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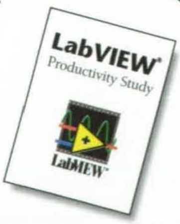

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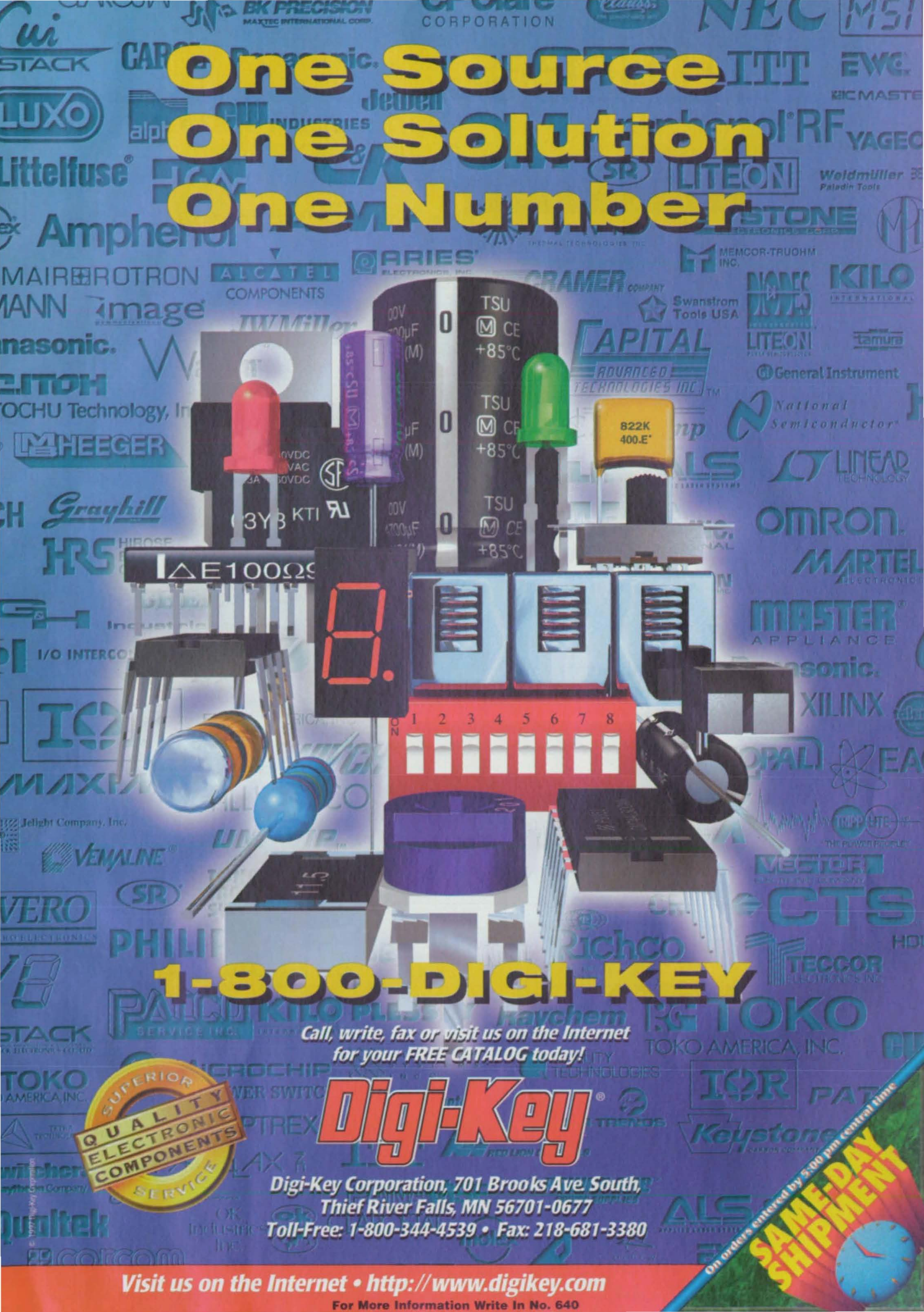
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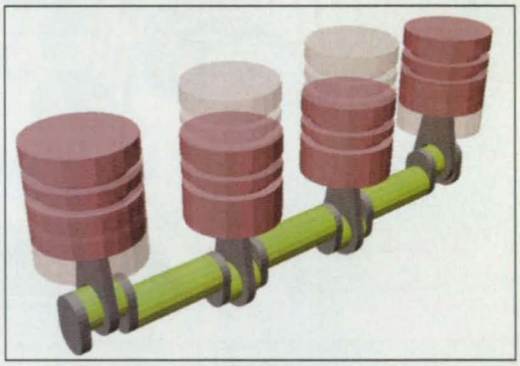

This month, we announce the winners of your 1996 Readers' Choice Awards for top products of the year, including the Gold Medal Winner for Product of the Year, Working Model 3D™ modeling, simulation, and analysis software from Knowledge Revolution, San Mateo, CA. See pages 24-25 for more information on the Product of the Year, as well as your choices for the "rest of the best" products of 1996.

Image courtesy of Knowledge Revolution

Contents *continued*

Special Supplements

On the cover:

Parasolid V8.0 solid modeling software from EDS Unigraphics, Maryland Heights, MO, was used to create this runner of a Kaplan turbine for Sulzer Hydro, a water turbine manufacturer. The software is one of 12 design/modeling programs highlighted in the Special Focus on Computer-Aided Design & Engineering, which begins on page 30.

Photo courtesy of EDS Unigraphics

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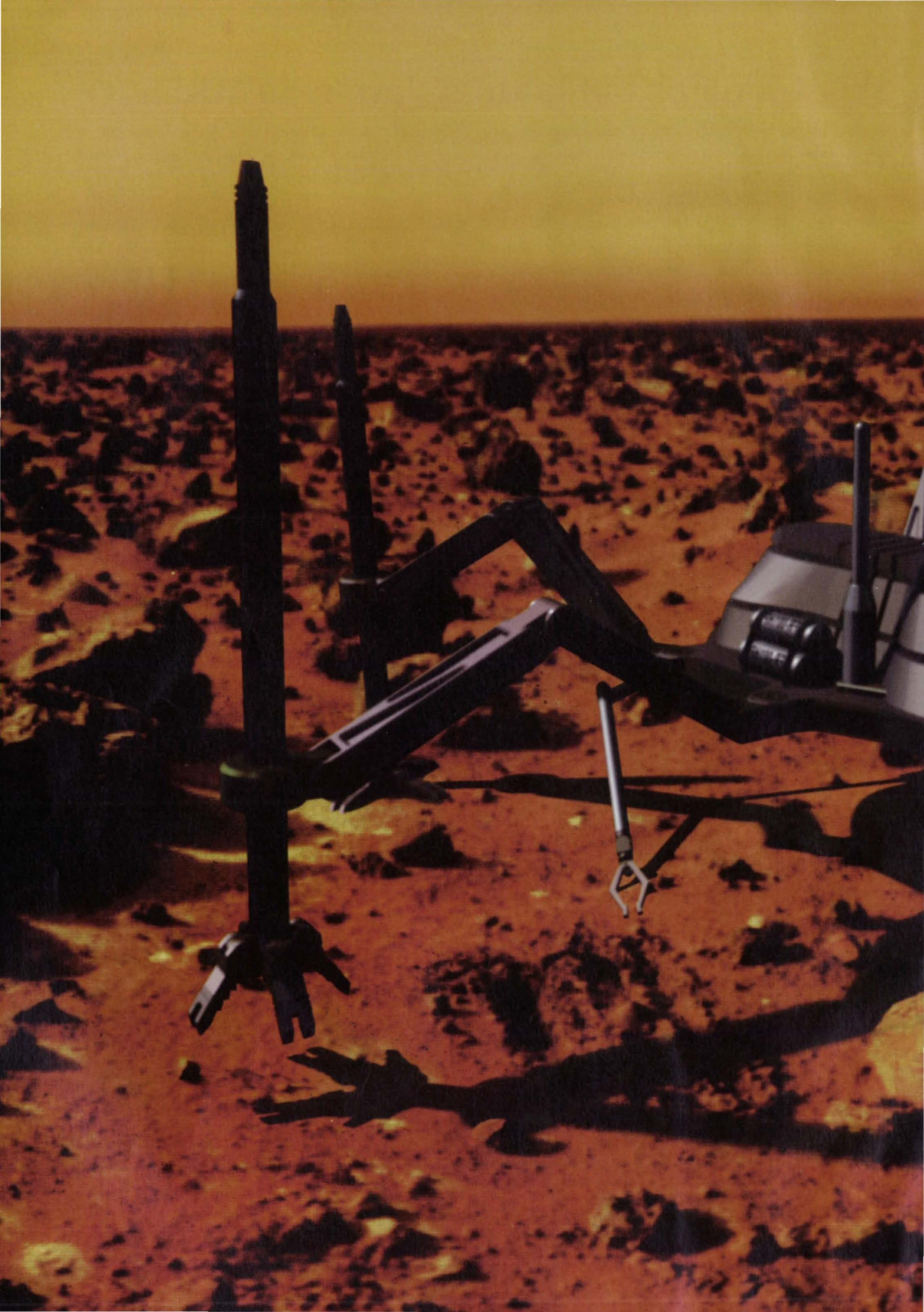

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NASA Commercial Technology Team

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
(415) 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.
Bill Sheehan
(407) 867-2544
billsheehan-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.
Ann Heyward
(216) 433-3484
ann.o.heyward@lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Harry Craft
(205) 544-5419
harry.craft@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 Program Offices

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

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

Dr. Robert Norwood
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(202) 358-2320
rnorwood@oact.hq.nasa.gov

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phodge@osfms1.hq.nasa.gov

Gerald Johnson
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g_johnson@aeromail.hq.nasa.gov

Bill Smith
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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-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.

Ismail Akbay
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

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

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

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

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

Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(216) 734-0094

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.

Karen Robbins
American Technology Initiative
Menlo Park, CA
(415) 325-5353

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

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

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

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

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

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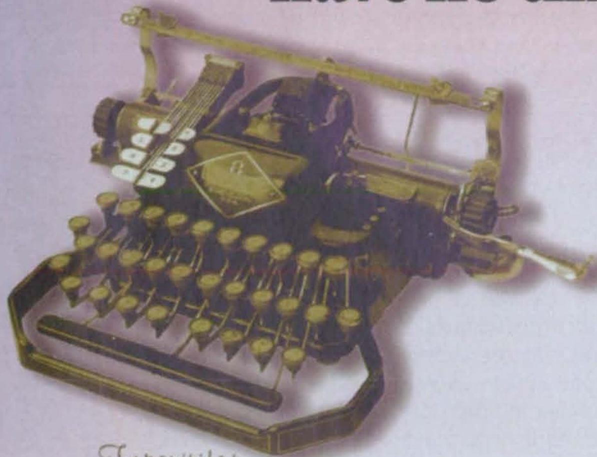
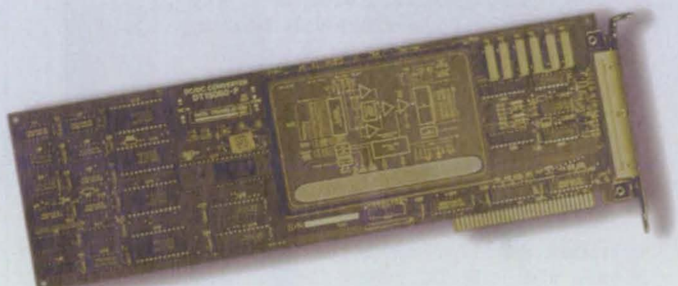


Typewriter c. 1922

Adding Machine c. 1941

Rotary Telephone c. 1953



ISA Data Acquisition Board c. 1984

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Reader Forum

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

*(**Editor's Note:** The following letter was sent in response to a January Reader Forum request from Nicholas Oshana Jr., who was seeking sources of graphite and other light materials.)*

I don't have any specific answers, but I do have two directions to take to find sources of graphite fabric and other sources/techniques for building strong, light structures. First, look into the experimental aircraft market, which is using exotic construction methods. Start with magazines in the local library, then call some of the smaller airports, and look for people who build experimental light aircraft. Also, try the Experimental Aircraft Association in Oshkosh, WI. The second place to look is in the model airplane area. Find someone who is familiar with the new model-building techniques. Graphite is being used extensively to add considerable strength to composite structures – balsa wood plus graphite strips, in many cases.

Robert M. Groh
Blue Springs, MO

The NASA software library shows that NASA has perfected an image-compression technique based on the storing of fractal equations vs. the image itself. The technique has been developed for the mainframe only. I am looking for an application for DOS and/or Windows. Presently, image storage on a PC, even after compression, averages 10 to 28 Kbytes. The fractal compression technique, as I understand it, would allow a single-page image to be reduced to a fixed 8 Kbytes, but would eliminate the ability to store the 256 shades of gray available with less efficient techniques. This would be a boon to PC users with applications limited to fax characteristics (binary, black/white). Can NASA Tech Briefs *readers help?*

Joseph M. Hunter
Systems Design Strategies
Laytonsville, MD

The solution to using high-velocity water to recycle munitions in an environmentally safe manner was found in NASA Tech Briefs. *Thanks to NASA, we were able to take a system from conception to market in less than nine months. Thank you!*

Paul Miller
Hopkins, MN

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Reader Forum, *NASA Tech Briefs,* 317 Madison Ave., Ste. 1900, New York, NY 10017.
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Please include your name, company (if applicable), address, and phone number or E-mail address.

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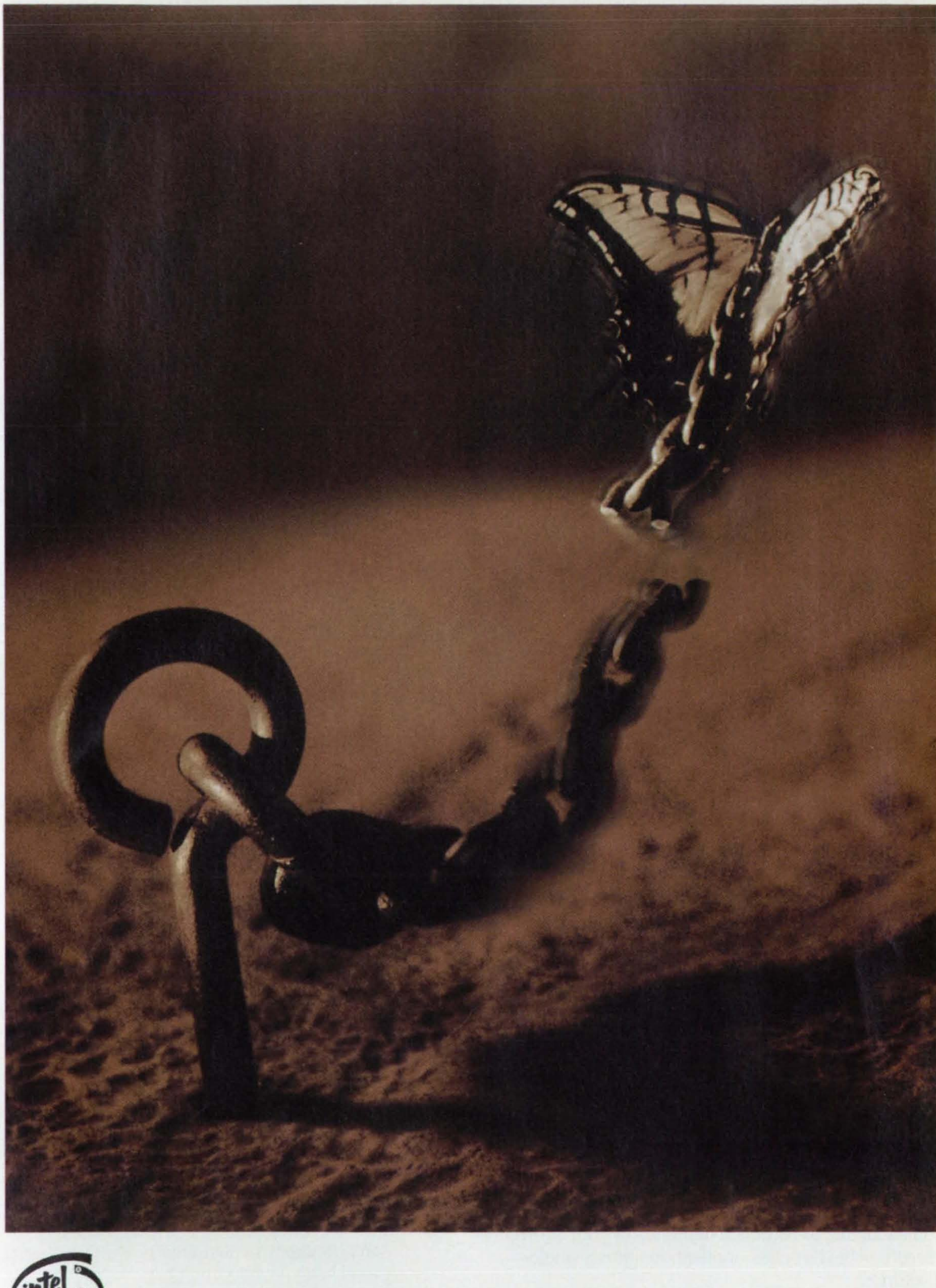


NASA NEWS BRIEFS

Hasbro, the Pawtucket, RI-based toy manufacturer, has teamed with NASA's Langley Research Center to develop a flying foam glider. The polyethylene foam Nerf glider had to be designed so that a child could fly it without any knowledge of aeronautics. Since previous attempts to construct a toy foam glider had been unsuccessful, Hasbro contacted the Center for Technology Commercialization, NASA's Regional Technology Transfer Center (RTTC) in Rhode Island. The CTC put Hasbro designers in touch with Langley to provide assistance in improving the flying distances and loop-to-loop stunt of its prototype gliders.

Ray Whipple, a Langley aerodynamics specialist who tests models of fighter planes, researched the problem and elicited help from two retired Langley researchers and model airplane specialists, Dave Robelin and Hewitt Phillips. With help from the Langley team, Hasbro designers learned about the physics of designing and flying gliders, including where to best locate the wings on the glider's fuselage and the proper angle for its tail surfaces. Said Hasbro's senior design director, Todd W. Wise, "Who knows better how to make things fly than NASA?"

Four Nerf gliders – two stunt and two long-distance – are already on the shelves of Walmart and Kmart stores. The gliders are unique to the toy industry: they fly and perform on the basis of their design and are propelled by throwing, rather than using a sling-shot or other launching device. They retail for between $7.99 and $10.99, depending on the model.

For more information, contact A. Donald Steinman of the Center for Technology Commercialization at 580 Ten Rod Rd., North Kingstown, RI 02852; Tel: 401-294-4400; Fax: 401-295-2825.

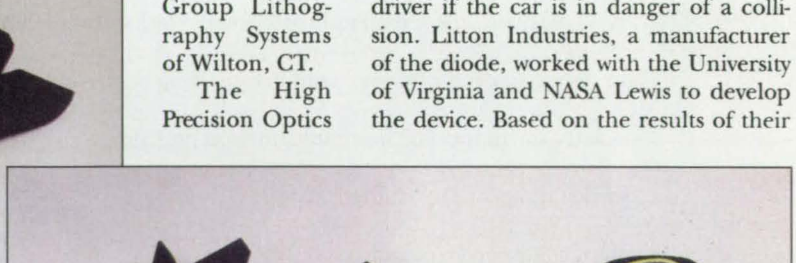
NASA and American industry have teamed to advance semiconductor technology, which might lead to breakthroughs in the next-generation computer microchip electronics industry. A four-party agreement, signed at the Technology 2006 conference and exhibition last October, brings together NASA's Goddard Space Flight Center; Tinsley Laboratories of Richmond, CA; SEMATECH, a not-for-profit, industry-funded consortium located in Austin, TX; and Silicon Valley Group Lithography Systems of Wilton, CT.

The High Precision Optics Joint Sponsored Research Agreement (JSRA) provides a means for Goddard to help further the state of optical art and optical systems technologies. The center is established as a leader in the advancement of ultraviolet mirror technology, and will provide UV systems, facilities, and other technical expertise. In return, Goddard will benefit by having higher precision optics for future space missions.

For more information, contact Donna Drelick of Goddard's Office of Public Affairs at 301-286-7995.

As you're cruising down the highway, keep an eye out for the top-of-the-line 1997 Mercedes Benz automobiles. They feature NASA-developed technology that may some day enable cars to guide themselves. The Auto Collision Avoidance Radar System (ACAR), a semiconductor/diode technology developed at NASA's Lewis Research Center, is mounted in the automobile's grill to alert drivers if they are in danger of colliding with an object or another car, and to help drivers navigate in the dark or in fog.

The system consists of a Gunn diode that produces radar waves, a detector, and a microprocessor. The microprocessor analyzes radar waves reflected from obstacles in front of the car, alerting the driver if the car is in danger of a collision. Litton Industries, a manufacturer of the diode, worked with the University of Virginia and NASA Lewis to develop the device. Based on the results of their



The four models of foam Nerf gliders

Multiple Pages Intentionally Left Blank

Readers' Choice Silver

Field WorkStation™ Computer

The FW7600 Field WorkStation™ laptop computer from FieldWorks, Eden Prairie, MN, boasts a MIL-SPEC rugged design for shock and vibration resistance, and 100 MHz 486 or Pentium processors. Operating on AC, battery, or 12V DC input power, the computer features multiple slots: one PCMCIA and three ISA for the standard model, and one PCMCIA plus three ISA or three PCI (or any combination of the two) for the Pentium model. It weighs only 14.7 pounds, and incorporates a Field MousePad pointing/drawing device, integral CD-ROM drive, and a one-piece chassis.

