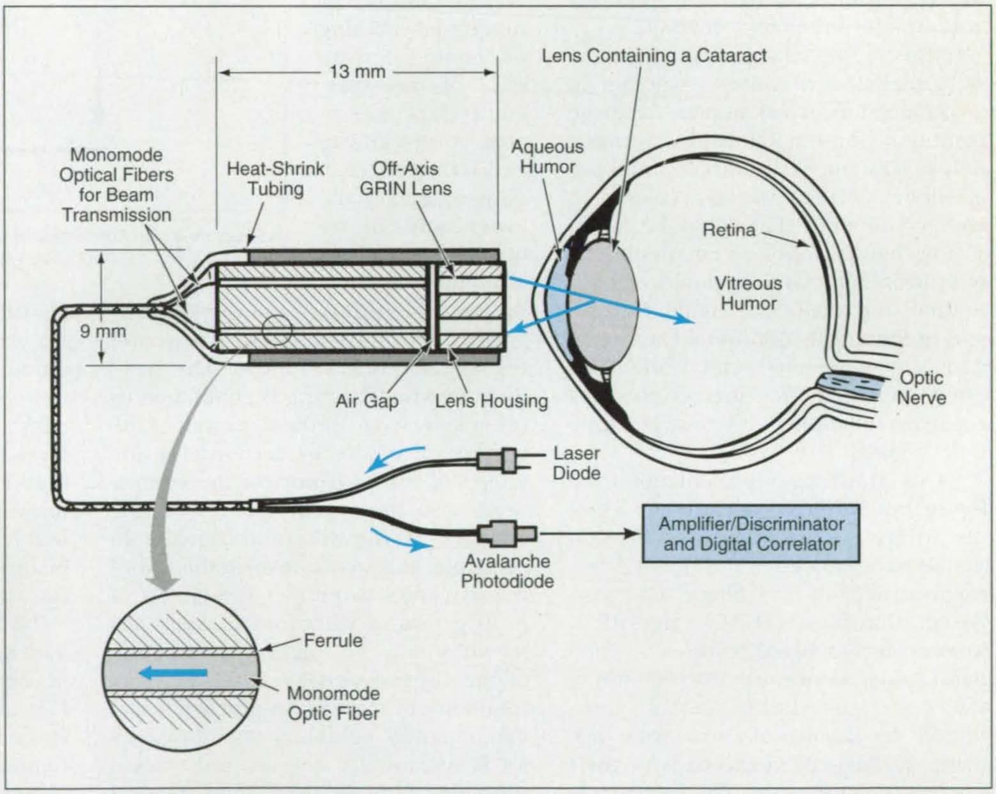
The probe (see figure) includes a probe head that holds two monomode optical fibers, of which one carries light with a power of a few microwatts from a laser diode to illuminate the region to be probed. The other optical fiber carries light scattered from the probed region to an avalanche photodiode (APD) for detection. The tips of the optical fibers in the probe head are aligned with an off-axis gradient-index-of-refraction (GRIN) lens, which is positioned with a gap of up to 0.5 mm from the fiber tips to obtain a tightly focused spot in the probed region.

In operation, the probe is positioned in front of an eye to illuminate the interior and measure light back-scattered from submicron particles in the interior. Because of Brownian motion of the particles, the back-scattered light forms a rapidly changing interference pattern (dynamic light scattering) that manifests itself as fluctuations in the output of the APD. Information about the sizes of particles and other aspects of the dynamics of the scattering medium can be extracted by processing the output of the APD through an amplifier/discriminator and a digital correlator to obtain a correlation function.

The correlation function gives information about the particles in the scattering volume. This information is useful for research and diagnosis of eye diseases and other diseases with ocular manifestations. For example:

- Cholesterol and blood-sugar molecules occur in the aqueous humors of patients with heart-related diseases and diabetes, respectively.
- Protein crystallines and possibly other particles in the lens have been conjectured to play a role in cataractogenesis. Research is needed to establish the exact causes of cataracts and to develop techniques for early diagnosis and treatment.
- Changes in macromolecules in the vitreous humor can be used to identify diseases of the posterior chamber of the eye and complications of those diseases; e.g., posterior vitreous detachment and diabetic retinopathy.

Thus, further development along this line holds promise for compact fiber-optic probes as clinical ophthalmic instruments for routine use.



The **Probe Makes No Contact** with the eye. Dynamic light-scattering measurements taken with the probe yield information on submicron particles inside the eye.