Readers' Choice Bronze

LeCroy Digital Storage Oscilloscopes

The LC334 and LC534 families encompass six high-performance, color, digital oscilloscopes for waveform capture display, measurement, and analysis. An Analog Persistence mode and 9" CRT displays allow signals to be viewed using the entire screen. The four-channel scopes offer an acquisition memory of up to 2 million points per channel, which can be combined for up to 8 million points in single-channel mode. Diagnostic, troubleshooting, and documentation tools are included; PCMCIA III capability is optional.

Readers' Choice Finalists

Solid Edge™ CAD software
Intergraph Corp., Huntsville, AL

ScopeMeter® B dual-channel test tool
Fluke Corp., Everett, WA

Onyx InfiniteReality™ visualization supercomputer
Silicon Graphics, Mountain View, CA

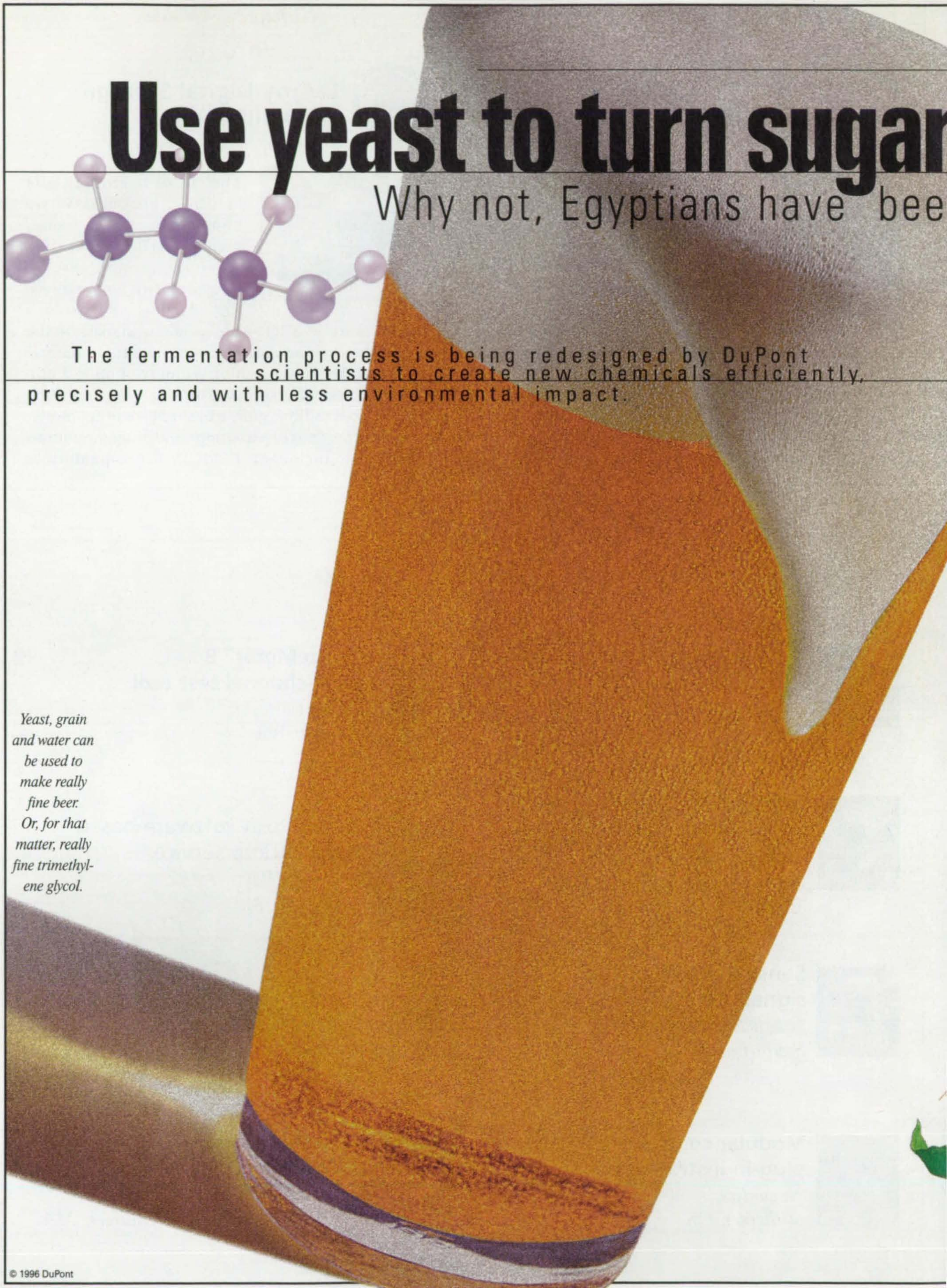
SafetyPosit software-based data backup service
Software Partners/32, Topsfield, MA

SensorPulse™ analog signal processors
Interactive Process Controls Corp., South Easton, MA

Electronic Product Definition software suite
Computervision, Bedford, MA

Modular computer plug-in instruments
Nomadics, Stillwater, OK

Euclid Quantum CAD/CAM/CAE/PDM software suite
Matra Datavision, Andover, MA



Use yeast to turn sugar

Why not, Egyptians have bee

The fermentation process is being redesigned by DuPont scientists to create new chemicals efficiently, precisely and with less environmental impact.

Yeast, grain and water can be used to make really fine beer. Or, for that matter, really fine trimethylene glycol.

into other molecules?

doing it for 4,000 years.

The transformation of sugars into alcohol by microscopic organisms has been known for a very long time. But only since the advent of genetic engineering is it feasible to think about harnessing the sophistication of biological systems to create molecules that are difficult to synthesize by traditional chemical methods.

For example, the polymer polytrimethylene terephthalate (3GT) has enhanced properties as compared to traditional polyester (2GT). Yet commercialization has been slow to come because of the high cost of making trimethylene glycol (3G), one of 3GT's monomers.

Comfortable, easy-care apparel may soon be made with fibers spun from chemicals that have been fermented from sugar.

Working the bugs in

The secret to producing 3G can be found in the cellular machinery of certain unrelated microorganisms. Some naturally occurring yeasts convert sugar to glycerol, while a few bacteria can change glycerol to 3G. The rub is that no single natural organism has been able to do both.

Through recombinant DNA technology, an alliance of scientists from DuPont and Genencor International has created a single microorganism with all of the enzymes required to turn sugar into 3G. This breakthrough is opening the door to low-cost, environmentally sound, large-scale production of 3G. The eventual cost of 3G by this process is expected to approach that of ethylene glycol (2G).

is no longer necessary o start with a barrel of l to produce chemicals. Corn, beets, rice—even potatoes— make great eed stocks.

A polymer for your thoughts

The 3GT polymer produced using our biosynthesized monomer has properties that exceed those of normal polyester. It is resilient and can be molded or extruded into fibers. The fibers are heat-settable and can be stretched at least 15 percent and recover without permanent "creep." They are stable to moisture and resistant to most common food stains, yet can be readily dyed using the same colors as conventional polyester. We foresee applications in markets such as apparel, home furnishings, upholstery fabric and carpet for automobile interiors. Even 3G has numerous applications. By combining it with various organic acids, polyols can be made as precursors to polyurethane elastomers and synthetic leathers.

A break for the environment

The 3G fermentation process requires no heavy metals, petroleum or toxic chemicals. In fact, the primary material comes from agriculture—glucose from cornstarch. Rather than releasing carbon dioxide to the atmosphere, the process actually captures it because corn absorbs CO_2 as it grows. All liquid effluent is easily and harmlessly biodegradable. What's more, 3GT can readily undergo methanolysis, a process that reduces polyesters to their original monomers. Post-consumer polyesters can thus be repolymerized and recycled indefinitely.

Can you play a role?

Throughout DuPont's history, many of our biggest contributions have come to market through collaboration with other companies. Development of 3GT could involve partnering with companies active in traditional polymer processing, separations technologies, recombinant DNA techniques, corn wet-milling and fermentation. If you possess these skills, or have ideas for end-use applications, we'd like to hear from you. Fax us on company letterhead with an indication of your interests to: DuPont, Dept. NT, 302-695-7615. Please limit your correspondence to nonproprietary, public-domain information only.

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Guiding Robots With the Help of Capaciflectors

These subsystems would help the manipulators avoid collisions with obstacles and guide the manipulators in final approach and soft contact with the intended objects.
(See page 44.)

Robust High-Temperature Microstrip Antennas

The proposed SiC-based microstrip antennas could withstand operating temperatures up to 500 °C and higher. They would be rugged and abrasion-resistant and could be useful on spacecraft, aircraft, and in automotive collision-avoidance systems.
(See page 48.)

High-Temperature Lubrication With a Vaporized Liquid

Vapor-phase lubrication can be used where traditional liquid lubricants fail. This type of lubrication could be used in advanced aircraft engines where temperatures can exceed 300 °C. The method is considered significantly more effective than the use of solid lubricants.
(See page 58.)

Thin-Film Thermocouples on Ceramics

Platinum-based thermocouples can be used at temperatures up to 1,500 °C. Such improved thermocouples are needed to measure the temperatures of advanced ceramic engines.
(See page 62.)

Tetherless, Optically Controlled Nanorovers

Efforts are under way to develop miniature, mass-producible, expendable robots that would weigh as little as 10 mg. These robots would rely on two bimorph legs that would move in inchworm fashion. Applications would include exploration of narrow passages and inhospitable terrains, micropositioning, and others.
(See page 92.)

Actuators for Rapid Development of Prototypes of Robots

A product line of gearmotor-type rotary electromechanical actuators has been designed to accelerate and facilitate the development of prototype robots. The new capabilities exceed those of commercially available actuators.
(See page 94.)

Self-Regenerating Water Iodinator

This unit can operate for many years without replacement or human intervention. Useful life expectancy is estimated to be 19 years; further refinement can extend the operating life to at least 30 years.
(See page 110.)

Special Focus: Computer-Aided Design & Engineering

Computing Off-Design Performances of Axial-Flow Turbines

A revised code incorporates improved mathematical models of flows and losses.

Lewis Research Center, Cleveland, Ohio

Preliminary studies of gas-turbine systems involve many repetitive calculations of geometries, design-point performances and — particularly for propulsion systems — off-design performances for all components. An analytical procedure and a computer program were originally developed to calculate the off-design performances of axial turbines. Mathematical models of flows and losses were used to compute performances over ranges of speeds and pressure ratios. A review of this procedure and software resulted in concerns that the axial-flow assumption was not adequate for turbines with high flow-path slopes, and that the loss model had not been sufficiently tested and calibrated with experimental data. Consequently, the flow and loss models were modified and calibrated on the basis of experimental performances of large aircraft-type turbines. The resulting revised code is called "AXOD."

The continuity calculation in the flow model was modified to include a flow-path slope derived from an axial-chord-length correlation and flow coefficient that have an input design value with a built-in reduction of two percent between low pressure ratio across a blade row and choke. The loss model was improved by revising the methodology for calculating blade-row efficiency and calibrating the incidence-loss law.

Efficiencies computed by use of the revised off-design performance model were compared with experimental values for seven aircraft-type turbines of varied design characteristics and operating over wide ranges of speed and pressure ratio. The experimental values were generally within one percent of the computed values and seldom beyond two percent. Maximum discrepancies between computation and experiment were reduced to about half of those from the original performance model.

An AXOD input file includes data for one or more cases, each of which consists of one speed line for a range of pressure ratios. The input for each case contains a number of NAMELIST data sets equal to the number of turbine stages. Three levels of output are available. All levels provide an input echo. The lowest level prints only the overall performance, the next adds stage-mean-line variables, and the highest adds the printout of all variables for all stations and all annular sectors.

AXOD is written in FORTRAN 77 for UNIX-based computers. It has been successfully implemented on a Sun4 SLC computer running SunOS 4.1.3 and an IBM RS/6000 computer running AIX4 using the standard FORTRAN 77 compilers. The standard distribution medium for AXOD is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. Alternate distribution media and formats are available upon request. AXOD was released to COSMIC in 1996.

This program was written by A. J. Glassman of the University of Toledo and E. E. Flagg of General Electric for **Lewis Research Center.** *For further information, **write in 76** on the TSP Request Card.*
LEW-16323

A Composite-Grid Method for Computing Two-Dimensional Flows

Both structured and unstructured grids are used.

Lewis Research Center, Cleveland, Ohio

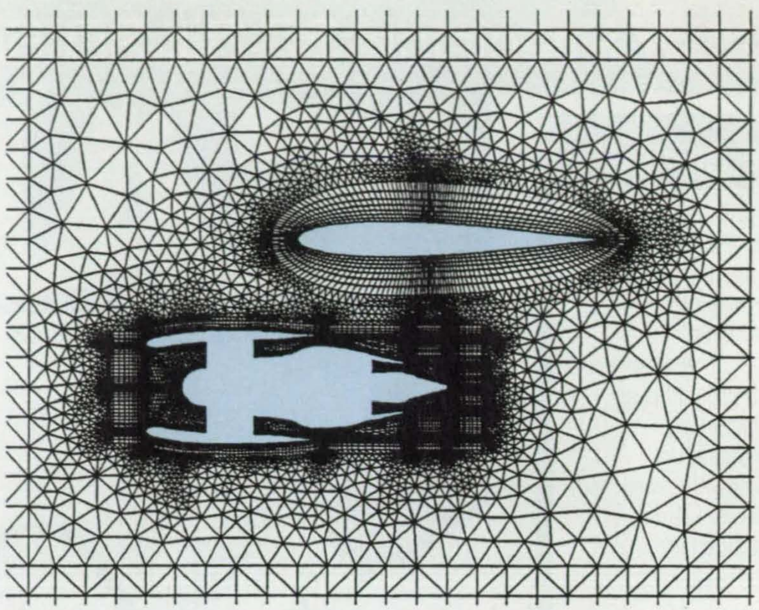
A method for computing two-dimensional flows bounded by complexly shaped surfaces involves solution of the Navier-Stokes equations on computational grids composed of both structured and unstructured grids. As used here, "structured" means having quadrilateral unit cells that are connected sequentially in both computational directions, while "unstructured" means having triangular unit cells that are not connected in any particular sequence and are related to each other in arbitrary ways that must be specified explicitly.

Structured grids can readily be made to conform to surfaces with simple shapes, and cells in structured grids can readily be clustered to provide adequate resolution of shocks, boundary layers, and other high-gradient phenomena. In such applications, structured grids offer the advantages of computational efficiency plus a large body of established theory and software for generating the grids and solving the Navier-Stokes equations on them. In comparison with structured grids, unstructured grids are less computationally efficient, and they are not as well suited to computing flows in regions with large gradients because it is difficult to cluster the cells of these grids. On the other hand, unstructured grids can readily be constructed from points on bounding surfaces, including surfaces with complex shapes.

In the present method, grids of both types are used in a way that maximizes the advantageous aspects and minimizes the disadvantageous aspects of each. Complexly shaped and multiply connected surfaces are partitioned into multiple, simply connected surfaces with simpler shapes. A structured grid is generated for computing the flow in the region near each simpler surface. In generating the structured grid at each surface, it is not necessary to provide in advance information for coupling of flow quantities with

those computed on grids at other surfaces. Instead, the space between the structured grids is filled with an unstructured grid that is connected to the boundary points of the structured grids (see figure). This composite-grid scheme provides flexibility for generation and separate manipulation of individual grids.

A composite-grid computer code that implements this method consists of three modules; a structured-grid flow solver, an unstructured-grid generator based on Delaunay triangulation, and an unstructured-grid flow solver. These modules were adapted from previously available stand-alone codes. Because a large part of the flow is computed on structured grids, the composite-grid code was built around the structured-grid flow solver, which is called "PARC2D." The unstructured-grid generator and the unstructured-grid flow solver are incorporated into the prior architecture of PARC2D. Inputs to the composite-grid code (including iteration control, boundary conditions, time steps, and grid-generator options) are entered through the PARC2D interface. In developing the composite-grid code, an effort was made to retain as much as possible of the prior PARC2D interface; a user familiar with PARC2D could easily begin to use the composite-grid code.



Structured and Unstructured Grids *can be used, for example, in mathematical modeling of flow about an airfoil/nacelle installation.*

This work was done by James R. DeBonis of **Lewis Research Center.** *For further information,* ***write in 66*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-16304.

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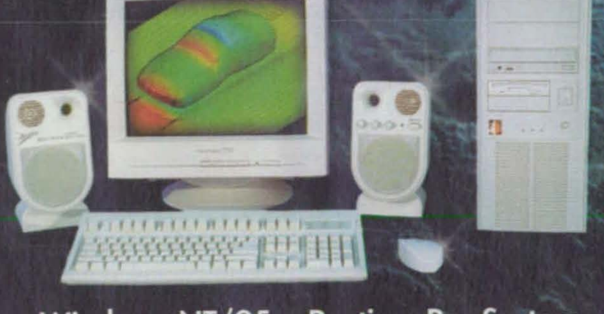

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Object Orientation Manipulator Program

This program facilitates the synthesis of animated images.

Lyndon B. Johnson Space Center, Houston, Texas

The Object Orientation Manipulator (OOM) computer program is an application program for creating, rendering, and recording three-dimensional computer-generated still and animated images by use of geometrically defined three-dimensional models, cameras, and sources of light, collectively denoted as animation elements. OOM does not provide the means to construct three-dimensional models; instead, it imports files of model data in binary format generated by the Solid Surface Modeler (SSM) computer program. Model files in other formats must be converted to the SSM binary format before they can be used in OOM. SSM is available as MSC-21914 or as part of the SSM/OOM bundle, COS-10047.

Among the features of OOM are detection of collisions (with visible and audible feedback), the capability to define and manipulate hierarchical relationships among animation elements, stereographic display, and ray-traced rendering. OOM uses Euler-angle transformations for calculating the results of translation and rotation operations.

OOM provides an interactive computing environment for the manipulation and animation of models, cameras, and sources of light. Models are the basic entities upon which OOM operates and are therefore considered the primary animation elements. Cameras and sources of light are considered secondary animation elements. In OOM, a camera is treated as simply a location within a three-dimensional space from which the contents of that space are observed. OOM supports the creation and full animation of cameras. Sources of light can be defined, positioned, and linked to models, but they cannot be animated independently. OOM can simultaneously accommodate as many animation elements as the memory of the host computer can accommodate.

Once the desired animation elements are present, the user can position them, orient them, and define any initial relationships among them. Once the initial relationships are defined, the user can display individual still views for rendering and output, or can define motion for the animation elements by use of an animation-editing option that provides a capability for interpolation. OOM provides the capability to save still images, animated sequences of frames, and the information that describes the initialization process for an OOM session. OOM provides the same rendering and output options for both still and animated images.

OOM includes software that provides a robust model-manipulation computing environment that features a full-screen viewing window, a menu-oriented user interface, and the aforementioned interpolative animation-editing option. It provides three display modes: solid, wire-frame, and simple. These modes enable the user to trade off visual authenticity for update speed. In the solid mode, each model is drawn on the basis of the shading characteristics assigned to it when it was built. All of the shading characteristics supported by SSM are recognized and properly rendered in this mode. If increasing complexity of a model impedes the opera-

tion of OOM, the wire-frame or the simple mode can be used. The wire-frame and simple modes provide faster screen updates than the solid mode does.

The creation and placement of cameras and sources of light is under complete control of the user. One source of light is provided in a default set of animation elements. It is modeled as a direct source of light analogous to sunshine. As in the case of the other animation elements, OOM can accommodate as many sources of light as the memory of the host computer can accommodate.

Animation is created in OOM by use of a technique called "key frame interpolation," which basically means interpolation between frames denoted as key frames. First, various program functions are used to load models, load or create sources of light and cameras, and specify the initial position of each animation element. When these steps are completed, the interpolation function is used to create an animation sequence for each element to be animated. An animation sequence consists of a number of frames (screen images) defined by the user, a subset of these frames being designated as key frames. The user defines the position and orientation of the active animation element in each key frame. The motion of the element between key frames is interpolated automatically by the software: this saves the user from having to define data for each animation element at each frame of a sequence. Animation frames and still images can be output to videotape, color printers, and disk files.

OOM is written in the C language for implementation on SGI IRIS 4D-series workstations running the IRIX operating system. A minimum of 8MB of random-access memory is recommended for this program. The standard medium for distribution of OOM is a 0.25-in. (6.35-mm) streaming magnetic IRIX tape cartridge in UNIX tar format. OOM is also offered bundled with SSM. Please see the abstract for SSM/OOM (COS-10047) for information about the bundled software. OOM 6.1 was released in 1993.

This program was written by Sharon Goza and S. Michael Goza of **Johnson Space Center,** *Brad Bell of Lincom, Inc., and David Norris, Erin Orgeron, David Shores, Tom Robinson, Mark Manning, Kurt McMullen, and Evelyn Miralles of Metrica, Inc. For further information,* ***write in 62*** *on the TSP Request Card.*
MSC-22263

Analysis and Design of Vibration-Damping Thick Laminates

Laminates can be designed to include compliant damping layers for enhanced damping.

Lewis Research Center, Cleveland, Ohio

Improved mathematical models of the mechanics of thick laminated composite (matrix/fiber) materials have been developed for use in analyzing the damping of vibrations in structures made of these materials and in designing the structures with a view toward optimizing their vibration-damping characteristics. Of particular importance is the aspect of these models that makes it possible to design laminates with embedded interlaminar damping layers to provide enhanced, tailorable damping.

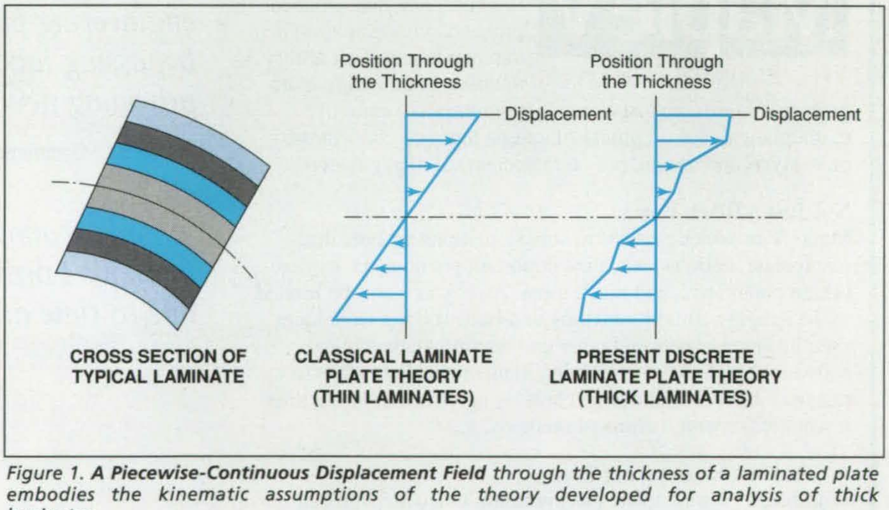

*Figure 1. **A Piecewise-Continuous Displacement Field** through the thickness of a laminated plate embodies the kinematic assumptions of the theory developed for analysis of thick laminates.*

In this approach, the modeling of damping at the laminate level is based on a novel discrete-layer laminate-damping theory (DLDT), which incorporates the assumption of a discrete, yet piecewise-continuous displacement field through a laminate (see Figure 1). The DLDT effectively captures both interply and intraply stresses. The overall damping capacity of the laminate includes contributions from extension, a combination of flexure and shear, and various coupling effects that may arise from the heterogeneous nature of the laminated composite material. The DLDT can accurately model the static and damped dynamic responses of thin and thick composite laminates, including those specially designed to incorporate compliant damping layers (see Figure 2). As represented in Figure 2, laminate 1 = $[C_4/i/9O_4]_5$ and laminate 2 = $[O_2/9O_2/i/O_2/9O_2]_5$, where i indicates the location of the damping layer.

The DLDT has been incorporated into structural-analysis methods: In this context, an exact semianalytical method for the simulation of the damped dynamic responses of composite plates has been developed. A finite-element method that is based on the DLDT and that incorporates a special four-node plate element has also been developed for the analysis of composite structures with

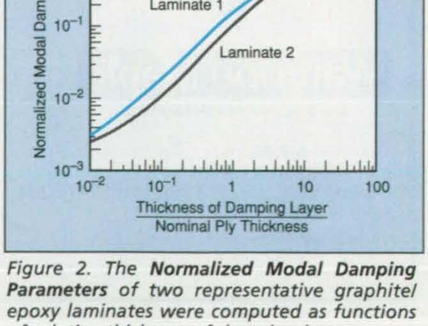

*Figure 2. The **Normalized Modal Damping Parameters** of two representative graphite/epoxy laminates were computed as functions of relative thickness of damping layers.*

various shapes and boundary conditions.

Among the products of these development efforts are three computer programs called "ICAN/DLDT," "STAT/DLDT," and "THICOPT."

ICAN/DLDT is an integrated code that incorporates the DLDT and that is formulated for use in analyzing the dynamics of thick composite plates and other laminates. STAT/DLDT incorporates the finite-element method described above and is intended for use in analyzing and tailoring code for composite-material components of engines. THICOPT (Thick Composite Plate Tailoring) is a versatile, computationally inexpensive code for optimal design of thick composite plates.

This work was done by D. A. Saravanos of Ohio Aerospace Institute for **Lewis Research Center.** *For further information,* ***write in 81*** *on the TSP Request Card.*

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Software for Interactive Generation of Two-Dimensional Grids

Grids can be fitted to almost any two-dimensional flow geometry.

Lewis Research Center, Cleveland, Ohio

TIGGERC is a computer program for generating two-dimensional multiblock grids. TIGGERC can be used to create mixed H-, C-, O- and I-grid meshes for studying any two-dimensional flow problem. The code was written for turbomachinery applications, but it is useful for any two-dimensional flows, including both external and internal flows. The multiblock aspect of the program provides flexibility for fitting grids to various flow geometries. A mouse-driven interface makes it possible to create and modify grids quickly and efficiently.

TIGGERC generates surface grids by use of hyperbolic-tangent or algebraic distributions of grid points on block boundaries. The interior points of each block grid are distributed according to a transfinite interpolation approach. TIGGERC has several features that enable the user to modify the distribution of points in the grid and to obtain smooth distributions along boundaries, providing greater control of the grid-generation process as well as freedom to define the chosen grid.

TIGGERC was written primarily for axisymmetric turbomachinery problems, but the flow geometry can be specified in any general two-dimensional coordinate system. A flow geometry — that is, a set of flow-path coordinates — can be created manually or entered as input from a data file. The corresponding grid can be specified in cylindrical, rectilinear, or nondimensional coordinates. Once the two dimensional boundaries have been established, a grid can be quickly generated for any algorithm that solves equations of two-dimensional flow. The output of TIGGERC is a grid file in PLOT3D multigrid format.

TIGGERC is written in FORTRAN 77 and C language for SGI IRIS workstations running IRIX 4.0.5 or higher. It has been successfully implemented on an SGI Indigo 2 computer running IRIX 5.2. Sample executable codes are included. The standard distribution medium for TIGGERC is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in IRIX tar format. Alternate distribution media and formats are available upon request. TIGGERC was released in 1996 and is a copyrighted work with all copyright vested in NASA.

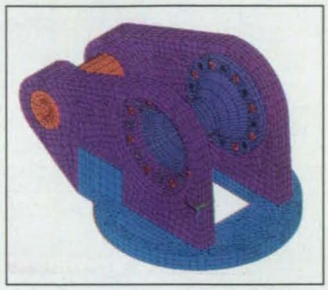
This program was written by D. P. Miller of **Lewis Research Center.** *For further information,* ***write in 92*** *on the TSP Request Card.*
LEW-16300

Computer-Aided Design & Engineering

Parasolid Version 8.0 **solid modeling software** from EDS Unigraphics, Maryland Heights, MO, provides enhanced blending, including curvature continuous blends, disc blends, and conic hold-line blends. Other enhanced features include non-uniform scaling of models, which allows modeling of the shrinkage of molded parts; and an upgraded tapering function to allow more topological changes to occur when draft is applied to a model.

A new capability, Partitioned Rollback, manages the history of models and quickly moves between states of a model. It enables feature-based applications to roll back a model to the point where a feature was added, reapply the modified feature using new model parameters, and reapply subsequent features to generate an updated model.

For More Information Write In No. 746



ANSYS, Houston, PA, has introduced DesignSpace™ **engineering software,** which solves engineering problems by managing internal mathematical models. It is integrated into a CAD environment, providing a flexible framework that allows CAD users to work with design components – project, model, environment, and answers.

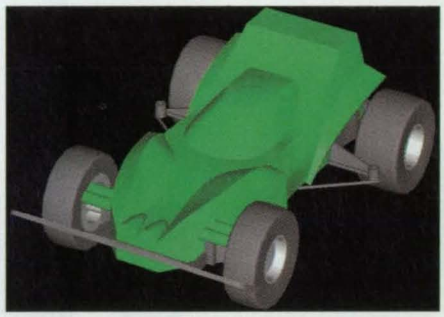
Users can pick a solid from the CAD drawing, along with a material from a customizable library. A basic framework of design information can be established using drag-and-drop shortcuts. Within the environment component, users may set environmental factors such as gravity and ambient temperature, as well as characterizing how the part interacts with its local environment. Once a model and its environment are defined, the answers component provides tools to interpret results and answer questions. It can support results output in a virtual reality modeling language (VRML) format.

For More Information Write In No. 743

Alias|Wavefront, Toronto, ON, Canada, has introduced Alias® Studio™ 8.0, Auto-Studio™ 8.0, and Alias Designer™ 8.0 **3D design software,** which include new features to enable integrated computer-aided industrial design. Cloud Fit™ allows designers to create 3D geometry from scan "cloud" data collected from a physical model; EvalViewer™ enables evaluation and processing of cloud datasets.

The programs include a series of tools that automate a number of routine tasks into one-step processes for creating and editing curves; the ability to identify and launch the specific tool that was used to create a particular geometric element; a draft angle/flange feature; a STEP translator for configuration-controlled 3D assemblies; and new data exchange technology for transfer to CATIA®. Designer, Studio, and AutoStudio are available for $7,495, $24,995, and $74,995, respectively.

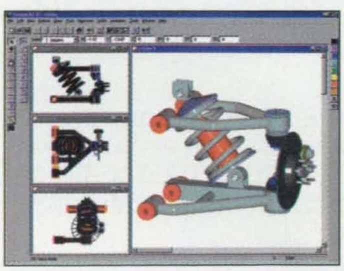
For More Information Write In No. 740



Ricoh Corp., San Jose, CA, has introduced Designbase 5.2 **surface/solid modeling software,** which performs surface/solid integration, feature-based parametric modeling, and advanced filleting operations. Enhanced capabilities include improved offset functions such as shelling, sharp and round corner offset, and offset collapsing topology.

Other functions include IGES solid read/write capability; faster surface/surface intersection; extended surface modeling capabilities; and enhanced graphics functions, C++ interface, and on-line documentation. The software is available for use on all major UNIX workstations, as well as IBM-compatible PCs running Windows NT or Windows 95, and is sold on a per-seat basis.

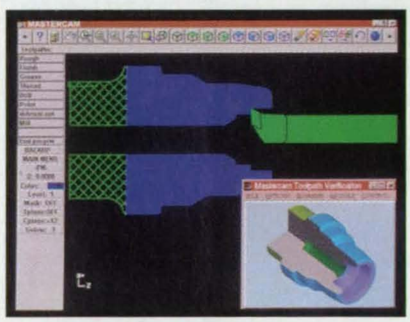
For More Information Write In No. 749



DesignCAD 97 **2D/3D CAD software** from ViaGrafix Corp., Pryor, OK, provides animation and 3D walk-through capabilities, AVI support, and 3D texture mapping, allowing users to assign textures to 2D and 3D objects such as marble, grain, wood, or cement. More than 200 2D drawing and editing commands are included. The 3D solid models created can be viewed from any perspective as shaded solids, wire frames, or as objects with the hidden lines removed from sight.

The 3D animation interface allows control of rotation, scale, movement, and viewing angle of individual objects in an animation. Specific objects in a drawing can be isolated and animated while leaving other elements of the drawing stationary. The software provides E-mail support, as well as support of communications-related file formats such as JPG, BMP, and VRML. It operates on systems running Windows 95 or Windows NT and is priced at $499.95.

For More Information Write In No. 750

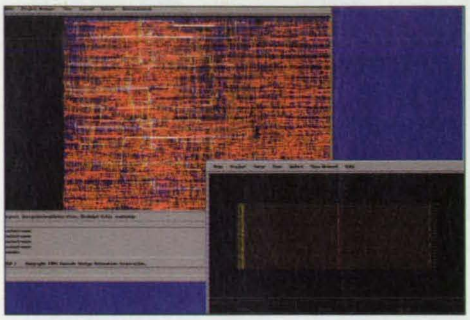


CNC Software, Tolland, CT, offers Mastercam Lathe Version 6.0 **CAD/CAM software** for contouring, grooving, profiling, threading, drilling, and point-to-point machining. The Windows-based software performs turning, two- through five-axis milling, two- and four-axis wire EDM, moldbase development, 3D drafting, design, and surface modeling. Enhanced turning features, new C-axis programming options, and new verification utilities that provide a quick view of finished parts, are included.

In addition to full CAD capabilities, the program features built-in bidirectional translators such as ACIS solids, IGES, DXF, and ASCII. An optional DWG translator is available, allowing direct transfer from AutoCAD to Mastercam.

For More Information Write In No. 751

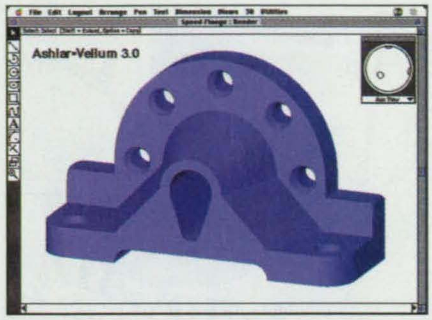
Computer-Aided Design & Engineering



Epoch 4.0 **physical design software** from Cascade Design Automation, Bellevue, WA, features the Seamless Physical Design™ environment for electronics engineers designing integrated circuits. It comprises libraries, module generators, place-and route, and power and timing analysis capabilities linked through a single design database.

Enhanced features include improved density, RC extraction capabilities, and integrated clock tree synthesis. The new version enables the inclusion of third-party cores, megacells, and other types of intellectual property through a cell import/export capability. The program runs on Hewlett-Packard and Sun Microsystems workstations; prices start at $135,000.

For More Information Write In No. 748



Ashlar, San Jose, CA, has introduced Vellum 3.0 **design and drafting software,** which provides solid modeling, visualization, and automatic hidden line removal for the generation of detail drawings in 2D and 3D. The program transforms wireframe data into surface data, which can be rendered for visualization and detail drawings.

A 3D user interface automatically identifies relationships such as endpoints, midpoints, center points, tangencies, and real and extended intersections. It features integrated parametric modeling, updating dimensions when parts are changed, and updating parts when dimensions are changed. The Windows-based software requires 6 Mb of hard drive space and costs $1,495.

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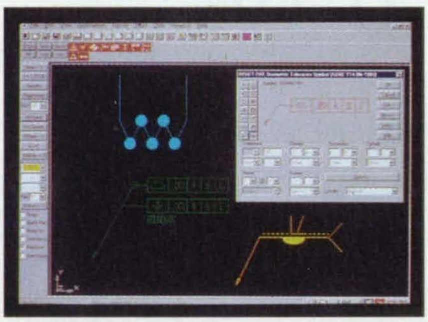
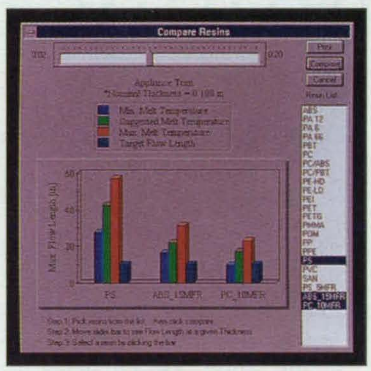


Draft-Pak® 7.55 for Cadkey **CAD accelerator software** from Baystate Technologies, Marlborough, MA, accelerates design and drafting operations for mechanical CAD. Designed for Windows 95, NT 3.51 and 4.0, and Windows for WorkGroups 3.11/3.1, the software includes dimension and detailing features to support current ASME Y14.5M standards.

Features include geometric tolerancing symbology, frame control for placement of compound symbols, and weld symbols that support DIN standards. Upgrades include new file management and navigation tools, enhanced animation, and a Visual Library that includes more than 550 symbols for fluid power, piping, electrical, sheet metal, and flow chart applications. The software is priced at $595.

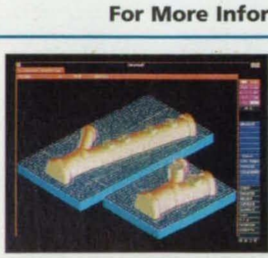
For More Information Write In No. 742



AC Technology North America, Louisville, KY, has released Dr. C-MOLD **molding software,** which allows plastics engineers to evaluate key variables within the molding system – including material, part design, mold design, and machine – and establish a feasible process window in five minutes or less. The software uses geometric parameters to describe the part, mold, and machine without the need for a FEA mesh or CAD model.

It features a material data system incorporating the melt flow characteristics of any commonly used resin; real-time results and displays; and instruction on how to set up the molding machine for optimal conditions. The software is available for PCs running Windows NT or Windows 95 and is priced at $1,299.

For More Information Write In No. 747



Cimatronit Version 8.0 **CAD/CAM software** from Cimatron Technologies, Burlington, ON, Canada, includes enhancements such as an improved NC machining module, which generates machining code directly from mixed solid, surface, and wireframe models. Technology templates store tool parameters and cutting modes as ASCII files for application to other parts. The software combines design and modeling tools with command output to computerized numerically controlled (NC) manufacturing equipment. The system's NC applications operate directly on design model data to generate toolpaths for any NC manufacturing process.

New functions for mold makers include Split, which divides the part along any plane and automatically applies mold drafts; and Reference Face, which applies draft to faces abutting a curved surface. When constructing models in the Solid sketcher, users can modify geometrical dimensions and constraints dynamically by clicking on any element and dragging or changing its value. The software is available for PC/Windows and UNIX platforms.

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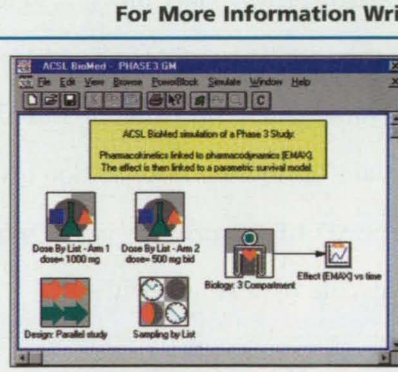

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Guiding Robots With the Help of Capaciflectors

Capacitive proximity sensors help to prevent hard collisions.

Goddard Space Flight Center, Greenbelt, Maryland

Robotic sensing-and-control subsystems of a proposed type would include capaciflectors (advanced capacitive proximity sensors described below) mounted on the end effectors of robotic manipulators. These subsystems would help the manipulators avoid collisions with obstacles and guide the manipulators in final approach to, and soft contact with, intended objects.