This work was done by Rafat R. Ansari and Kwang I. Suh of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Life Sciences category,* ***or circle no. 128*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

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Books & Reports

Phospha-s-Triazines and Other Compounds for Use as Additives

A report describes research on selected compounds as additives to perfluoroalkyether (PFPAE) fluids that are used as synthetic lubricants for metal parts. Additives are needed to inhibit both thermo-oxidative degradation of, and corrosion of metals by, the PFPAE fluids in the presence of oxidizing atmospheres. [An earlier phase of this research was reported in "Performance of Perfluoroalkylether Lubricant System" (LEW-15603), *NASA Tech Briefs*, Vol. 19, No. 9 (September 1995), page 123.] The phase of research described in the present report included (1) synthesis of novel phospha-s-triazines, phosphate esters, and related additive compounds and (2) evaluation of these and previously available additives with respect to degradation- and corrosion-inhibiting behavior and thermal and hydrolytic stability, in an effort to develop a data base of optimum PFPAE/additive/alloy combinations. The other materials included in the study were six different alloys and four commercial PFPAEs. None of the additives tested was found to undergo hydrolysis at a temperature of 100 °C. The phosphate esters were found to be the most effective and, in particular, were fully effective in arresting the degradation of the PFPAEs in the presence of metal alloys and oxygen at temperatures up to 300 °C. In an overall rating, the additives in order of decreasing effectiveness were found to be phosphates > phosphate/diester mixture > phosphine ≥ phospha-s-triazines.

This work was done by K. J. L. Paciorek of Lubricating Specialties Co. for **Lewis Research Center.** *To obtain a copy of the report, "Phospha-s-Triazines and Related Compositions of Improved Hydrolytic and Thermal Stability," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category,* ***or circle no. 195*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16561.

Production of Tar in Pyrolysis of Large Biomass Particles

A paper presents a study of the production of tar in the pyrolysis of spherical biomass particles, with computational simulations performed by using

For More Information Circle No. 440

the macroparticle portion of the model described in "Generalized Mathematical Model of Pyrolysis of Plant Biomass" (NPO-20068) elsewhere in this issue of *NASA Tech Briefs*. The particles were chosen to have sizes of the order of 1 cm, representative of typical waste wood chips. The numerical results indicate that tar formed in primary reactions decomposes in secondary reactions that occur both within particles and in exterior boundary layers; the net amount of tar available for collection is thereby reduced substantially. An analysis of the competing tar-generation and tar-decomposition reactions results in finding reactor-temperature ranges for maximizing tar yields; the range in a given case is a function of the initial particle size and of the efficiency with which pyrolysis products ejected from particles are cooled and the decomposition reactions thereby quenched in the surrounding medium. The tar yield in a given case also depends on the choice of inert carrier gas, primarily via its effect on the heat capacity of the medium. The report concludes by presenting results of a sensitivity study of the influences of the density, thermal conductivity, and heat capacity of the biomass and of the primary heats of reaction.

This work was done by Josette Bellan and Richard S. Miller of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the paper, "Tar Yield and Collection From the Pyrolysis of Large Biomass Particles," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 123*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20067

Wheel Drive of Mars Rover

A brief report summarizes the design of the lightweight, high-torque wheel drive of a small robotic vehicle used to explore the surface of Mars. Planetary gearing was selected for compactness and high torque capability. The input stages were fitted with ball bearings to survive the cold (down to −100 °C) Martian atmosphere with very light lubrication. To reduce length, a conventional output shaft and its bearing were not chosen; instead, the last-stage planetary shafts were mounted directly on the wheel hubs. A wheel and its gearing are supported by a single "X"-type main ball bearing that takes radial and axial loads as well as offset moments. The balls in this bearing are made of an acetal plastic and are used without lubrication. To reduce weight, hard-anodized, aluminum races were machined directly into the affected structure; after machining, the races were hard-anodized and coated with polytetrafluoroethylene. The inside diameter of the main bearing is large enough to enable the bearing to contain the motor and gear assembly.

This work was done by Donald B. Bickler, Howard J. Eisen, and Angel Olivera of Caltech for **NASA's Jet Propulsion Laboratory.** *No further documentation is available.*
NPO-20077

Evaluation of Droplet-Evaporation Models for Gas/Liquid Flow

A report presents an evaluation of eight mathematical models of the evaporation of liquid droplets — models that are used in the numerical simulation of a variety of gas/liquid flows, including cooling sprays, burning liquid-fuel sprays, fire-suppression sprays, and air/fuel-premixing flows in combustors. Included in the study were two versions of a classical model that includes transient drop-heating effects, four versions of a heat-mass-transfer-analogy model, and two nonequilibrium models based on the Langmuir-Knudsen evaporation law. The models were used to predict evolutions of droplet diameters and temperatures, and the predictions were compared with experimental observations, for droplets of benzene, decane, heptane, hexane, and water vaporizing in convective airflows. All models performed nearly identically at low evaporation rates at gas temperatures significantly lower than the liquid-boiling temperatures. For gas temperatures at and above boiling temperatures, there were large deviations among the various model predictions. Nonequilibrium effects were found to become significant for initial droplet diameters <50 μm, and to increase with slip velocity. The models based on the Langmuir-Knudsen law agreed most closely with the experimental results, though not because they account for nonequilibrium effects; instead, the superiority of these models was attributed to the incorporation of a corrected heat-transfer equation.

This work was done by Josette Bellan, Kenneth Harstad, and Richard Miller of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Evaluation of Equilibrium and Non-Equilibrium Evaporation Model for Many-Droplet Gas-Liquid Flow Simulations," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category,* ***or circle no. 140*** *on the TSP Order Card in this issue to receive a copy by mail ($5 charge).*
NPO-20259

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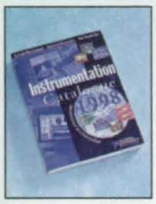

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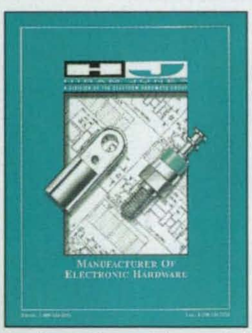

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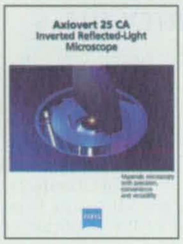

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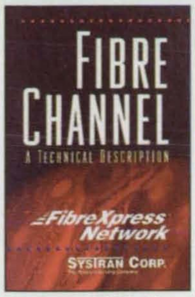

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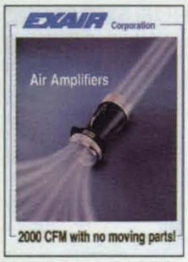

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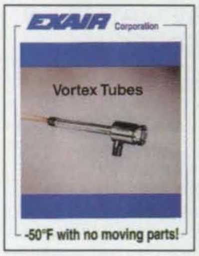

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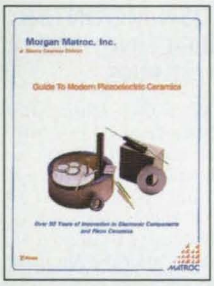

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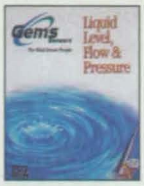

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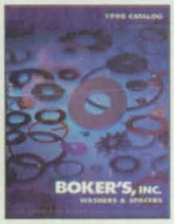
For More Information Circle No. 635



WASHERS & SPACERS

Boker's FREE, 40-page 1998 Catalog offers over 14,000 non-standard sizes with no tool charges. Outside diameters of 0.080" to 2.631", a variety of inside diameters and thicknesses, and 2,000 material variations create millions of possibilities. Materials include low carbon steel sheet, five types of spring steel, stainless steel, aluminum, brass, copper, and nickel silver. New user-friendly list displays non-metallic washers such as Delrin®, Teflon®, Mylar®, and nylon. Metric sizes available. Boker's Inc., 3104 Snelling Ave., Minneapolis, MN 55406-1937; Tel: 800-927-4377; Fax: 612-729-8910; http://bokers.com

Boker's Inc.

For More Information Circle No. 636

PERMANENT COATING FOR MOLDS/DIES IMPROVES RELEASE & WEAR-LIFE

New MAGNAPLATE HTR® surface enhancement coating increases the mold release efficiency of all molds and dies made of any metal by creating a permanent surface with an extremely low coefficient of friction. Can be made thermally or electrically conductive or non-conductive. Thermally conductive coatings exhibit consistent temperature. Works where sprays, additives, other dry-lubricants have failed. General Magnaplate Corp., Linden, NJ 07036; Tel: 800-852-3301; Fax: 908-862-6110; e-mail: info@magnaplate.com; http://www.magnaplate.com

General Magnaplate Corp.