Like other capacitive proximity sensors, a capaciflector puts out a signal indicative of the capacitance between a sensing electrode and an object in the vicinity. A capaciflector includes at least one sensing electrode laid out over a larger shielding electrode (reflector), both electrodes being driven by alternating voltages of equal magnitude, frequency, and phase. The driven shield increases the range and spatial resolution by reconfiguring the sensing electric field according to established principles of electrostatics. Capaciflectors, other capacitive proximity sensors, and related developments were described in several previous articles in *NASA Tech Briefs*; namely, "Capacitive Proximity Sensor Has Longer Range" (GSC-13377), Vol. 16, No. 8 (August, 1992), page 22; "Capacitive Proximity Sensors With Additional Driven Shields" (GSC-13475), Vol. 17, No. 11 (November, 1993), page 40; "Capacitive Sensors and Targets Would Measure Alignments" (GSC-13491), Vol. 18, No. 9 (September, 1994), page 44; "Phase-Discriminating Capacitive Sensor System" (GSC-13460) Vol. 17, No. 10 (October, 1993), page 24; "Steerable Capacitive Proximity Sensor" (GSC-13489), Vol. 18, No. 9 (September, 1994), page 48; "Capacitive Sensor with

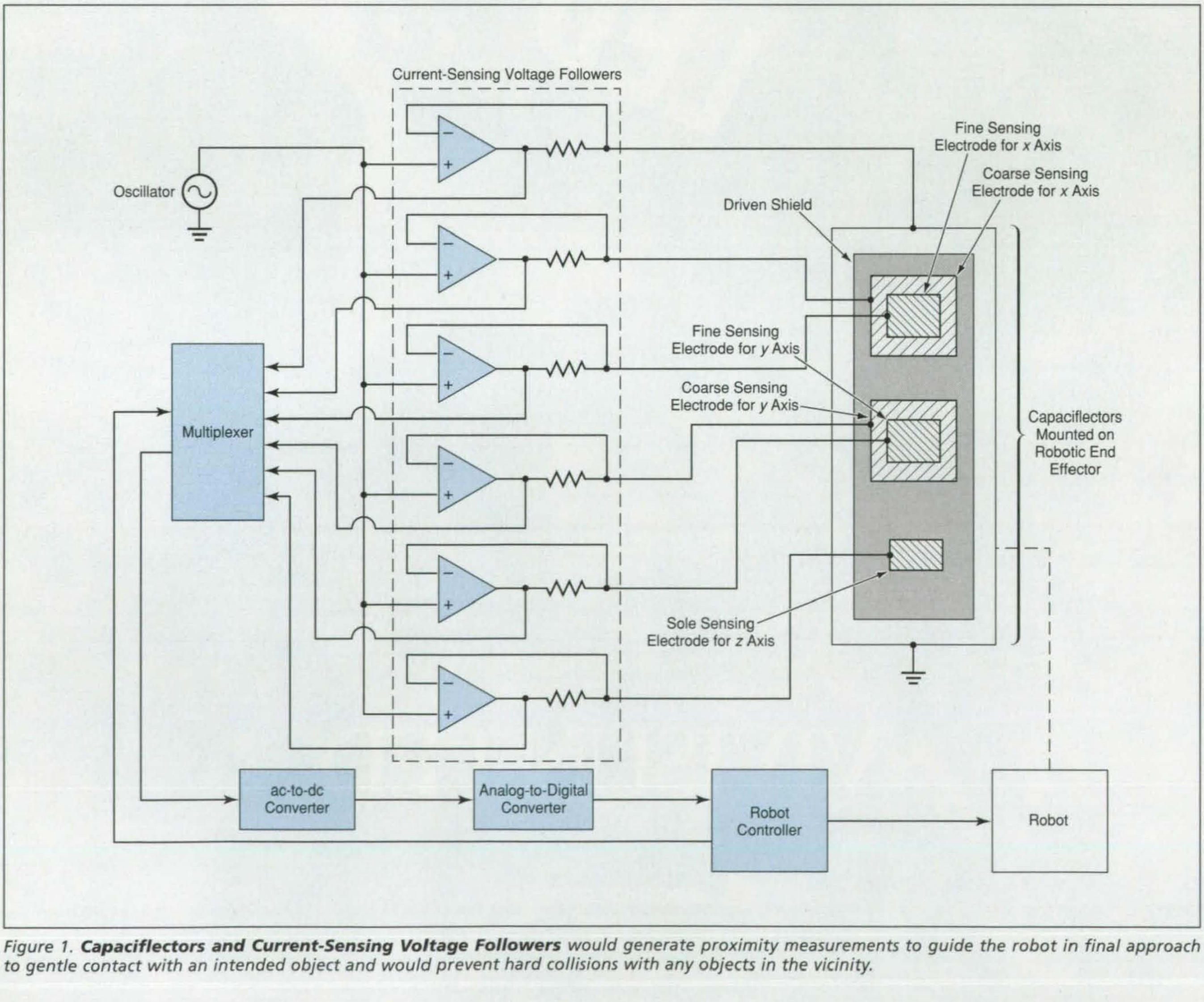

Figure 1. ***Capaciflectors and Current-Sensing Voltage Followers*** *would generate proximity measurements to guide the robot in final approach to gentle contact with an intended object and would prevent hard collisions with any objects in the vicinity.*

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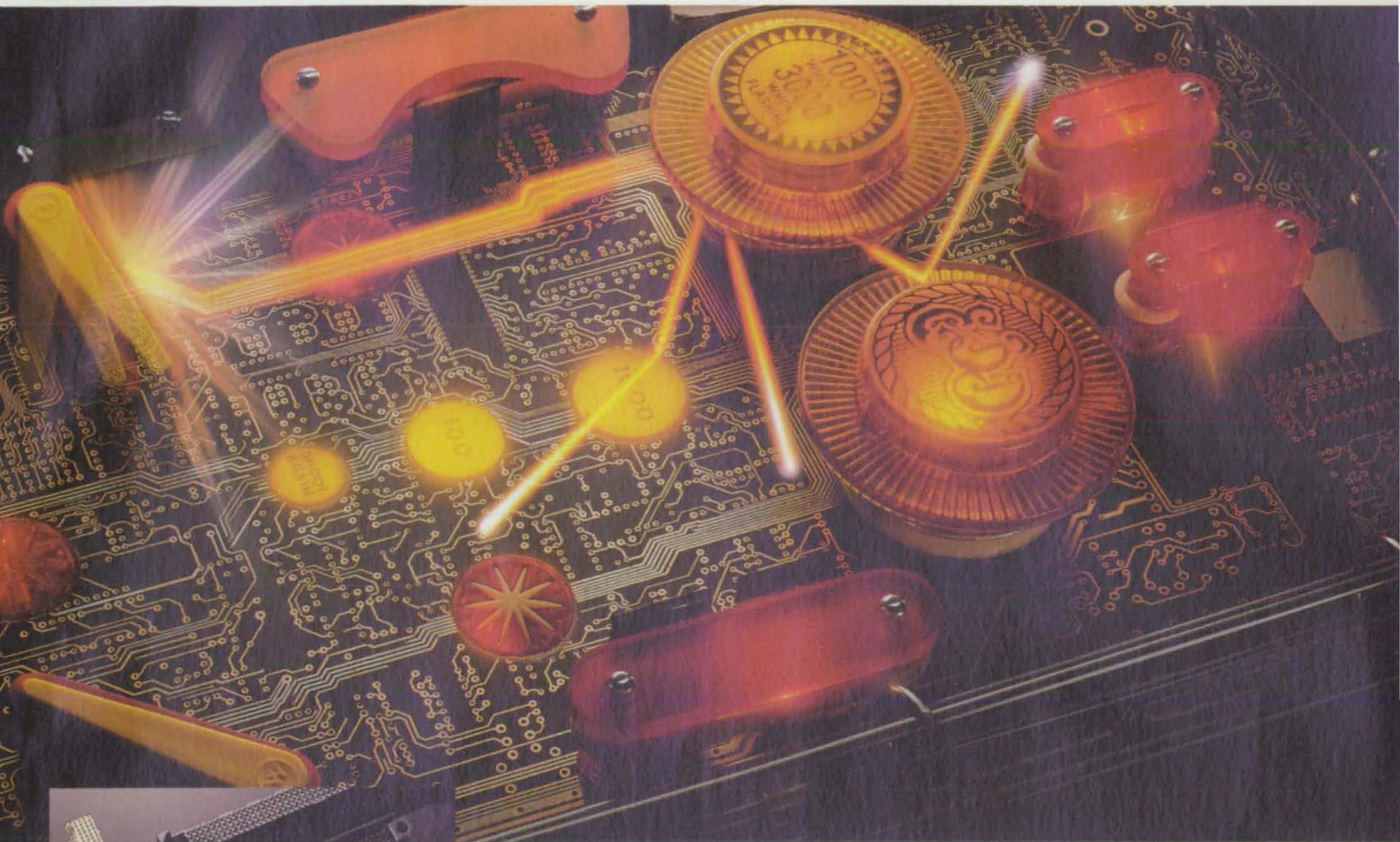

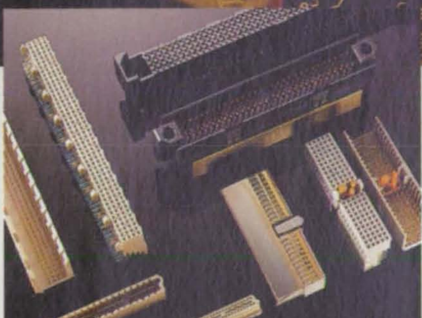

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Driven Shields and Bridge Circuit" GSC-13541) Vol. 18, No. 8 (August, 1994), page 34; "Capaciflector Camera" (GSC-13564), Vol. 18, No. 10 (October, 1994), page 58; and "Current-Measuring Voltage-Follower Circuits" (GSC-13563), Vol. 20, No. 11 (November, 1996), page 50.

Figure 1 illustrates a typical sensing-and-control subsystem according to the present concept. In this case, a capaciflector for three-dimensional (x, y, z) proximity sensing would include a driven shield, a sensing electrode for coarse proximity measurements along the x axis, a sensing electrode for fine proximity measurements along the x axis, a similar pair of sensing electrodes for proximity measurements along the y axis, and a single sensing electrode for proximity measurements along the z axis. All of the electrodes would be excited by an alternating voltage from the same oscillator, each electrode being fed through a current-measuring voltage-follower circuit. The output of each such circuit would be a voltage indicative of the current in the sensed capacitance and thus of the sensed capacitance itself. These outputs would be fed via a multiplexer, converted to dc, digitized, and fed to a digital processor in the robot-control system.

Because of the fundamental nature of capacitive proximity sensing, the variation of sensed capacitances with relative position and orientation of a sensor and a sensed object would provide data equivalent to a fictitious force field that could be a source of signals to control the motion of the robotic manipulator in the vicinity of the object. Thus, collisions could be avoided and the manipulator could be guided into proximity and alignment with the intended object without making prema-

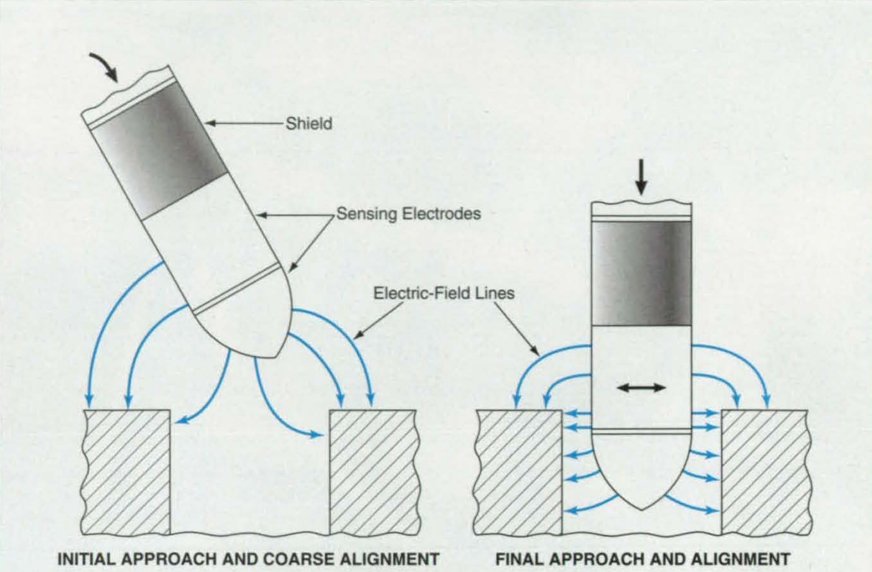


*Figure 2. A **Pin Covered With a Capaciflector** would be brought near a hole, then aligned with and inserted in the hole, without making contact with the hole until final approach and alignment were complete. The robot-control system would use the processed capacitance readings from the sensing electrodes as indications of the position and orientation of the pin with respect to the hole.*

ture contact with the object (see Figure 2). The initial approach would typically involve a raster scan of the manipulator while capaciflector outputs were processed to determine positions of closest approach in scan planes that were progressively brought closer to the object, without bringing them so close as to risk collision. This scan would yield data on the approximate position and orientation of the object relative to the manipulator. Following the scan, the capaciflector outputs would be processed and used for guidance as the manipulator was dithered into soft contact with the object.

One of the advantages of capacitive proximity sensing (in comparison with optical proximity sensing) is that it provides highly precise ranging and alignment in close. Another advantage is that it does not depend on illumination and does not require clear lines of sight; thus, capacitive proximity sensing widens the variety of applications in which docking and berthing can be performed robotically. With a sufficient number of sensors and the concomitant signal- and data-processing hardware and software, it should even be possible to identify a capacitively sensed object or at least to determine whether it is or is not the intended object.

This work was done by John M. Vranish of **Goddard Space Flight Center**. *For further information,* ***write in 48*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13614.

Robust High-Temperature Microstrip Antennas

Both the supporting structures and the conductors would be made of SiC.

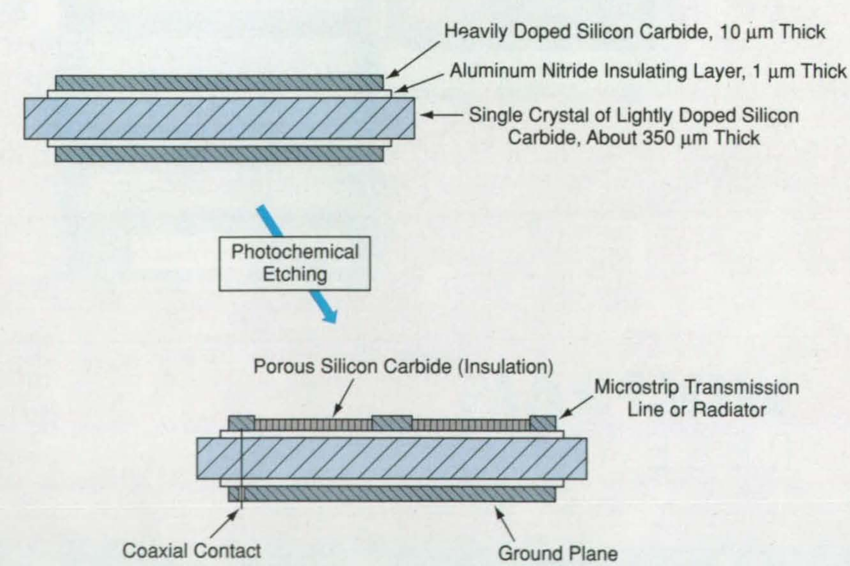
NASA's Jet Propulsion Laboratory, Pasadena, California

Millimeter- and submillimeter-wavelength microstrip antennas of a proposed type would be made largely of silicon carbide. State-of-the-art microstrip antennas are made with polytetrafluoroethylene (PTFE) dielectric substrates that support metallic transmission lines and radiator patches; the PTFE substrates cannot withstand operating temperatures above 150 °C. The proposed SiC-based microstrip antennas could withstand operating temperatures up to 500 °C or even higher. The proposed antennas would be rugged and abrasion-resistant. They would be particularly useful on spacecraft, on aircraft, and in automotive collision-avoidance systems.

According to the proposal, an antenna would be made in a sandwich configuration (see figure), with a core layer of lightly doped α-SiC. The core, only 350 μm thick, would serve as a strong, stable, dielectric support for the electrically conductive microstrip elements. Electrically insulating films of aluminum nitride would be deposited on the faces of the core, and electrically conductive 10-μm-thick surface layers of heavily-n-doped α-SiC would be deposited on the insulating films. These surface layers would have electrical resistivities of about 0.005 MΩ·cm.

One conductive surface layer would serve as a ground plane. The other conductive surface layer would be photoelectrochemically modified to form insulating regions between conducting strips, thereby defining microstrip transmission lines and radiator patches. In the photoelectrochemical process, the affected surface layer would be immersed in a suitable aqueous electrolytic etching solution and would be exposed to an image of the microstrip elements in light with photon energies greater than the band gap (≈3 eV) of SiC. In the process, the SiC in the exposed areas would become porous and would at-tain electrical resistivities of about 10 MΩ·cm. The photochemical process could produce a conductive pattern with a resolution of about 0.5 μm, which would be acceptable for operating frequencies up into the terahertz range.

This work was done by Virgil B. Shields, Margaret A. Ryan, and John Huang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 29*** *on the TSP Request Card. NPO-19765*



A ***Silicon Carbide Microstrip Antenna*** *would be made from a sandwich of aluminum nitride and differently doped silicon nitride layers. The microstrip circuit elements would be formed by photoelectrochemical etching of one of the surface SiC layers.*

Micromachined Opto/Electro/Mechanical Systems

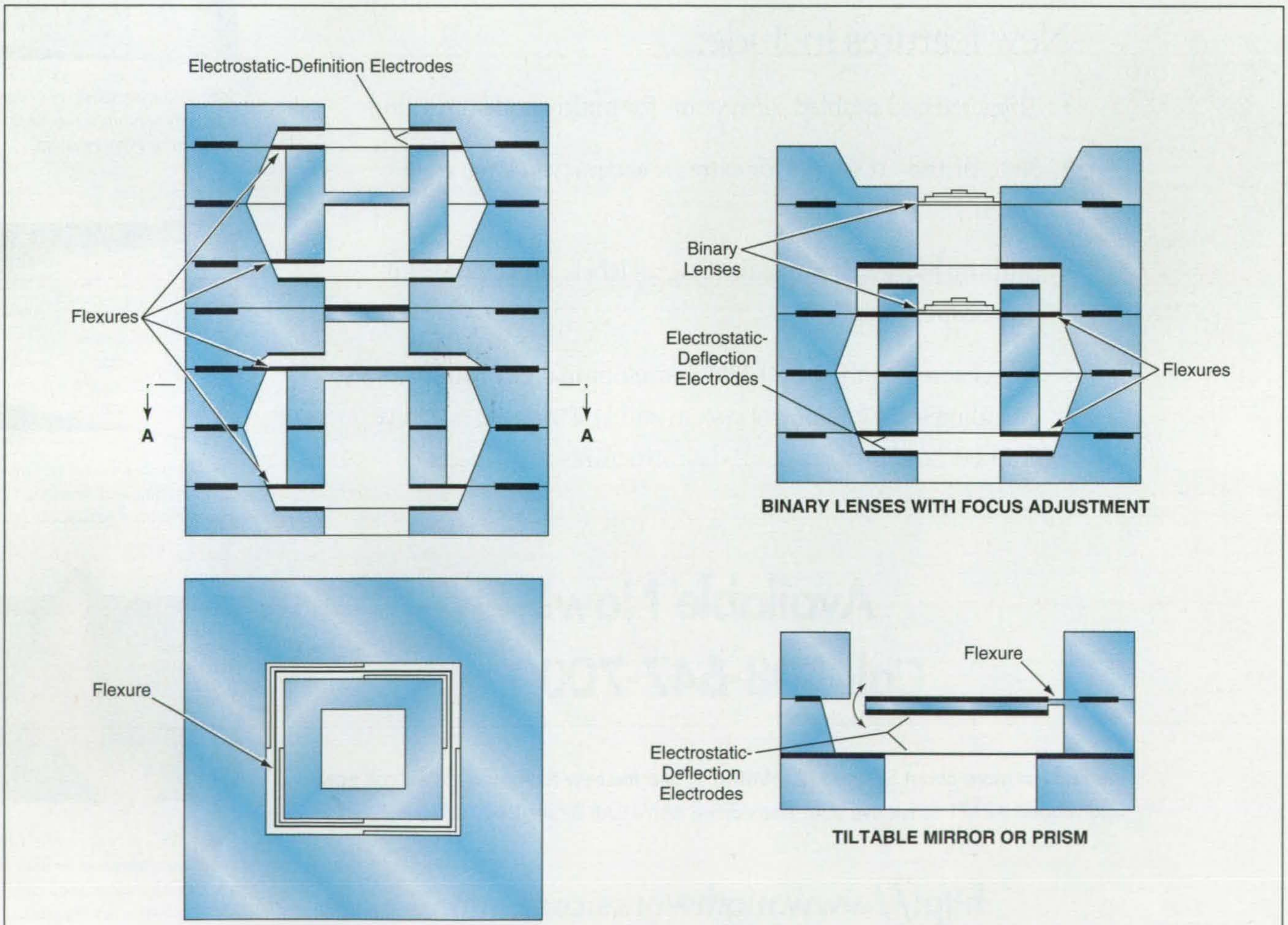
A new generation of miniature optoelectronic instruments is proposed.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optoelectronic instruments would be miniaturized to an unprecedented extent, according to a proposal, by use of components and systems fabricated by micromachining. These instruments could include television cameras and imaging spectrometers, for example. The micromachining approach should eventually make it possible to manufacture broadcast-quality color television cameras no more than several millimeters thick (including optics) for prices of the order of those of typical integrated circuits.

As in conventional optical instruments, the optical elements proposed would be mechanically adjusted to effect such functions as focusing, bandpass spectral tuning, scanning, and shuttering. However, the necessary movements would be generated on a microscopic scale. For this purpose, the affected optical elements could be micromachined integrally with crab-leg flexures or other flexible supports, along with electrodes for electrostatic control and measurement of deflection (see figure).

For example, consider an instrument that includes an imaging array of photodetectors, a micromachined array of microlenses, and perhaps a micromachined two-stage Fabry-Perot filter. With suitable design, such a combination of components could provide focussing in individual pixels or groups of pixels along with fast single-shot



Electrostatic Deflection Electrodes *would be deposited on micromachined optical components with integral flexures. Electrostatic deflection would provide fast, repeatable adjustments. Deflections could be computed from capacitances between electrodes, as measured by use of electrical excitations at frequencies much greater than those of the mechanical resonances of the components.*

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shuttering, repetitive fast shuttering (chopping), and/or imaging in a rapid sequence of different wavelengths. The two-stage Fabry Perot filter would act as a narrow-band-pass filter when its pass bands were adjusted to overlap at one wavelength, or like a closed shutter when its pass bands were set so that none overlapped. Because the electrostatic deflections of the micromachined optical elements would be characterized by frequencies of multiple kilohertz, one could obtain nearly simultaneous images at different wavelengths in the one instrument.

This work was done by Benjamin P. Dolgin, Frank T. Hartley, and Paul K. Henry of Caltech and Paul M. Zavracky of Northeastern University for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 4*** *on the TSP Request Card. NPO-19467*

Fast Obstacle Detection via Triangulation of Light Spots

The unique geometry of light beams simplifies computation.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optoelectronic system detects obstacles on and near the ground, at distances up to about 65 cm from a small robotic vehicle. The system is expected to enable safe travel at speeds up to 6 cm/s. Based on triangulation of light spots projected onto the nearby terrain by multiple laser beams, the system is designed to satisfy requirements to be light in weight, operate with minimal power and no moving parts, detect the laser spots in full sunlight, and process the images of the laser spots rapidly and with minimal computation.