For More Information Circle No. 637

ELECTRONIC HARDWARE

Globe Electronic Hardware, Inc. introduces its latest 260-page catalog, which provides complete engineering dimensions and specifications for our entire line of precision electronic hardware. Products include: Standoffs, Spacers, Captive Panel Screws, Retainers, Handles, Ferrules, and other quality components in both American and metric standards. Globe Electronic Hardware, Inc.; Tel: 800-221-1505; Fax: 718-457-7493; www.globelectronics.com

Globe Electronic Hardware, Inc.

For More Information Circle No. 638

PLC PRODUCT SELECTION MADE SIMPLE

Much more than just a listing of products and pricing, the impressive 500-page catalog from PLCDirect™ combines detailed product descriptions with plenty of technical illustrations to step you through the process of selecting various PLC hardware and software, PC-based control, operator interface, and terminal block products that are right for your application. PLCDirect by Koyo, 3505 Hutchinson Rd., Cumming, GA 30040; Tel: 800-633-0405; Fax: 770-889-7876.

PLCDirect by Koyo

For More Information Circle No. 639

SENSOR CONTROL & IMAGE CAPTURE

Sensoray's DAQ boards interface industrial sensors in lab & industrial measurement, imaging & control applications for CompactPCI, ISA, PCI, PC/104, STD, and VME bus systems. Available are: Smart A/Ds - 8 to 16 differential inputs to interface to any combo of 7 sensor types; Machine Control - DIO, encoder I/O, A/D, D/A, & watchdog on one multifunction board; Frame Grabbers - low-cost, real-time capture of color and mono images w/SDKs. Sensoray, Portland, OR; Tel: 503-684-8005; Fax: 503-684-8164; e-mail: info@sensoray.com; www.sensoray.com

Sensoray

For More Information Circle No. 640

LATEST BOOK TEACHES NONLINEAR FEA & MECHANICAL EVENT SIMULATION

Linear and Nonlinear Finite Element Analysis in Engineering Practice explores nonlinear and linear theory. *Finite Element Modeling in Engineering Practice* is the industry standard for linear analysis. CD-ROM has search engine and color graphics. Address: 150 Beta Dr., Pittsburgh, PA 15238.

APD

For More Information Circle No. 641

LEARN MORE ABOUT FEA

Finite Element Analysis in Action! is a proven, effective, instructional video and interactive CD-ROM for engineers. Live laboratory and computer demonstrations show how to better use any FEA software. Learn more about the basic physical principles behind FEA, how engineering judgment affects analysis, how tiny flaws affect material strength, boundary conditions and more. Address: 150 Beta Dr., Pittsburgh, PA 15238; Tel: 1-800-48-ALGOR; www.algor.com; apd@algor.com; or Fax: +1(412)967-2781.

APD

For More Information Circle No. 642

DOWNLOAD A FREE TRIAL OF SUPERDRAW III

Superdraw III is powerful CAD for engineering. Test drive the best precision finite element model building tool anywhere with our free trial software available at www.algor.com. Learn about Algor's FEA and Mechanical Event Simulation software, read Algor's newsletter and view frequently updated animations of FEA analyses. Address: 150 Beta Dr., Pittsburgh, PA 15238; Tel: +1(412)967-2700; www.algor.com; info@algor.com; or Fax: +1(412)967-2781.

Algor, Inc.

For More Information Circle No. 643

FREE *ALGOR IN ACTION* VIDEO AND CD-ROM

Free video has 18 action-packed minutes of real-world examples combined with Algor's Accupak/VE Mechanical Event Simulation demonstrations. Engineers use Accupak/VE to simulate real-world behavior of mechanical designs having motion or impact. CD-ROM has a variety of other new animations and technical information. Address: 150 Beta Dr., Pittsburgh, PA 15238; Tel: +1(412)967-2700; www.algor.com; info@algor.com; or Fax: +1(412)967-2781.

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TEST AND MEASUREMENT

Just because your budget is limited doesn't mean your test equipment has to be limited, too. By leveraging technology from HP's high-performance instruments, the HP Basic Instruments collection offers tools that fit your budget without compromising quality. You'll find all the fundamentals, from power supplies to DMMs to scopes. Hewlett-Packard Co.; Tel: 800-452-4844, ext. 1832.

Hewlett-Packard Co.

For More Information Circle No. 645

1998 PCMCIA PRODUCTS CATALOG

The new PCMCIA-PC CARD standard has been incorporated into applications such as datalogging, agriculture, digital film, and wireless communications. Envoy Data has just released its new catalog for these new applications, plus many other products like: memory; I/O (serial, parallel, SCSI, A/D) cards; PC card drives for ISA, IDE, SCSI; and industrial cards and drives, multimedia, industrial, and engineering tools for PCMCIA applications. Envoy Data Corporation, 6 E. Palo Verde, #3, Gilbert, AZ 85296; Tel: 602-892-0954; Fax: 602-892-0029; e-mail: info@envoydata.com; www.envoydata.com

Envoy Data Corporation

For More Information Circle No. 646

LOVE CONTROLS 1/16 DIN TEMPERATURE/PROCESS CONTROL

The Love Controls 16A Series temperature/process controls offer a high level of functionality in a compact 1/16 DIN package featuring universal input for thermocouples, RTDs, or process signals, PID, fuzzy logic, auto/manual station, ramp/soak, and much more. Love Controls Division, Dwyer Instruments, Inc., PO Box 338, Michigan City, IN 46361-0338; Tel: 800-828-4588 or 219-879-8000; Fax: 219-872-9057; www.love-controls.com

Love Controls Division, Dwyer Instruments

For More Information Circle No. 647

MACHINE VISION & AUTOMATED IMAGING

New Images Report covers best practices in machine vision and automated imaging. Includes technology articles on applying real-time machine vision, getting the most from your frame grabber, code for acquiring high-res images, and case histories. Specifications for state-of-the-art vision systems, boards, and software also included. Imaging Technology Inc., 55 Middlesex Turnpike, Bedford, MA 01730; Tel: 781-275-2700; Fax: 781-275-9590; e-mail: info@imaging.com; www.imaging.com

Imaging Technology, Inc.

For More Information Circle No. 648

FREE 1998 PC & PCMCIA SOLUTIONS HANDBOOK

Quatech's new 1998 product handbook details our extensive line of quality communication, data acquisition, and signal conditioning products for PCMCIA, ISA, and PCI. New for 1998 are 2- and 4-port RS-232 PCI serial adapters and the SignalPro Series of board level signal conditioning modules. Product overviews, photos, and complete technical specifications are provided. For your free copy call 1-800-553-1170; e-mail: sales@quatech.com; or visit our website: http://www.quatech.com

Quatech, Inc.

For More Information Circle No. 649

VACUUM CLEANING SYSTEMS

This new, six-page brochure features Nilfisk's full line of industrial vacuum cleaning equipment, including: continuous-duty and wet/dry vacuums; vacuum-assisted power tools; and specialty products such as explosion-proof, compressed air, and mercury vacuum cleaners. Highlights include product application photos, and illustrations of the three filtration systems available. Nilfisk of America, Inc., 300 Technology Dr., Malvern, PA 19355; Tel: 610-647-6420; Fax: 610-647-6427; www.nilfiskamerica.com

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For More Information Circle No. 650

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Seastrom Mfg. Co. Inc.

For More Information Circle No. 651

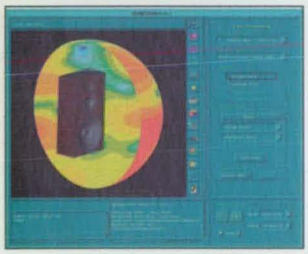
New on Disk

IPT Corp., Palo Alto, CA, has introduced FORTRAN-lint Year 2000 **source code analyzer software** for FORTRAN 77 and 90. It includes a Year 2000 debugging tool that provides a cross-reference table documenting all variables in the source code, and any equivalences to it, regardless of what name it assumes. The FORTRAN90-lint can also map out unfamiliar programs.

For More Information Circle No. 714

MARC Analysis Research Corp., Palo Alto, CA, has introduced MARC K7.1 and Mentat 3.1 **finite element analysis (FEA) software** for nonlinear problem-solving in areas such as metal-forming operations, deformation of elastomers, buckling analysis, thermal studies, and biomechanics simulation. Included are enhanced adaptive meshing operations, new fluid mechanics functions, and improved CAD integration with IGES, VDAFS, and DXF readers.