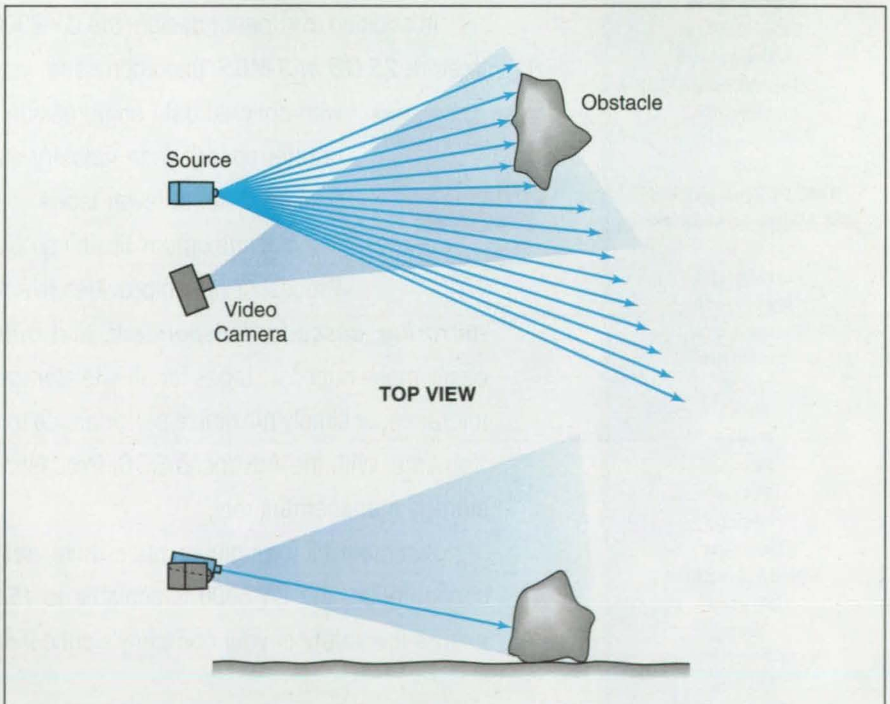
This system is derived from an older laser-based obstacle-detection system in which obstacles were detected by processing of images of stripes of light projected by multiple lasers. In the older system, it was necessary to compute differences between images taken with and without illumination because there was not enough power available to make the stripes bright enough to be detectable in sunlight without such differencing. However, image differencing is undesirable because it requires the vehicle to stand still while acquiring two images, which slows down the net speed of the vehicle.

In the present system, the projected laser illumination is not spread out along stripes. Instead, the illumination remains concentrated in spots projected by narrow laser beams; the spots are bright enough to be detectable in images, without need for differencing. The source of light in this system is a laser diode, the output of which is collimated and split into 15 beams that lie in the same plane, forming a fanlike pattern (see figure). The source is oriented so that the plane of beams tilts downward from the source, the central beam intersecting a nominal level ground surface at a horizontal distance of about 50 cm.

The system includes a video camera, aimed to view the laser-illuminated spots on the terrain. The camera is mounted at the same height as that of the source, with a lateral offset. The video image is digitized and processed to determine the locations of the spots and thus of any obstacles. To enhance the detectability of the laser-illuminated spots, the light entering the camera is band-pass-filtered at the laser wavelength of 860 nm, which lies somewhat away from the peak of the solar spectrum.

The arrangement is such that, assuming linear camera optics, each laser beam defines a unique scan line in the video image. Consequently, each laser-illuminated spot can be immediately identified in the image as lying along one of the laser beams. Moreover, the knowledge that each spot of light necessarily lies along one of the scan lines can be exploited to reduce the amount of computation necessary to locate each spot. The horizontal distance of the spot from the source and the elevation of the spot can be determined from (1) the known tilt of the beam and (2) the position of the spot along the beam, as determined from its position along the known scan line in the video image. A thresholding operation is then performed on the elevation of each spot to determine whether an obstacle is present.

This work was done by Larry Matthies, Tucker Balch, and Brian Wilcox of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 13*** *on the TSP Request Card. NPO-20032*



A ***Video Camera Views Light Spots*** *projected onto the nearby terrain by laser beams that fan out from a source laterally offset from the camera. Data from images acquired by the camera are processed to identify obstacles revealed by the locations of the light spots.*

Shot Counter for a Pulsed Laser

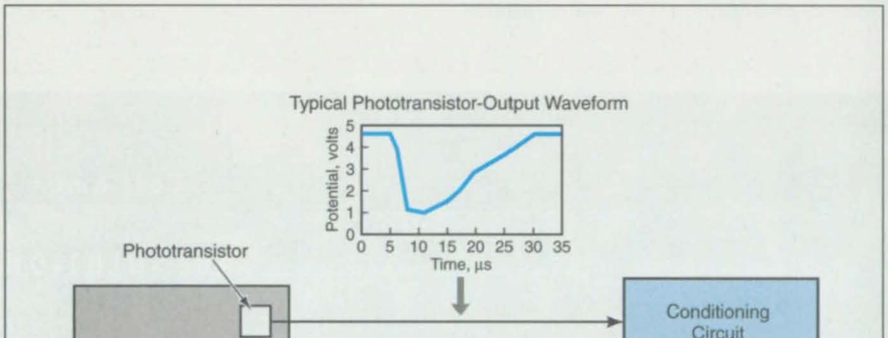
The number of flashes is counted to determine when to replace the flash lamp.

Lewis Research Center, Cleveland, Ohio

An apparatus that detects and counts pulses of light has been incorporated into a pulsed-laser system to count the number of flashes emitted by the laser-pumping flash lamp. It is desirable to count the number of flashes to determine when the flash lamp has reached the end of its useful life (typically of the order of 106 flashes), at which time it must be replaced. Although counting flashes may seem like a straightforward proposition, no equipment was previously available for this purpose; instead, numbers of flashes were determined by error-prone techniques like counting trigger pulses or estimation from total logged operating times.

The apparatus (see figure) includes a phototransistor mounted in the laser housing, near the flash lamp and out of the direct path of the laser beam. In response to each flash, the phototransistor generates an electrical pulse, which is fed to a comparator for conditioning. For each detected flash, the comparator puts out a square pulse at transistor/transistor-logic level, suitable for use as a clock pulse in counting circuitry. The pulses are fed to two cascaded decade counters combined with a nonretriggerable multivibrator to obtain a single pulse for each successive accumulation of 100 detected flashes.

The pulses are fed to a commercial counter/display unit, which thus indicates the accumulated number of flashes in multiples of 100. This unit includes a push-button switch for resetting the count to zero when a new flash lamp is installed. When the main power supply of the flash counter is turned off, the counter memory is preserved by battery-powered backup circuitry. To prevent false counting in response to



*The **Phototransistor in the Laser Housing** detects flashes from the lamp. The output of the phototransistor is then processed to count the flashes in multiples of 100.*

ambient light, the main power supply should be turned off when the laser housing is opened for maintenance or repair.

This work was done by William Yanis of NYMA, Inc., for **Lewis Research Center**. *For further information,* ***write in 75*** *on the TSP Request Card.*

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-16311.

Frequency and Phase Compensation in a Pulse-Transmission System

John F. Kennedy Space Center, Florida

A scheme for frequency and phase compensation has been devised for a wideband microwave system that communicates lightning electric-field and derivative waveforms from remote sensing stations to a central station. Compensation is needed to correct for waveform distortions caused by temporal variations of signal-propagation characteristics (e.g., effects of rain) and by finite frequency responses of radio transmitting and receiving equipment. Once the distortions are removed, the times of arrival of the waveforms can be measured accurately to locate the lightning strikes. The present scheme is based on the Fourier-transform relationship between (a) the phase and amplitude frequency response of a communication link and (b) the time response of the link to a pulse, which has a bandwidth greater than the 12-MHz bandwidth of the communication link. Several times per day, each remote station is commanded to transmit such a pulse. The response to the pulse is digitized at the central station, then fast-Fourier-transformed to obtain a transfer function, which is then inverted and used to remove the distortion from received lightning waveforms. With such compensation, differences between times of arrival can be determined to within a few nanoseconds. Without such compensation, errors in differences between times of arrival could be as large as several hundred nanoseconds, resulting in position errors of hundreds of meters.

This work was done by Pedro J. Medelius and Yosef Yariv of I-NET and Ewen M. Thomson and Steve Davis of the University of Florida for **Kennedy Space Center**. *For further information,* ***write in 59*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11852.

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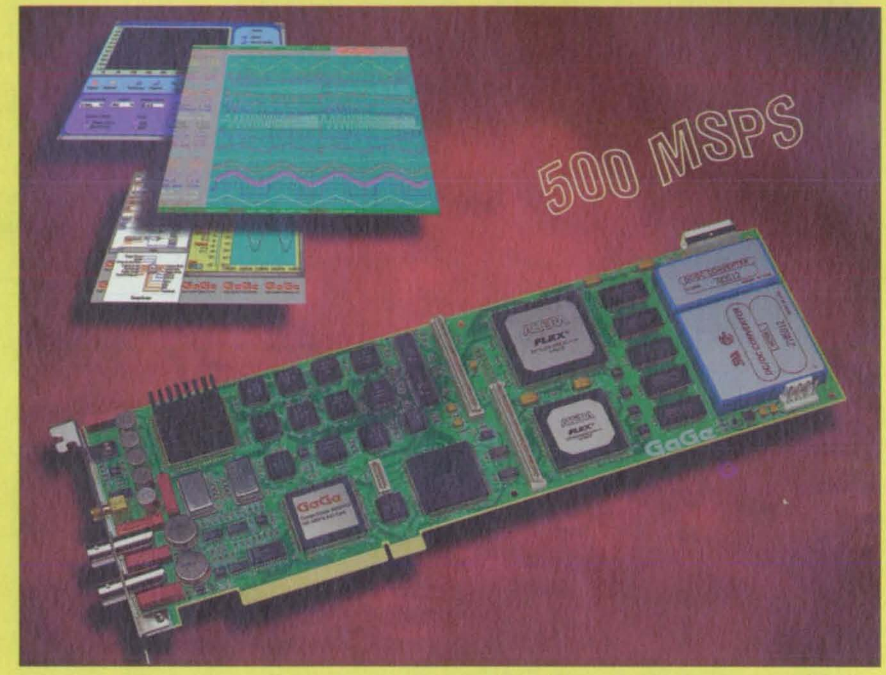

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Portable Wide-Band EPR Spectrometers

Instead of scanning in magnetic field, these instruments would scan in frequency.

NASA's Jet Propulsion Laboratory, Pasadena, California

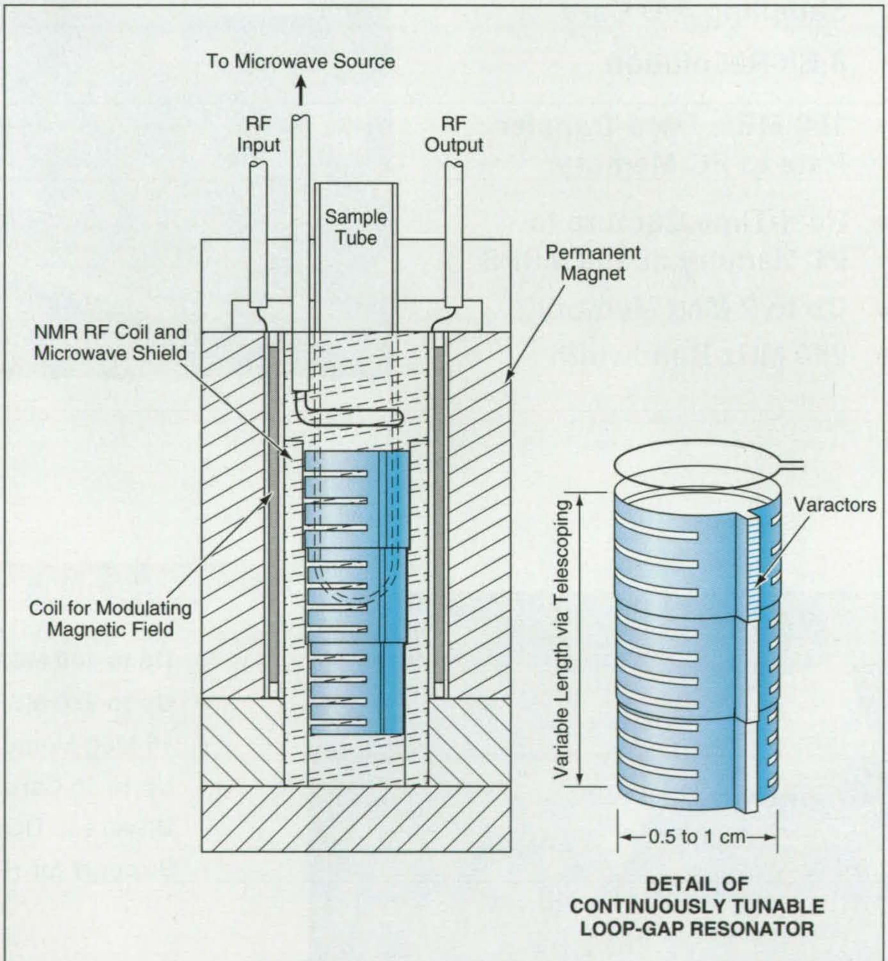
Portable, wide-band electron-paramagnetic-resonance (EPR) spectrometers have been proposed for use in field analysis of organic and inorganic compounds in various states of oxidation in soils, minerals, and rocks. When fully developed, these instruments would be applicable to almost the full range of analyses to which conventional laboratory EPR spectrometers can be applied. The proposed instruments are likely to become economically competitive with conventional EPR spectrometers; this would make the proposed instruments attractive for use in laboratory instruction in educational institutions.

In a conventional laboratory EPR spectrometer, a microwave field is generated at a fixed frequency of about 9 GHz while a magnetic field generated by a large electromagnet is scanned between 0 and an upper limit that typically lies between 9 and 15 kG. A conventional portable EPR spectrometer is similar to a conventional laboratory EPR spectrometer, except that it is equipped with a small permanent magnet with an adjustable yoke to make it portable. Unfortunately, the scan range provided by the small magnet is limited as compared to that of the full-size laboratory version, and the range of applications of the portable version is correspondingly limited.

In an EPR spectrometer according to the proposal, the scan would be performed in frequency instead of in magnetic field. The magnetic field would be fixed at a value between 2.3 and 3.5 kG, and the frequency would be varied in the approximate range of 1 to 20 GHz. The fixed magnetic field would be provided by a permanent magnet, which would weigh less and occupy less space than would an electromagnet capable of generating an equal field. Moreover, the elimination of the electromagnet would reduce the overall power consumption.

A practical field instrument for general magnetic-resonance spectrometry would likely comprise both an EPR spectrometer of the proposed type and a nuclear-magnetic-resonance (NMR) spectrometer. The figure illustrates the principal components of such an instrument. The NMR capability would be provided by a small coil that could be used to generate an oscillating magnetic field at radio frequencies (RF).

approximate range of 500. The most promising resonator design concept for this purpose appears to be that of a cylindrical loop-gap resonator with mechanical coarse tuning via telescoping of cylindrical segments and electronic fine tuning by use of varactors placed across circumferential gaps.



*This **Magnetic-Resonance Spectrometer** would be an integrated combination of both an EPR spectrometer of the proposed type and an NMR spectrometer.*

The major technical challenge in developing the proposed instruments is that of developing microwave resonators that would be tunable over the required frequency range and would have resonance quality factors in the

This work was done by Soon Sam Kim and Narayan R. Mysoor of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 42*** *on the TSP Request Card.*
NPO-19532

High-Temperature Lubrication With a Vaporized Liquid

Vapor-phase lubrication can be used where traditional liquid lubricants fail.

Lewis Research Center, Cleveland, Ohio

Vapor-phase lubrication has been investigated for use in machines in which temperatures are high enough to cause decomposition of traditional liquid lubricants. Such machines include advanced aircraft engines. In efforts to satisfy high-temperature performance criteria for advanced aircraft engines, designers are ever more frequently using components made from superalloys and ceramic composites. Many of these components will operate under tribological conditions at temperatures in excess of 300 °C. At present, no known liquid lubricant can lubricate at temperatures above 300 °C without undergoing significant decomposition. Solid lubricants have been considered, but the higher coefficients of friction and higher rates of wear that occur in the presence of solid lubricant films makes the solid-lubricant approach unattractive.

In this version of vapor-phase lubrication, a small quantity of an organic liquid is vaporized in an air stream that is directed to sliding surfaces where lubrication is needed. In the vicinity of the sliding surfaces, the vapor undergoes chemical reactions that deposit thin layers of lubricous material on these surfaces. The deposits can provide effective lubrication at temperatures greater than 300 °C.

Organic phosphorus compounds, including tricresyl phosphate (TCP) have been used as the lubricants in previous studies of vapor-phase lubrication. Although some success was achieved in those studies, many problems remained unsolved. For instance, vapor-phase lubrication worked only for high concentrations of TCP in air, and it was found that the lubricated system could not self-recover (this means that once the flow of the TCP vapor was shut off and the coefficient of friction consequently increased drastically, restarting the flow of TCP vapor did not cause the desired restoration of the coefficient of friction to its previous lower level).

In research at Lewis Research Center and Cleveland State University, polyphenyl thio-ether has shown promise as a liquid that could be used as vapor-phase lubricant. Initial tribological experiments were conducted in a high-temperature friction-and-wear apparatus, in which a cast-iron rod was loaded against a reciprocating cast-iron plate, using a 4-kg load mass to generate a contact pressure of 1.2 MPa. The temperature of the plate was 500 °C. The rate of flow of polyphenyl thio-ether used as the lubricant in this apparatus was varied from 1.2 to 0.16 mL/h; this corresponds to a range of vapor concentration from 0.07 to 0.009 percent. The temperature of the vapor was 400 °C. A thin film was deposited at the wearing contact, resulting in coefficients of friction as low as 0.03 (see figure). At the end of the test, no wear of the cast iron rod and plate was detectable. In addition, it was found that this system could self-recover after shutoff of the polyphenyl thio-ether vapor.

There may be uses for vapor-phase lubrication in industries other than aerospace. For example, a form of vapor-phase lubrication has been tested

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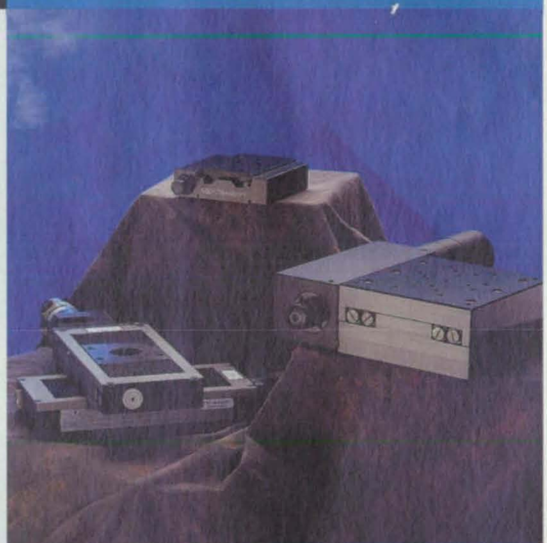

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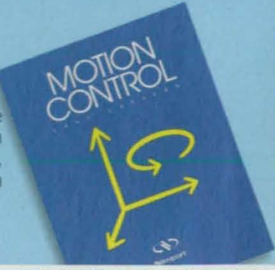

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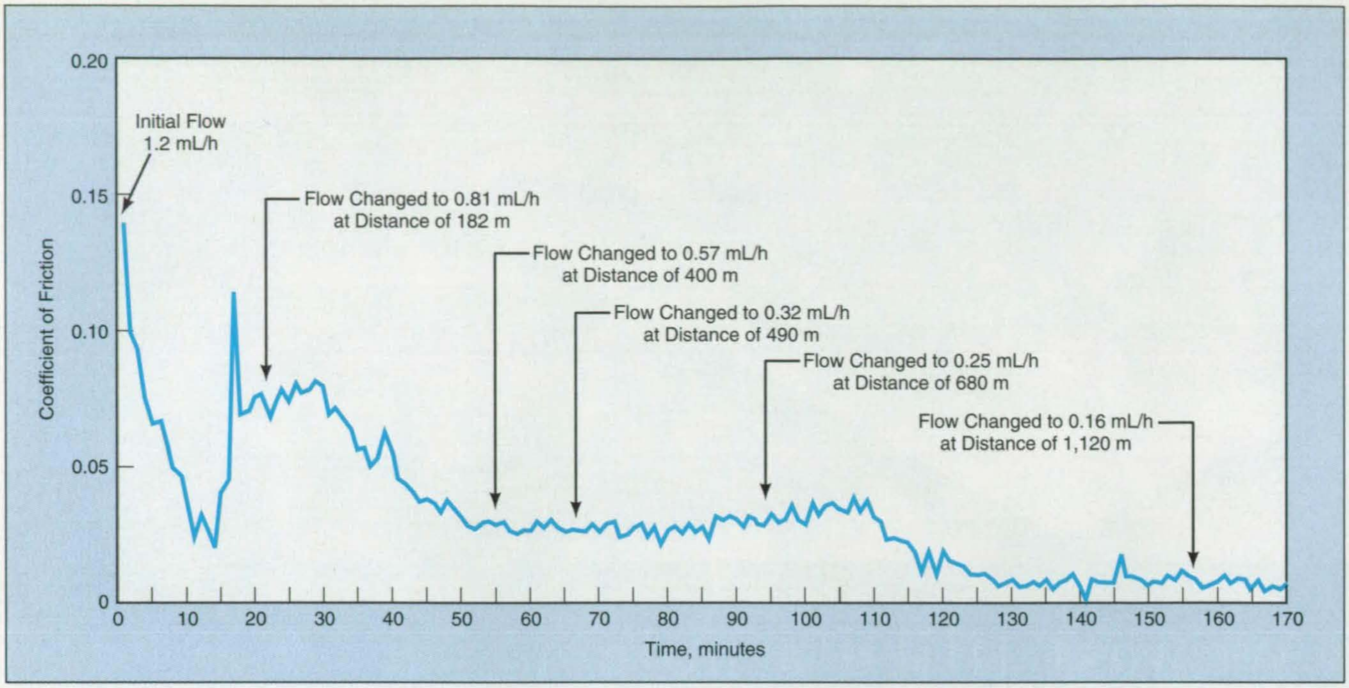


*The **Coefficient of Friction Varied** with time and with the rate of flow of polyphenyl thio-ether. The distances indicated with the changes in concentration are total sliding distances since the beginning of the test.*

by a forging company seeking to replace graphite, which it now uses as a solid lubricant.