For More Information Circle No. 710

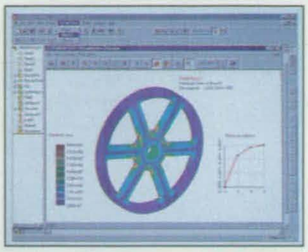


Automated Analysis Corp., Ann Arbor, MI, has introduced COMET 4.0 **acoustic analysis software**, which enables designers to predict acoustical performance before building a physical prototype. Capabilities include dynamic modeling and optimization of acoustic poroelastic (foam) materials, and the ability to identify and predict noise sources in a three-dimensional field using numerical solutions. The program is integrated with a variety of popular CAE software products.

For More Information Circle No. 716

DSP Blockset v2.0 large-scale **DSP simulation software** from The MathWorks, Natick, MA, is part of the DSP Workshop suite of tools for simulating, visualizing, and prototyping new algorithms. Blockset v2.0 enhancements include faster buffering, rate conversion blocks, and an optimized matrix math library.

For More Information Circle No. 712



DesignWorks **motion, structure, and thermal analysis software** from CADSI®, Coralville, IA, enables users of SolidWorks to make design improvements immediately within SolidWorks using the DesignWorks simulation tools. Features include the ability to automatically calculate velocities and accelerations; perform steady state convection and conduction heat transfer studies; and perform stress, displacement, and natural frequency studies.

For More Information Circle No. 715

Version 3 of MSC/NASTRAN for Windows **modeling and analysis software** from MacNeal-Schwendler Corp., Los Angeles, CA, allows users access to geometric associative modeling using ACIS or Parasolid-based geometry kernels. Users can import and modify geometry from CAD solid-modeling systems or create solid finite-element models directly with Version 3 modeling tools.

For More Information Circle No. 711

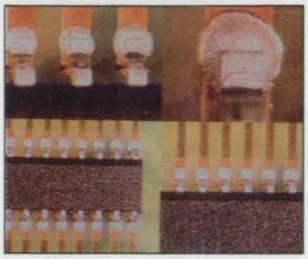
Vellum Solids **solid modeling software** from Ashlar, San Jose, CA, enables CAD users working in 2D to switch to 3D without changing design paradigms. The program combines wireframe, surface, and solids modeling to identify faces, edges, holes, endpoints, midpoints, center points, tangencies, and real and extended intersections. It uses ACIS 3.0R1; Windows 95/NT and Mac OS Power Macintosh compatibility will be available.

For More Information Circle No. 717

SBS Technologies, Carlsbad, CA, has introduced DataXpress network-distributed **data acquisition software** for Windows NT that supplies network-wide access to real-time data. Program device servers acquire data from various interfaces, store current values in a real-time database, display the data using multiple graphical elements, and distribute the information on the network. Custom programs and analysis applications can be created using Microsoft-compatible OLE and ActiveX technologies.

For More Information Circle No. 718

New on the Market

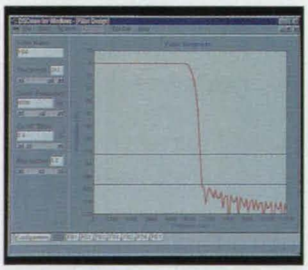


EPO-TEK E2101 **silver-filled epoxy** from Epoxy Technology, Billerica, MA, is a two-component adhesive for use in place of solder. It is 100% solids, contains no solvent or thinners, and adheres to silicon wafers, glass, and metals (copper, silver, gold). It does not flow when subjected to heat and cures at 150°C in one hour, 175°C in 15 minutes, and snap-cures at higher temperatures.

For More Information Circle No. 729

The SBC54 battery-powered, standalone **single-board computer** from Innovative Integration, Westlake Village, CA, features onboard DSP for control, data acquisition, and communications applications. Features include dual plug-in sites for interchangeable, modular I/O; a single 9- to 18-volt battery supply; and a Texas Instruments' TMS320LC549 16-bit fixed-point digital signal processor operating at up to 100 MIPS.

For More Information Circle No. 726

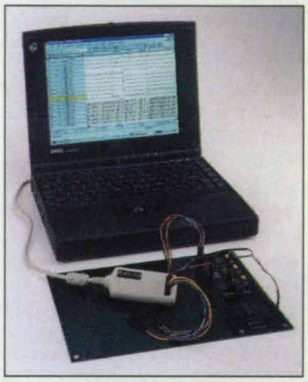


Microstar Laboratories, Bellevue, WA, has introduced the Model iDSC 816 8-channel, 16-bit resolution **digital data acquisition board** for PC-based systems requiring anti-aliasing filters. The board features two 80-MHz digital signal processors controlled by an onboard 486 and supported by 4 MB of onboard memory; optical isolation; 8 channels with simultaneous sampling and independent filters; and cut-off frequencies up to 20.48KHz, selectable by channel.