This work was done by Wilfredo Morales of **Lewis Research Center** *and E. Earl Graham and Bengi Hanyaloglu of Cleveland State University. No further documentation is available.*

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 Rd., Cleveland, OH 44135. Refer to LEW-16048.

Materials

Thin-Film Thermocouples on Ceramics

Platinum-based thermocouples can be used at temperatures up to 1,500 °C.

Lewis Research Center, Cleveland, Ohio

Thin-film thermocouples on ceramic substrates have been developed to withstand temperatures up to 1,500 °C for times of 50 h or more. These are prototypes of thermocouples that would be used to measure the temperatures of ceramic parts in advanced, high-temperature engines.

The thermocouple metals are platinum and an alloy of 87 percent platinum with 13 percent rhodium (thermocouples made of this combination of metals are called "type R" in the industry). A thermocouple is made by sputtering films of these metals directly onto an electrically insulating ceramic substrate (e.g., silicon dioxide, silicon nitride, aluminum oxide, or mullite).

Alternatively, a thermocouple can be made by sputtering films of these metals onto a thin, electrically insulating ceramic film on an electrically conductive ceramic substrate (e.g., silicon carbide). Typically, the thin, electrically insulating ceramic film is a two-layer film made of an aluminum oxide film that has been sputter-deposited to a thickness of about 2 µm on an adherent silicon dioxide layer that has been thermally grown to a thickness of 2 µm on the surface of a silicon carbide substrate.

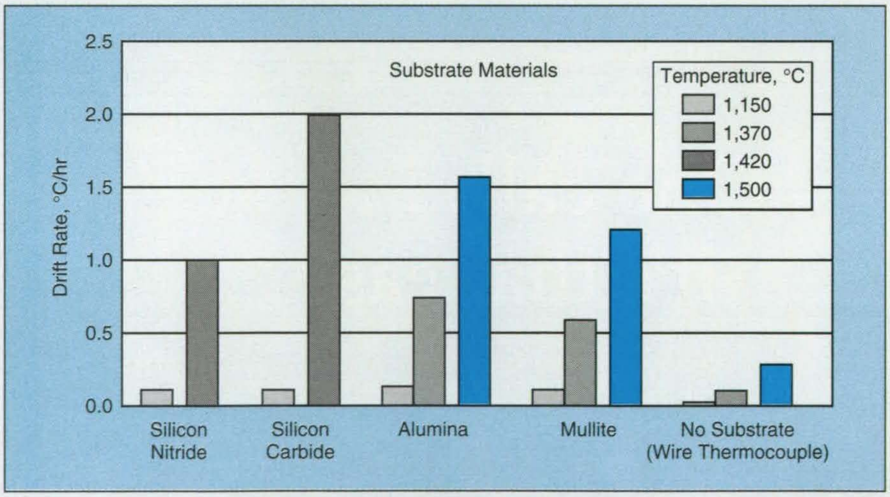
The metal thermocouple films are typically about 12.5 cm long, about 3 cm wide, and 5 to 7 µm thick. Lead wires made of the same materials as those of the thermocouple films are attached to the films by parallel-gap welding. The lead wires, which have a diameter of 75 µm, are routed through ceramic tubes to electrical connectors.

Experimental thin-film thermocouples were tested in ceramic-tube furnaces in both steady-state and thermal-cycling modes at temperatures up to 1,500 °C. In calibration tests, the output of a thin-film thermocouple matched that of a standard wire thermocouple within 3 percent. Small amounts of drift were observed, ranging from negligible values to 2 °C/h, depending on the substrate material and the temperature (see figure). A main cause of drift was oxidation of rhodium at temperatures below about 1,000 °C; above this temperature, the rhodium oxide dissociates. Above about 1,250 °C, however, drift again became noticeable, apparently because of chemical reactions at film/substrate interfaces.

Oxidation of silicon nitride substrates was visible in tests at temperatures above about 1,000 °C. At temperatures above about 1,250 °C, both silicon nitride and silicon carbide substrates deteriorated noticeably, with resultant bubbling and other deformations leading to eventual delamination of the thermocouple films. No changes in the appearances of the aluminum oxide and mullite substrates were seen; thin-film sensors on these materials exhibited very little deterioration in the tests.

This work was done by Raymond Holanda of **Lewis Research Center.** *For further information,* ***write in 34*** *on the TSP Request Card.*

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 Rd., Cleveland, OH 44135. Refer to LEW-16072.



The ***Temperature Indications*** *of experimental thin-film thermocouples drifted with time to various extents, depending on substrate materials and temperatures. The drift of a conventional wire thermocouple is shown for comparison.*

Putting Sulfur-Capturing Sorbents Into Coal Agglomerates

Sulfur is chemically bound in the ashes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process has been developed to incorporate sulfur-capturing sorbents into agglomerates of coal particles imbued with liquid fuels that contain sulfur (e.g., oils from tar sands). The sulfur-capturing sorbents are typically calcium compounds that bind the sulfur chemically in the ashes instead of allowing the sulfur to escape into the air in volatile combustion products.

The process is based partly on concepts described in "Impregnating Coal


Ultramid

With Calcium Carbonate" (NPO-17696), *NASA Tech Briefs*, Vol. 15, No. 12 (December 1991), page 46. The overall effect of the process is to form microscopic particles of calcium carbonate *in situ,* evenly distributed throughout the agglomerate. The coal agglomerates are subsequently used in the beneficiation process for upgrading high sulfur oils such as tar-sands oil.

In the entire process, the first step is the preparation of the calcium-impregnated coal agglomerates. A variety of approaches have been investigated, but the process most appealing to commercialization is described in NPO-17696. In a preferred version of the process, the agglomerate is soaked for about 2 h in a 1 M aqueous solution of calcium acetate (or other calcium salt) in an atmosphere of carbon dioxide at a pressure of 5.6 MPa. The main overall chemical reaction is carbon dioxide + calcium acetate + water → calcium carbonate + acetic acid. The calcium carbonate is formed as fine particles in the pores of the agglomerate. The impregnated agglomerate is then dried in preparation for use in the oil beneficiation.

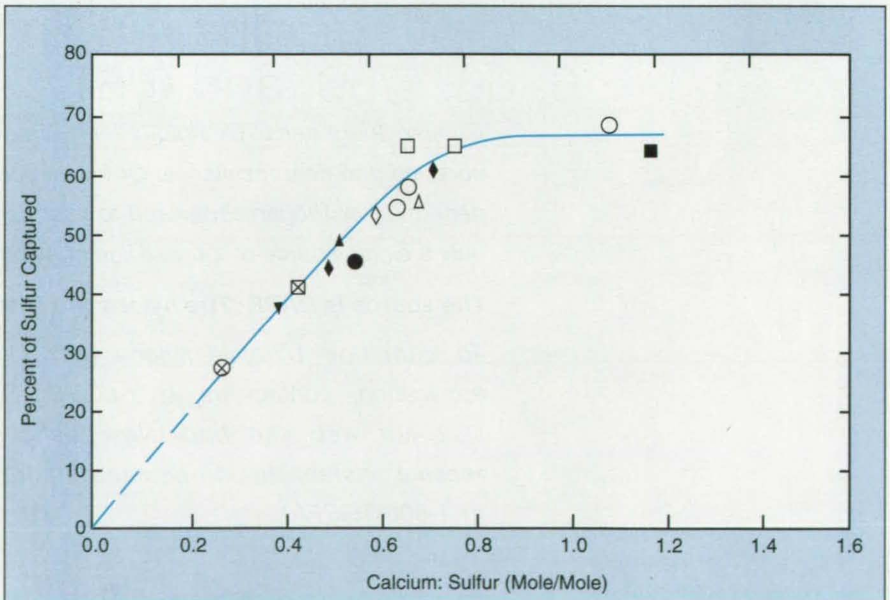
In the second step of the entire beneficiation process, the calcium-impregnated coal agglomerates are mixed with the high-sulfur liquid, i.e., tar-sands oil. The organic sulfur compounds in the oil adhere to the coal agglomerates and are selectively removed from the oil during the oil agglomerate separation, step three. The result of this step is a sulfur-free liquid, which can be utilized as a clean-burning fuel for various applications. The sulfur-laden coal agglomerates can also be cleanly combusted because of the calcium impregnated into the coal. During this combustion process, the sulfur is bound to the calcium, originally deposited in the coal pores as calcium carbonate, and included in the coal ash. The gaseous combustion products are, therefore, free of sulfur oxides. In essence, through the inclusion of calcium-impregnated coal agglomerates in the oil beneficiation process, two clean-burning fuels are obtained and the sulfur removal takes the form of ash-bound calcium sulfide in place of a flue-gas scrubber effluent and additional expensive cleanup steps.

This work was done by Gerald E. Voecks and Robert L. Phen of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 47*** *on the TSP Request Card.*

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

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

Refer to NPO-19106, volume and number of this NASA Tech Briefs *issue, and the page number.*



The ***Percentage of Sulfur Captured*** *upon burning of an agglomerate treated by the in situ calcium-impregnation process depends only on the final relative concentrations of calcium and sulfur before burning. The data points clustered around the curve represent various combinations of calcium salt, acetate, or calcium formate solutions (i.e., formate, acetate, nitrate) used in coal agglomerate preparation.*

Electronics TECH BRIEFS

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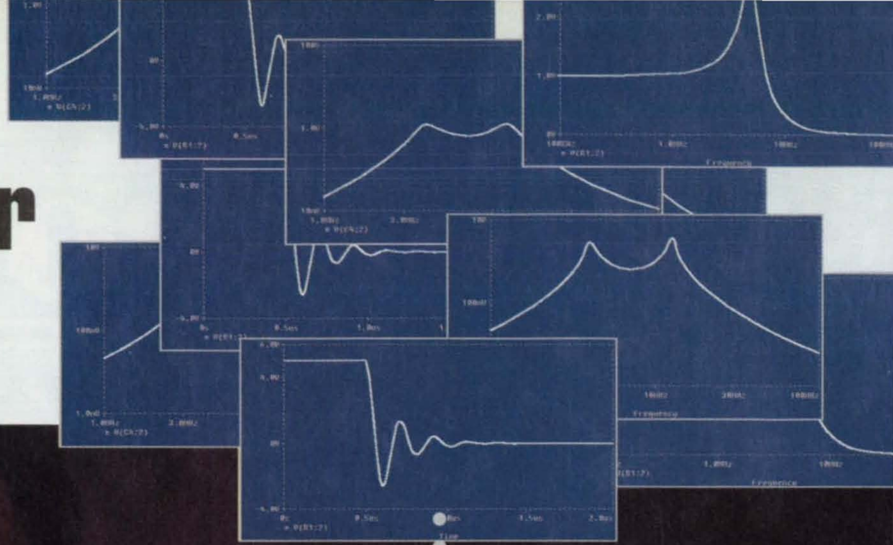

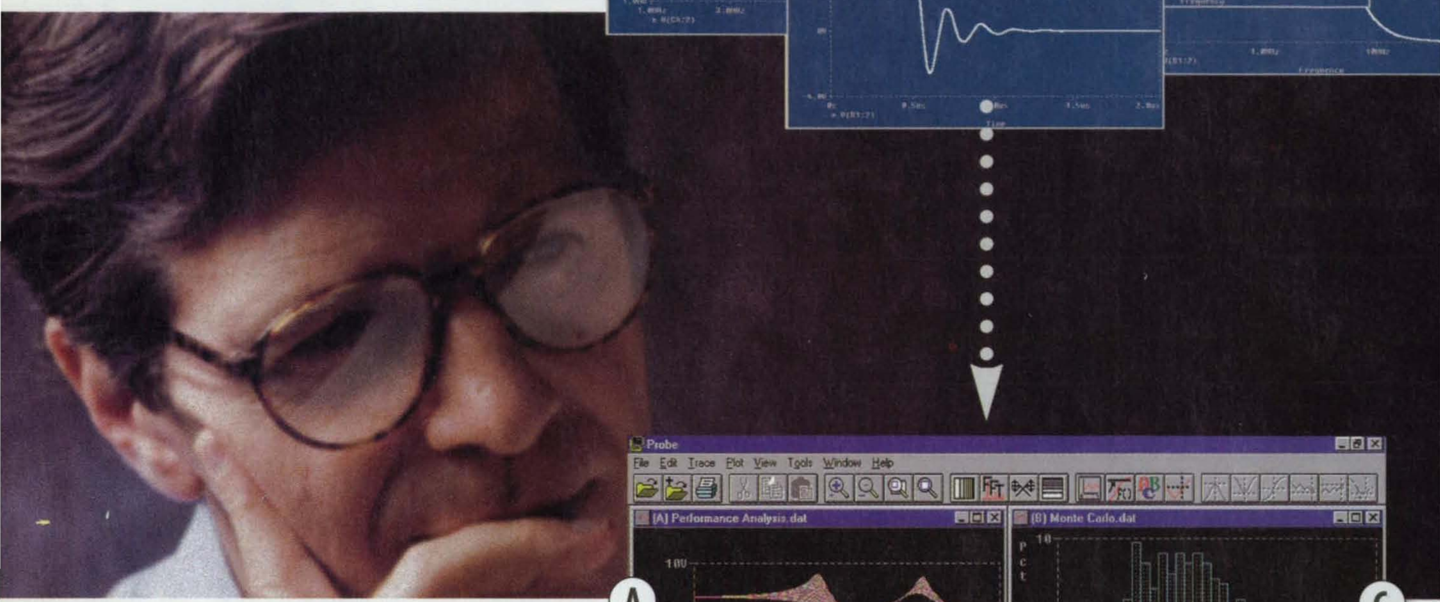

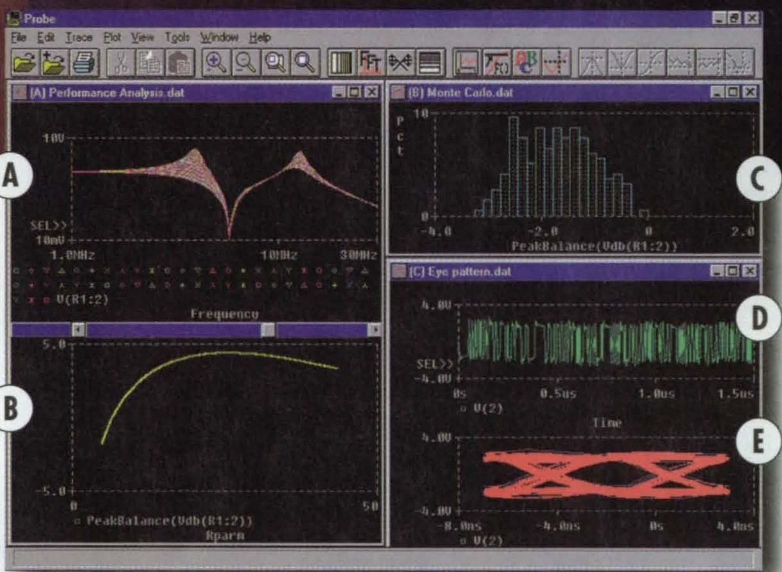

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Electronics TECH BRIEFS

Electronics Tech Briefs Supplement to *NASA Tech Briefs* March 1997 Issue Published by Associated Business Publications

ELECTRONICS TECH BRIEFS

DEPARTMENTS

On the cover:

The W3F high-frequency feedthrough chip capacitor from AVX Corp., Myrtle Beach, SC, serves as an in-line filter for noise reduction and decoupling applications in telecommunications and computer networking equipment. The 1206 integrated passive component (IPC) is smaller than the typical 1808 chip, making it suitable for designers seeking to save board space.
Photo courtesy of AVX Corp.

NEWS BRIEFS

Notes from Industry and the Federal Laboratories

A workshop held late last year brought together materials experts from industry, government, and universities to enhance the competitiveness of the U.S. electronics industry by identifying issues pivotal to its success in the international marketplace. Sponsored by the Electronic Materials Working Group, an organization of representatives from government agencies supporting various electronics programs, the meeting produced the findings and recommendations contained in a report, *Beyond the Technology Roadmaps: An Assessment of Electronics Materials Research and Development.* "To support the continuing push towards increased material complexity and reduced feature size," the report says, "the U.S. government should work to create an environment that encourages electronic companies to increase their participation in R&D." Copies of the report (NISTIR 5777) are available from Michael A. Schen, B320 Polymer Bldg., NIST, Gaithersburg, MD 20899-0001; (301) 975-6741; Fax: (301) 869-3229; E-mail: michael.schen@nist.gov.

Through its Small Business Technology Transfer (STTR) program, the Department of Defense will award $36 million this fiscal year in research and development contracts to small technology companies working cooperatively with research institutions such as universities and federally funded R&D centers. The solicitation closes April 2. For more information, call (703) 205-1596.

Carborundum Corp.'s Microelectronics Division and several other industry members have entered into a cooperative research and development agreement (CRADA) with the U.S. Air Force and the Defense Advanced Research Project Agency (DARPA) to develop aluminum nitride (AlN) microelectronics packaging. With DARPA funding of 50 percent, the remainder is shared by the partners, including IBM, Dow Chemical, Hughes Aircraft, Evans Co., and MIT.

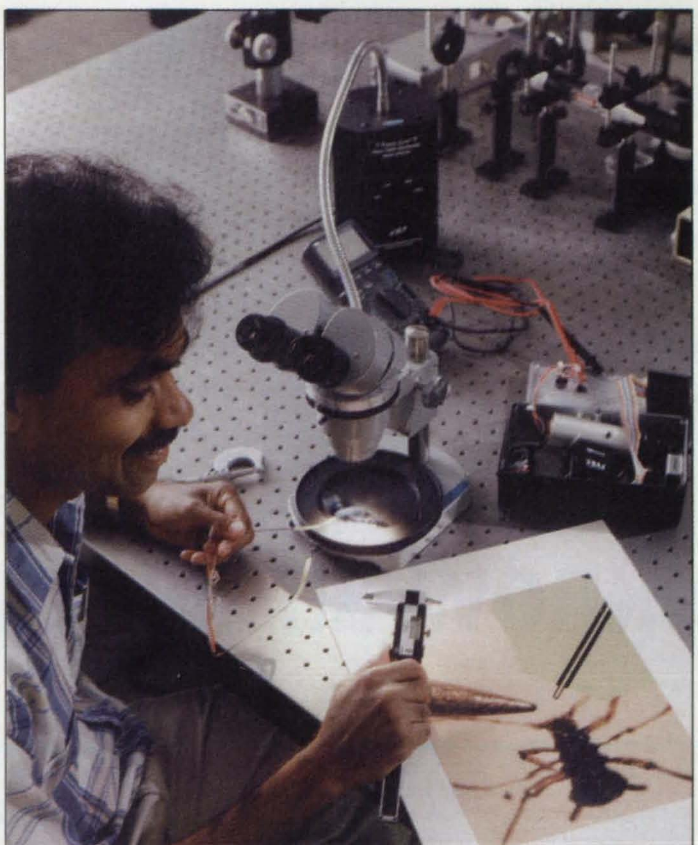
The material is seen as a solid dual-use product, with applications beyond the military in autos, wireless phones, information systems, and collision avoidance systems. AlN's high thermal conductivity makes it a cost-effective alternative to heat sinks and other heat management devices. Furthermore, it can be produced as a multilayer structure, thus permitting 3D wiring. An alliance between Carborundum and IBM led to the codevelopment of proprietary processes that allow aluminum nitride to be mass-produced on existing manufacturing equipment.

The team's developmental aims include translation of the knowledge base generated for high-volume manufacturing of alumina to AlN; use of the core science to control metallization, sintering, and forming of AlN; development of low-cost raw materials, specifically AlN powder; and development of an enabling plating technology. The team expects increasing market acceptance in applications where thermal management issues dominate substrate selection, *i.e.,* telecommunications and radar, particularly as the cost comes down through economies of scale and the specific cost reductions targeted by the CRADA.

An additional goal is to help establish a strong domestic packaging base to reverse the dominance of Japanese suppliers, who now have more than 80 percent of the $2-billion annual market, including almost 90 percent of military hermetic packaging.

Inquiries about the material should be directed to Dr. Roger S. Storm, Carborundum Microelectronics, 10409 S. 50th Place, Phoenix, AZ 85044; (602) 496-5125.