For More Information Circle No. 724

Poly-Tite® **sidelatch couplings** from Parker Hannifin Corp., Brass Products Division, Otsego, MI, are available in through-type and shutoff inserts, and in bulkhead quick-coupler configurations. Body, nut, and sleeve are pre-assembled. They feature a working range up to 150 PSI from 0 to 150°F with polyethylene tubing, and up to 300 PSI from 0 to 175°F with nylon tubing.

For More Information Circle No. 721



The Pod-A-Lyzer 8020 **portable logic analyzer** from Boulder Creek Engineering, Santa Cruz, CA, is a palm-sized, 18-channel, 100-MHz analyzer that features Version 2.1 software, a Windows-based program that controls the unit via an RS-232 serial port. It provides set-up, acquisition, display, and analysis of 18 channels of digital input, allowing acquired waveforms to be viewed, printed, and saved to disk. Acquisition files can be shared via floppy disk or e-mail.

For More Information Circle No. 730

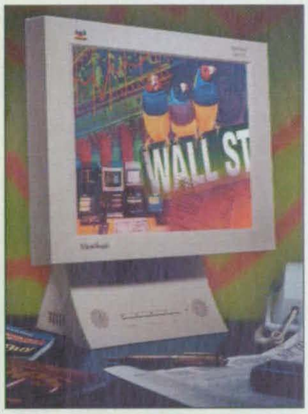
Industrial **pressure transducers** from Keller PSI, Oceanside, CA, were designed for corrosive liquids, refrigerant gases, compressor pressures, natural gas, and hydraulic systems. Units come in standard pressure ranges from 100 to 8000 PSI. They feature 316 stainless-steel wetted surfaces and welded construction. Operating from unregulated DC supply, they provide standard outputs, including voltage and current-loop versions.

For More Information Circle No. 725

New on the Market

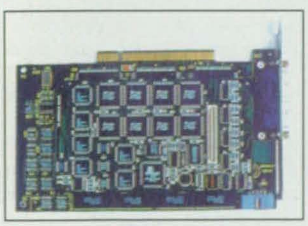
Mountain Optech, Boulder, CO, offers the SE-23000 HDR 23-GB ruggedized **removable magnetic disk drive**, which can collect data at 5 MB/sec. The drives function in extreme environments under shock and vibration conditions in all attitudes. They feature temperature firmware, heaters, built-in fans, and conformal coating of the electronics.

For More Information Circle No. 723



ViewSonic Corp., Walnut, CA, offers the VPA138 ViewPanel® **LCD flat-panel display** that measures 13.8" and features a panel thickness of less than 2.5". It runs on 40 watts of power and displays in landscape and portrait modes with an ESP. The display provides images with 200 nits brightness at a maximum NI resolution of 1,024 x 768 (XGA) and a 75Hz refresh.

For More Information Circle No. 732

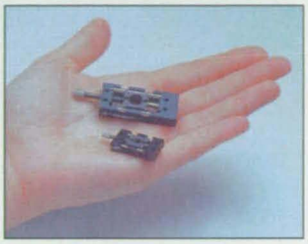


Imaging Technology, Bedford, MA, offers the IC-MTD **frame grabber** for digital multitap cameras. The card handles 8- or 16-bit data from a variety of automated-imaging and machine-vision applications. A half-slot PCI bus board, it accepts data from cameras with multiple digital outputs and provides a maximum total throughput from camera to frame grabber of 80 MB/sec. It can transfer video data to the host PC memory in less than 4 msec.

For More Information Circle No. 727

Herion USA, Warrendale, PA, has introduced the Model 31D electronic **pressure switch**, which is available in three pneumatic ranges from vacuum to 360 PSI. Features include digital display of actual pressure, LED status indication, and adjustable hysteresis. The switch is suitable for resistive or inductive loads up to 1A; switching points can be calibrated without applied pressure. A strain gauge pressure sensor and solid-state output are featured.

For More Information Circle No. 733



Newport Corp., Irvine, CA, has introduced linear-action **miniature stages** with footprints from 1" long by 0.5" wide by 0.2" tall. One version uses micrometers; others offer 80-thread-per-inch adjustment screws for submicron typical resolution. Stages also can support loads in excess of 0.75 pound. They are available in x, xy, and xyz configurations and feature a carriage design for low wobble.

For More Information Circle No. 722

The PC100D Dual Counter/Timer **plug-in board for PC computers** from Advanced Research Instruments Corp., Boulder, CO, can be software-configured as two independent counter/timers; two simultaneous counters controlled by a single timer; or two alternating counters (zero dead time). Maximum repetition rate of each counter is 50 MHz.

For More Information Circle No. 720

Furon, Hoosick Falls, NY, offers F300, F500, F700, and F900 Series **sheet gasketing materials** that are designed to withstand chemicals, heat, and high pressure. The F300 mechanical grade material is available in gray or white; the F500 general-purpose material is brick red; the F700 blue material features high compressibility; and the F900 is an off-white FDA-compliant material for food and drug applications. All are available in sheet sizes of 48 x 48" or 60 x 60" in thicknesses of 1/32", 1/16", and 1/8".

For More Information Circle No. 728

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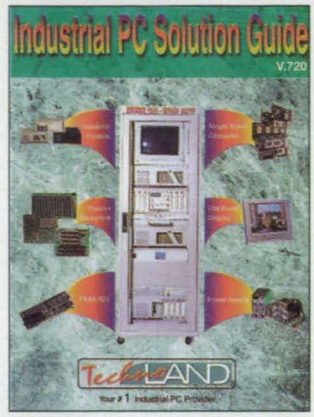
New Literature



TechnoLand, Sunnyvale, CA, has released a 50-page catalog of **industrial PC products**. Included are a range of single-board computers, rack-mount chassis, accessory kits, power supplies, and flat-panel monitors.

For More Information Circle No. 700

Columbia Research Laboratories, Woodlyn, PA, offers an eight-page Short Form Catalog describing **acoustic sensors and pressure transducers**. Products include piezoelectric accelerometers, force balance accelerometers and inclinometers, strain and acoustic sensors, and LVDTs.

For More Information Circle No. 706

A four-page brochure from Sumitomo Metals, Saddle Brook, NJ, describes pipeline **processors** for image-processing applications. Products range from 8- or 12-bit histogram processors at 40 or 50 MHz to frame buffer controller LSIs.

For More Information Circle No. 707

EIS, Fabrico Division, Hillside, IL, offers a 184-page engineering manual describing electrical **insulating and shielding materials** from 25 manufacturers. Featured are electrical insulation, pressure-sensitive tapes, static control and EMI/RFI shielding products, and industrial products.

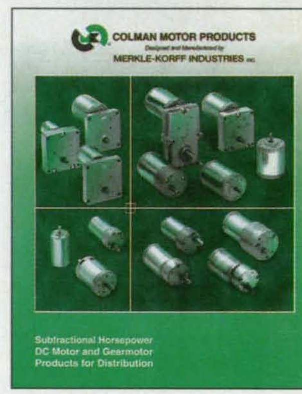
For More Information Circle No. 708

Thomson Micron, Ronkonkoma, NY, has released a technical bulletin on the PowerTRUE 90 right-angle **gearhead.** It offers peak torque of 9,752 in.-lb; a backlash of 6 arc-minutes; and ratios from 1:1 to 5:1 in 60, 75, 100, 140, and 180 mm square frame sizes.

For More Information Circle No. 702

SKY Computers, Chelmsford, MA, has released four-page datasheets on the SKYbolt II 6U and SKYbolt II 9U VME **multiprocessor accelerators**. The accelerators are used in creating numerically intensive applications in medical imaging, signal processing, pattern recognition, and seismic processing.

For More Information Circle No. 704



Merkle-Korff Industries, Des Plaines, IL, offers a 56-page catalog of Colman Motor Products, including subfractional **DC motors and gearmotors**. Included are permanent magnet DC motors; in-line, plastic, and pancake gearheads; and optional accessories such as tachometers, connectors, encoders, and clutches/brakes.

For More Information Circle No. 705

A reference guide from LEMO USA, Santa Rosa, CA, describes **connectors** available in single, multi, or mixed contact insert configurations. These include coaxial, triaxial, high-voltage, fiber-optic, fluidic/pneumatic, and thermocouple.

For More Information Circle No. 701

Pittman, Harleysville, PA, offers a four-page brochure on Series 3400 ELCOM II™ **brushless motors.** Features include three-phase slotless stator; four-pole rotor with neodymium iron boron magnets; six-step commutation at 60 electrical degrees; and motor and winding parameters.

For More Information Circle No. 703

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