Researchers at the Department of Energy's Oak Ridge National Laboratory (ORNL) are fashioning microsensors the width of a human hair for detecting and measuring any number of quantities–relative humidity, temperature, pressure, flow, viscosity, sound, natural gas, mercury vapor, and ultraviolet and infrared radiation. In an experiment several years ago, Thomas Thundat of ORNL's Health Sciences Research Division (HSRD) noted that humidity affected the performance of an atomic force microscope's cantilever, and from this observation sprang the new series of sensors. Newly available micromachining techniques make fabrication of rugged, extremely sensitive microcantilever sensors.

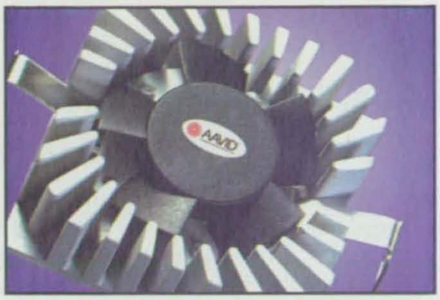


Thomas Thundat of ORNL observes the magnification of a pen point, an insect, and the tip of a cantilever sensor such as the one he is holding.

Typical of the sensors, which project from miniature chips about the size of a grain of rice, is a gold-coated cantilever that absorbs mercury vapor, causing it to bend and change the way it vibrates. Such changes in position or vibration rate are detected by measuring wobble in reflected laser beams. But Bruce Warmack, another member of the HSRD team that also includes Eric Wachter, Mitch Doktycz and Rick Oden, says that future detectors will probably be based on piezoresistance–changes in electrical resistance induced by increased bending or reduced vibration.

One of the ORNL's patented microminiature sensor technologies has been licensed to Consultec Inc., which has created a prototype mercury vapor sensor and infrared thermometer.

INTEGRATED FAN HEAT SINKS: SMALLER, MORE POWERFUL



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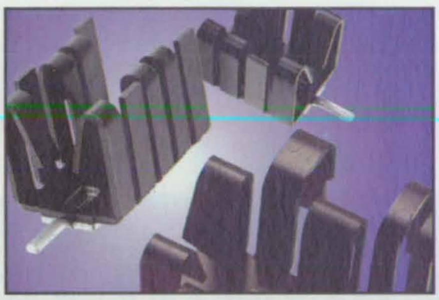

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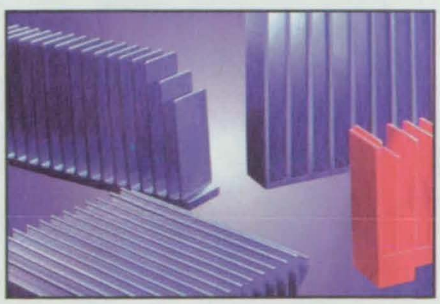

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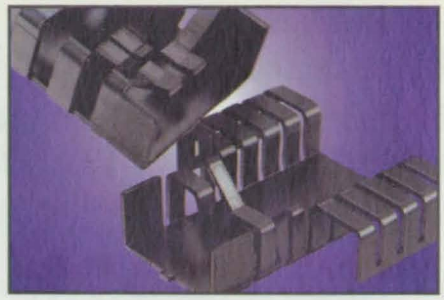

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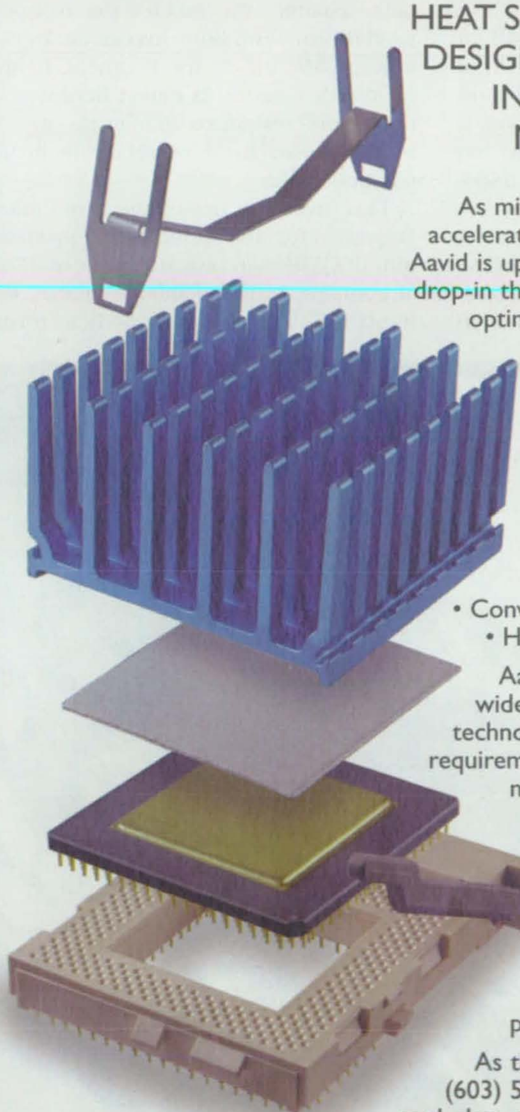

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Practical Method for Making Materials with Giant Magnetoresistance

Novel material requires application of only a small external magnetic field at room temperature.

Lawrence Berkeley National Laboratory, Berkeley, California

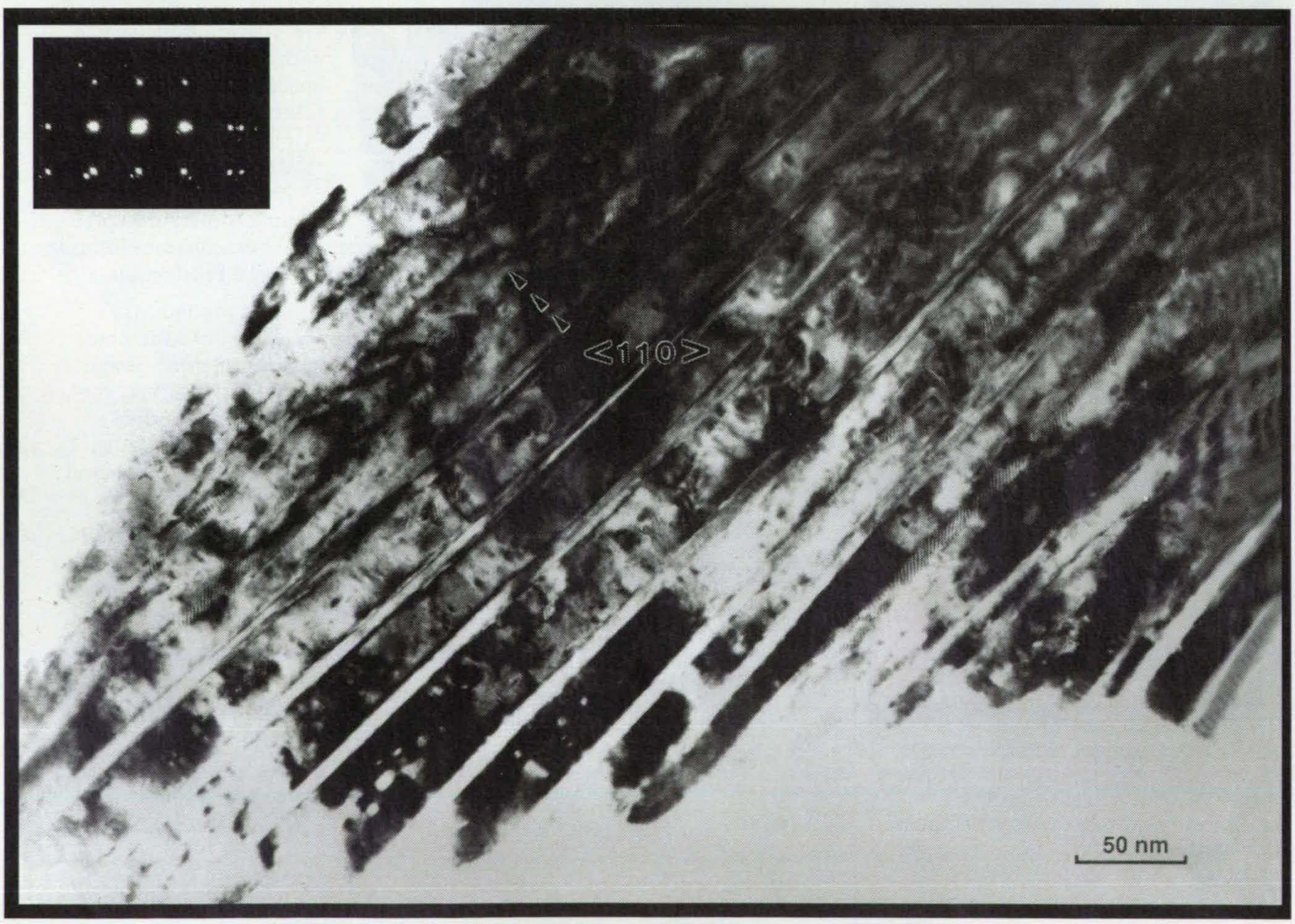
Lawrence Berkeley National Laboratory researchers have invented a new, cost-effective method of producing materials that exhibit giant magnetoresistance (GMR) upon application of a small external magnetic field at room temperature. Until now the practical utility of materials exhibiting GMR properties was limited by difficulty in manufacturing the material and by the large magnetic fields required to produce the effect (2-4 Tesla).

The new materials exhibit GMR at room temperature in a magnetic field of 3 kiloOersteds or less. The novel material, which can be manufactured using a practical and inexpensive process, has great potential for use in high-resolution, fast sensors to read magnetic media.

GMR sensors with their high resolution allow for high data densities. In the quest for higher storage capacity in computer hard drives, researchers hope to cram more information into the same amount of space on the drive surface. In order to make this feasible, the read sensor in read/write heads must be able to sense magnetic fields from ever-decreasing areas on the disk's surface. The GMR effect manifests itself as a large drop in the read sensor's electrical resistance as the head passes over small areas of magnetized material. The smaller the magnetic field needs to be to produce a resistance change, the smaller the magnetized information domains can be. In essence, GMR makes the magnetic fields on the disk easier to detect because of the "giant" resistance change produced in the sensor head by relatively small magnetic fields.

This invention makes the economics favorable for the commercial production of GMR materials. This new material contains grains of microlamellae, or miniature layered particles that form spontaneously during manufacture. These small structures give rise to GMR properties, with minimal hysteresis or delay in magnetization of the material. The material can be made in commercial quantities by melt spinning, rather than by slower methods such as sputtering, expensive molecular beam epitaxy, or laser ablation. Grams of material can be fabricated quickly at reasonable cost. No annealing is necessary for high-quality performance.

This work was done by Johannes Bernardi, Gareth Thomas, and Andreas Huetten at **Ernest Orlando Lawrence Berkeley National Laboratory**. *A patent is pending on this technology, which is available for licensing. Contact Steven Hunter, Technology Transfer Department, Berkeley National Laboratory, University of California, 1 Cyclotron Road, M/S 90-1070, Berkeley, CA 94720; (510) 486-5366; FAX: (510) 486-6457.*



Electron micrograph of **Giant Magnetoresistive (GMR) Material**.

MCM-Based RISC Processor With Programmable Hardware

This pocket-sized computer has 20 MIPS of processing power and 2.5 MB of RAM.

NASA's Jet Propulsion Laboratory, Pasadena, California

A 32-bit reduced-instruction-set-computing (RISC) digital data processor is designed to be readily configurable in hardware and software, both before and during use, for adaptation to various specific tasks. This processor includes 2.5 MB of random-access memory (RAM); 640KB of electrically erasable, programmable read-only memory (EEPROM); and programmable hardware in the form of four RAM-based field-programmable gate arrays (FPGAs); all packaged as a multichip module (MCM) with dimensions of 2 by 4 by 0.25 in. (51 by 102 by 6 mm) and mass of 100 g (see figure). Operating at a clock frequency of 25 MHz, the processor can execute as many as 20 million instructions per second (MIPS) while consuming a power of 7.5 W.

The design of the processor follows an innovative approach to programmable hardware to provide flexibility during the design and operational states of the life cycle of a system in which the processor would be installed. The design also provides the capability for programming of time-multiplexed hardware functions as needed, thereby reducing further the overall mass and volume of processor hardware needed to accomplish various tasks. The programmable-hardware aspect of the design implements a concept of hardware "users": the programmable hardware is made accessible to system users and application users.

The design of a flexible system should include partitioning of memory to provide sufficient memory for programs and for access to information, stored in memory, on the configurations of the system-user and application-user parts of the programmable hardware. In addition, the programmable hardware of such a system can support any of a variety of 32-bit RISC processors.

The system-user programmable hardware performs a number of distinct functions, including the following:

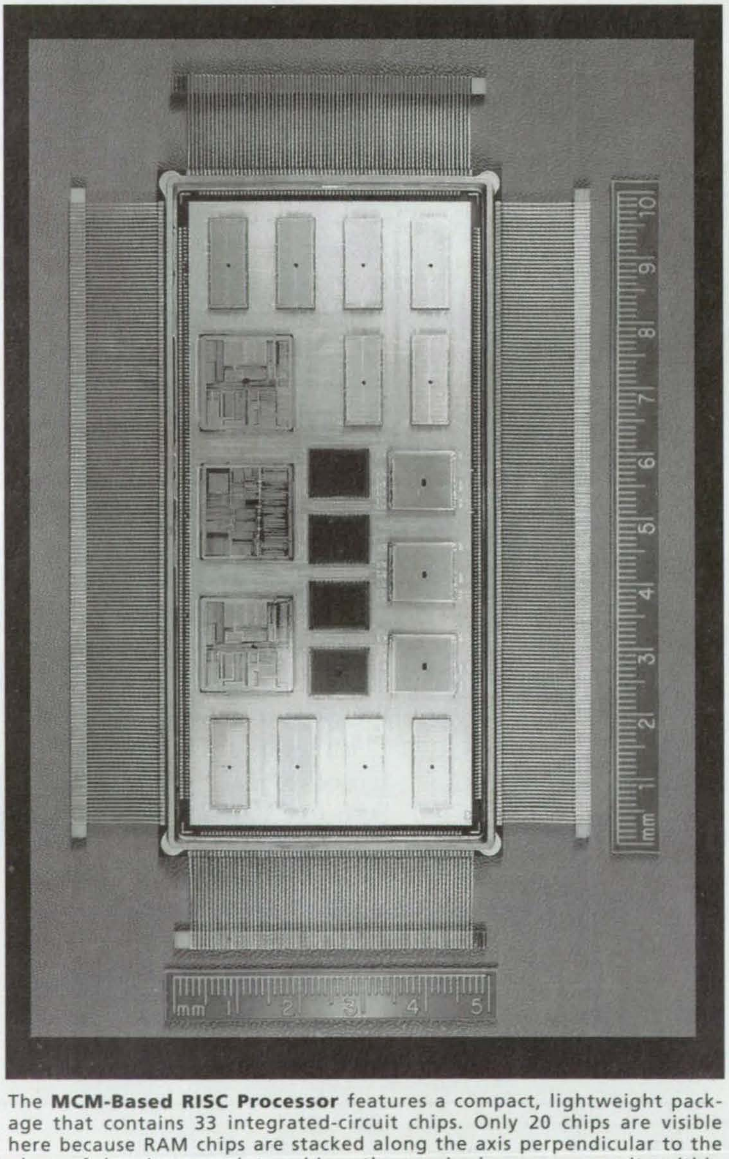
- Acting as an interface between the data-transfer protocol of the processor and the corresponding protocol(s) of the system in which the processor is installed;
- Memory input/output and management functions;
- Management of system-interrupt resources; and
- Management of specialized hardware specific to the system.

The implementation of these functions in programmable hardware makes it possible to use only that portion of the system hardware that is needed for a specific task.

The application-user programmable hardware enables application users to design efficient algorithms or application programs in hardware to achieve complex hardware/software codesigns. The application-user programmable hardware also provides flexibility for application users to implement time-multiplexed hardware configurations.

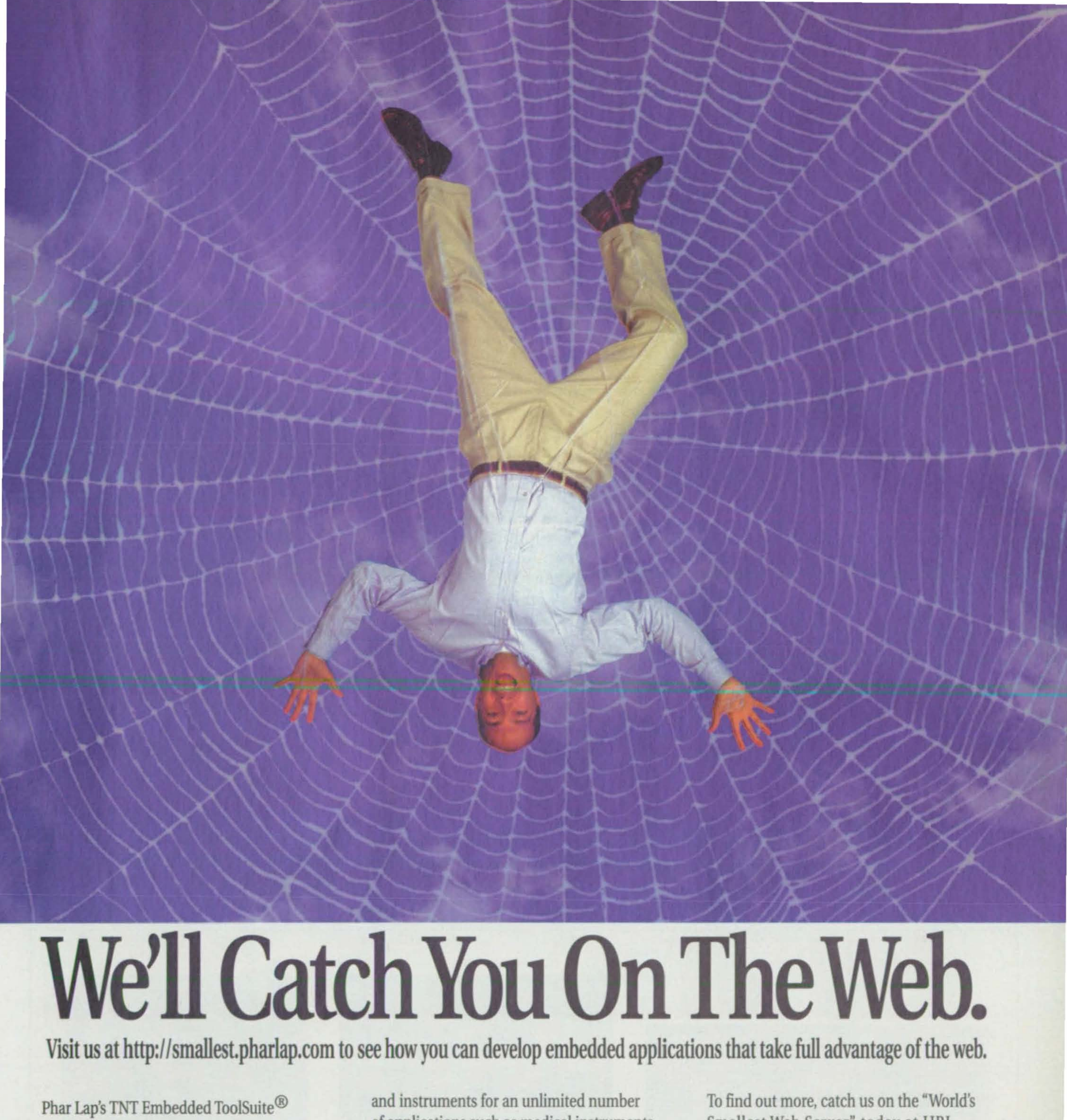
The MCM incorporates a set of 32-bit processor chips, along with the FPGA, RAM, and EEPROM chips mentioned above. A 128-KB portion of the EEPROM stores data for multiple configurations of the FPGAs, and these data can be modified by bus masters. The rest of the EEPROM stores programs.

The MCM is designed and built as a silicon circuit board, which is a silicon wafer with an internal decoupling capacitor and high-density interconnections among chips and other components implemented by routing wires deposited on silicon dioxide layers. The integral decoupling capacitor eliminates the need for numerous decoupling capacitor chips, which would otherwise occupy valuable area. These design features, along with stacking of RAM chips, make it possible to cram a total of 33 chips into the MCM. The problem of dissipating the heat from such dense circuitry is solved by use of an aluminum nitride package; aluminum nitride has a relatively high thermal conductivity. Moreover, aluminum nitride has a low coefficient of thermal expansion; this helps to prolong the lives of interconnections.



The **MCM-Based RISC Processor** features a compact, lightweight package that contains 33 integrated-circuit chips. Only 20 chips are visible here because RAM chips are stacked along the axis perpendicular to the plane of the photograph to achieve the required memory capacity within a design limit on volume. Connections to external circuits are made via 442 pins.

This work was done by Michael A. Newell, Wai-Chi Fang, Richard Johannesson, and Leon Alkalaj of Caltech for **NASA's Jet Propulsion Laboratory**. *For further*



*information, **write in 79** on the TSP Request Card.*

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

Larry Gilbert, Director
Technology Transfer
California Institute of Technology
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Refer to NPO-19785, volume and number of this NASA Tech Briefs *issue, and the page number.*

Photopolymerization of Electrically Conductive Films

These films can be patterned to form printed circuits.

Lewis Research Center, Cleveland, Ohio

A method of photopolymerization of electrically conductive polypyrrole films on electrically insulating substrates has been invented to enhance the manufacture of printed-wiring boards, printed-wiring flexible harnesses, housings for shielding against electromagnetic interference, and related products that are basic to modern electronic circuitry. This method provides the potential for a faster, cheaper, simpler, less-polluting alternative to conventional electroless deposition of copper, which involves expensive catalytic precious-metal seeds and toxic chemicals in chemically unstable plating baths that must be monitored and controlled with great care. Like electroless plating, this method is used to coat an electrically nonconductive substrate with a thin, electrically conductive surface layer, upon which a thicker film of metal (usually copper or nickel) can thereafter be deposited electrolytically by conventional techniques.

In this method, a film is formed from a coating solution that contains silver nitrate and pyrrole monomer, using ultraviolet light to initiate polymerization. If the solution also contains a suitable amount of aniline to reduce the high photo- and thermal activity of pyrrole, the film can be patterned (e.g., to form printed wiring); this is done by exposing the monomer-coated substrate to the ultraviolet light through a patterned mask, then developing (in the photographic sense) the pattern by using solvents to remove the monomeric coating from the unexposed areas. The method can be used to form through holes as well as patterned conductive strips (see figure).

The method admits of numerous variations in processing sequences, temperatures, times, and ingredients of monomeric solutions. For example:

- Typically, the monomeric solution contains 1/8 mole of silver nitrate per mole of pyrrole, but other ratios could be used.
- In addition to the ingredients mentioned, the monomeric solution can contain a small amount of paratoluenesulfonic acid, which helps to harden the polypyrrole film.
- After exposure and development, a patterned film can be heated to a temperature of 105 °C for 20 minutes to cure the polymer (that is, to complete the polymerization).

This work was done by Oliver J. Murphy, Dalibor Hodko, G. Duncan Hitchens, and Eric T. Clarke of Lynntech, Inc.; David L. Miller of Huntsman Corp.; and Donald L. Parker of Texas A & M University for **Lewis Research Center.** *For further information, **write in 22** on the TSP Request Card.*

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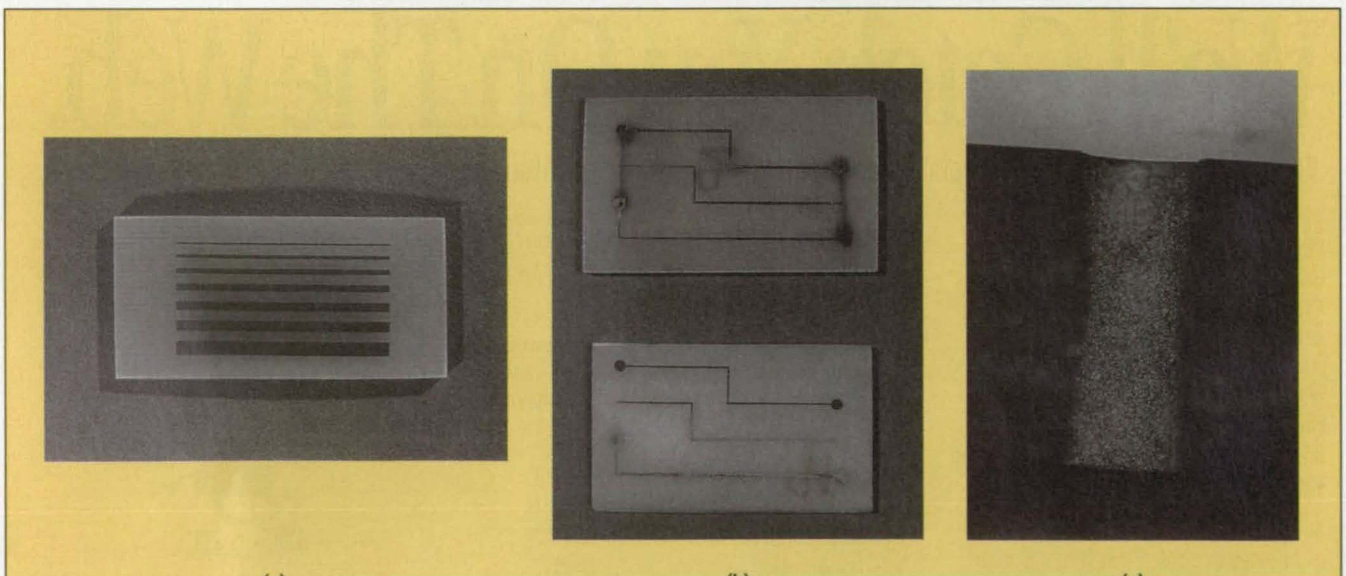

(a) (b) (c)

Photopolymerization Process for the manufacture of printed-wiring boards is illustrated in three photographs: (a) line patterns of conducting polypyrrole/polyaniline formed on a fiberglass epoxy composite substrate; (b) copper-plated and as-produced photopolymerized conducting polymer line patterns on fiberglass/epoxy substrates; and (c) a copper-plated polymerized conducting polymer film on the wall of a through-hole in a printed wiring board.

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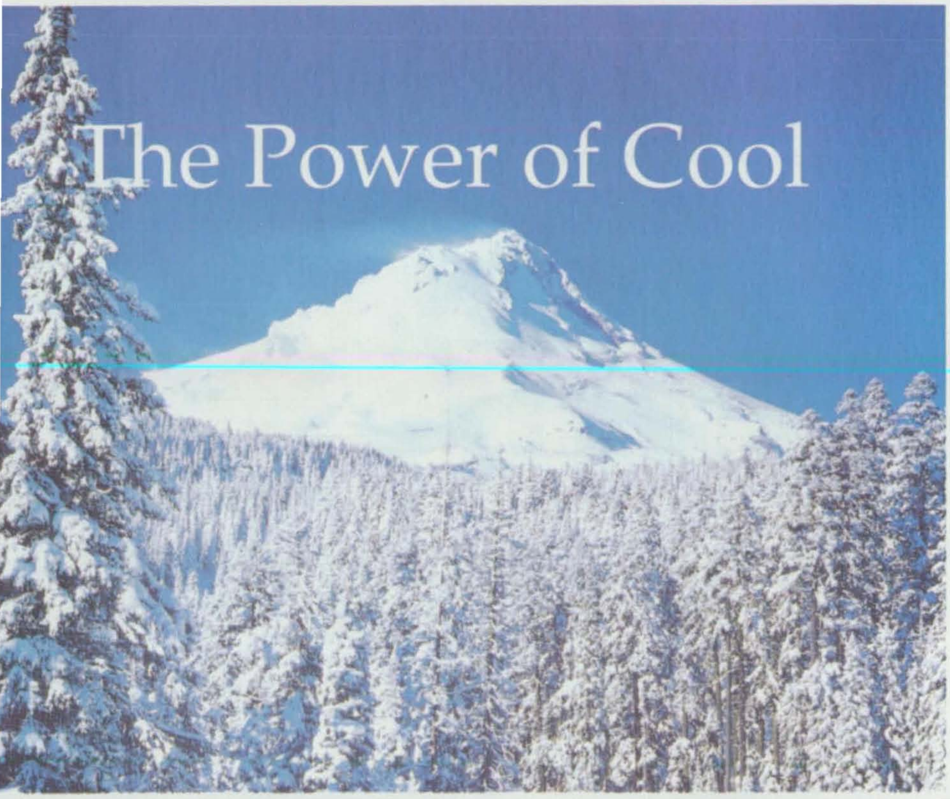

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Czochralski Crystal-Growth System With Diameter Control

Diameter control enhances the quality of nonlinear optical crystals.

Marshall Space Flight Center, Alabama

The figure shows an experimental Czochralski crystal-growth system with provisions for monitoring and control of the diameter of the growing crystal. The system can be used to grow oxide or organic crystals from melts, and is designed especially for growing high-quality single crystals of organic nonlinear optical materials. Moreover, the system is automated; once the system is set up and running, the technician can leave the system unattended and turn to other tasks.

In Czochralski growth of an organic nonlinear optical material, variations in the diameter of the growing crystal induce stresses that cause defects in the crystal lattice. These defects act as light-scattering centers, which reduce the efficiency of nonlinear optical devices made with pieces of the crystal. Thus, the diameter of the growing crystal is critical and must be controlled precisely to ensure crystalline quality high enough for commercial nonlinear optical devices.

In this system, a crystal grows from the lower end of a shaft that is slowly pulled out of a temperature-controlled melt by a lead-screw mechanism driven by a stepping motor under computer control. The shaft extends down from a motor that rotates the growing crystal in the melt. To provide for measurement of the weight of the growing crystal, the motor is mounted on top of an electronic balance on the lead-screw-driven platform. The output of the electronic balance is sent to the computer.

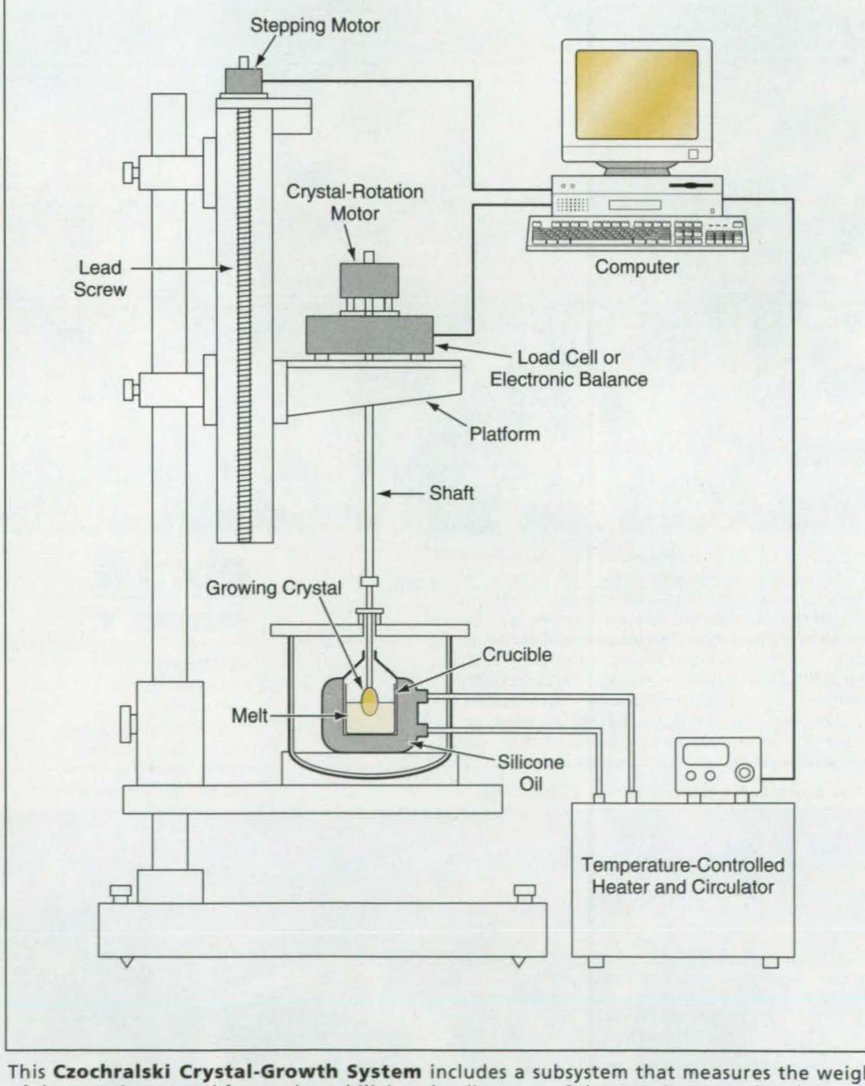
The computer runs a program that provides control of the crystal profile (via control of the heater power and pull rate) from seed extension and necking through full-diameter growth, to termination and cooling. The program includes a file that contains such parameters as the mass densities of the crystalline material and of the melt, the diameter of the crucible that contains the melt, the length and diameter of the seed crystal, the cone angle for the initial stage of growth, the nominal full diameter of the crystal, the nominal rate of growth of the crystal, proportional/integral/derivative control parameters for different stages of growth, filtering factors for minimizing noise during acquisition of data, and feedforward values for controlling heater power.

As part of the control computations, the weight of the crystal as a function of time, the diameter of the crucible, and the mass densities of the crystal and melt are used to calculate the diameter and length of the crystal. If desired, temperature measurements can be used instead of, or in combination with, weight measurements to control the temperature, and a power-feedback loop can be added to the program to stabilize the heater input power.

The weight-sensing subsystem can be used in stabilizing the rate of solidification as well as the diameter. Fluctuations in the rate of solidification cause fluctuations in the rate of incorporation of dopants, giving rise to nonuniformity of doping in the crystal. Thus the weight-sensing subsystem can help ensure the chemical uniformity of the crystal.

This work was done by Benjamin G. Penn and Donald O. Frazier of **Marshall Space Flight Center** *and Robert Metzl, M. D. Aggarwal, W. S. Wang, and J. Choi of Alabama Agricultural and Mechanical University. For further information,* ***write in 74*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center ; (205) 544-0021. Refer to MFS-26420.



This **Czochralski Crystal-Growth System** includes a subsystem that measures the weight of the growing crystal for use in stabilizing the diameter of the growing crystal and the rate of solidification.

An Optical Filter for Underwater Communications

A filter with an ultranarrow linewidth (0.20 nm) and high transmission (40%) at 532 nm holds much promise.

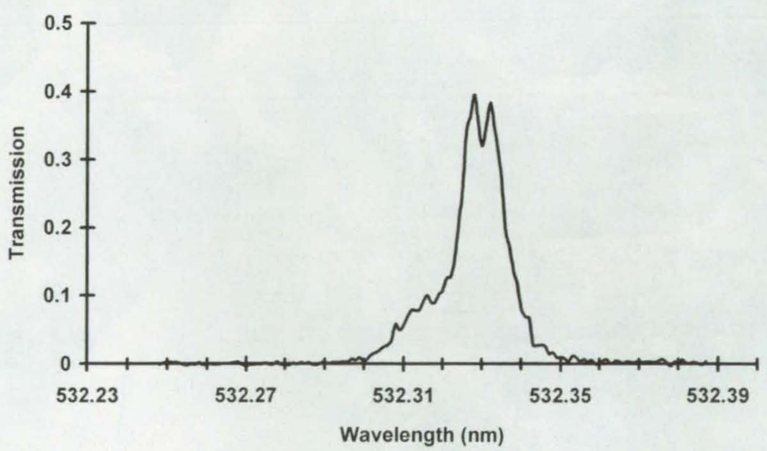
Naval Air Warfare Center, Aircraft Division, Warminster, Pennsylvania

The practical operation of an underwater-communication or ocean-water lidar system requires a matching narrow-bandwidth laser transmitter and filter combination operating in the blue-green spectral region. Since Nd^{3+}-doped yttrium aluminum garnet (YAG) is the most well developed solid-state laser to date, a filter operating at the second-harmonic wavelength of this laser is of considerable practical interest. A team has developed the first-ever Induced Dichroism Excited Atomic Line (IDEAL) optical filter operating at the doubled YAG frequency with a linewidth less than 10 GHz and a transmission of at least 40% for polarized light.

The uniqueness of this filter is in the principle behind its operation, one the team believes has not been used before in the development of filters. A schematic representation of the experimental setup is shown in the figure inset. The $4S_{1/2}$ to $4P_{1/2}$ transition is excited with circularly polarized light at 770 nm from a 10-ns pulsed dye laser. The filter operates on the $4P_{1/2}$ to $8S_{1/2}$ transition at 532.33 nm similar to a Faraday Anomalous Dispersion Optical Filter (FADOF). The plane of polarization of the incoming light, which is near-resonant with the atomic transition, is rotated by 90° and passes through a set of cross-polarizers. These block all light except what has been rotated by the cell. However, unlike conventional FADOF filters, no external DC magnetic field is necessary for its operation. A circular birefringence at 532 nm induced by the circularly polarized pump beam is believed to be responsible for the polarization rotation.

A typical transmission spectrum of the filter is shown in the figure. It was obtained by tuning the circularly polarized pump beam with a peak intensity of approximately 0.8 MW/cm^2 to the $4S_{1/2}$ to $4P_{1/2}$ resonance at 769.9 nm. With the polarizers crossed, the low-intensity (10 mW/cm^2) probe beam was scanned through the $4P_{1/2}$ to $8S_{1/2}$ transition. The transmitted probe intensity as a function of wavelength was measured by the photomultiplier tube and recorded. The filter transmission at a particular wavelength is a ratio of this intensity to that measured with the pump beam blocked and polarizers uncrossed.

The filter transmission reached the optimum value near 532.33 nm. As the pump intensity was increased, starting from 5 kW/cm^2, the peak transmission increased monotonically until a maximum of about 40% was reached at 0.8 MW/cm^2, then levelled off and slightly decreased at even higher intensities. The transmission depended on the spatial and temporal overlap between the pump and probe pulses, and disappeared when the pump pulse was turned off, or either of the two beams was tuned away from the respective resonance. This confirms that the filter operates on the $4P_{1/2}$ to $8S_{1/2}$ ES transition.



Transmission vs. wavelength for the **IDEAL optical filter**.

The principal feature of the spectrum, two barely resolved peaks, was reproduced in repeated scans for all the pump intensities used in this experiment. This feature was interpreted as the two characteristic peaks of a conventional FADOF spectrum that could not be resolved with the broader-linewidth laser used in the experiment. An attempt was made to characterize the structure by measurement of the spectrum under higher resolution using a pressure-scanned etalon in the probe dye laser's cavity. But because of the large pulse-to-pulse fluctuations in the laser's energy that resulted from the insertion of the intracavity etalon, a reliable transmission measurement has not yet been possible.

Two observations about the characteristics of the IDEAL optical filter may be made. First, the 40% peak transmission demonstrated herein should not be considered optimized because the linewidth of the probe laser was somewhat larger than the Doppler linewidth of the transition. A preliminary model of the induced circular birefringence suggests that transmissions of up to 90% may be measurable with a narrower, more stable probe beam.

The second issue concerns the noise expectations of the filter, since it is actively pumped. Any excitation mechanism that could upconvert the 769.9-nm pump photons to photons near 532.33 would be a significant source of noise for this filter. The results of a preliminary noise measurement showed no such measurable noise down to about 100 photons/pulse, the limit set by scattered light from the doubled YAG pump laser. It may be instructive to compare this number to 4.7 X 10^4 photons detected at the filter transmission peak under the experimental conditions. The team is pursuing more quantitative measurement of the noise level.

In summary, this efficient narrow-band optical filter is at a wavelength of practical and operational interest for both underwater communications and laser radar systems. Moreover, any system that requires high transmission and narrow linewidth at 532 nm will find this filter of great utility.

This work was done by Dr. Richard Billmers and Dr. Vincent M. Contarino at the **Naval Air Warfare Center, Aircraft Division,** *Warminster, PA. For more information please call (215) 441-1569 or (215) 441-3283.*

Device-Quality GaAs on Si Interlayers on Diamond Substrates

Electronic and heat-sinking materials can be integrated into monolithic devices.

Lewis Research Center, Cleveland, Ohio

A material and fabrication process have been invented for making GaAs-based integrated electronic circuits with superior heat sinking. As shown in the figure, the material consists of (1) a top layer that comprises strips of electronic-device-quality (single-crystal) gallium arsenide alongside of dielectric strips containing sublayers of silicon dioxide and silicon nitride on top of (2) multiple layers composed predominantly of gallium arsenide, all of which rest on (3) an interfacial layer of single-crystal silicon on (4) a substrate of polycrystalline synthetic diamond. The GaAs, Si, and diamond are in complete, intimate contact at the atomic level and thus can be regarded as combined into a single material. By use of this material, electronic and heat-sinking components can be integrated into monolithic devices to exploit the thermal coupling afforded by atomic-level contact and the exceptionally high thermal conductivity of diamond. According to a preliminary thermal analysis, high-speed GaAs-based digital circuits made of this material could function at about 100 times the present industry maximum power density.

A typical wafer of this material has a diameter between 1 and 3 inches (between 2.5 and 7.6 cm) and a total thickness between 326 and 427 µm. The top layer of GaAs interspersed with SiO_2 and Si_3N_4 is 2 to 3 µm thick, the Si layer is 25 µm thick, and the diamond layer is 300 to 400 µm thick. The GaAs is grown in the recesses between the SiO_2/Si_3N_4 dielectric strips. The pattern of these recesses is tailored to the specific application.

The material and the fabrication process are compatible with standard integrated-circuit fabrication equipment and techniques. In the first step of the process, a 1/8-in. (3-mm) thick wafer of (100)-oriented single-crystal silicon is cut 4° off axis toward (011); this is done to help compensate for the 4-percent mismatch between the Si and GaAs crystal lattices.

The sequence of deposition of the diamond and GaAs layers is dictated in large part by considerations of processing temperatures and differences among the coefficients of thermal expansion of the component materials. In the second step of the process, synthetic diamond is grown on one side of the wafer by chemical vapor deposition. Next, the thickness of the silicon layer is reduced to 25 µm by either mechanical lapping on the surface not coated with diamond, followed by polishing, or chemical etching.

There follows a rather complex sequence of steps in which the uncoated surface of the silicon is cleaned and subsequent layers are deposited, etched, and patterned. A layer of silicon is deposited by molecular-beam epitaxy to a thickness of 1 µm, followed by the next-to-top dielectric SiO_2 sublayer (1 µm thick), followed by the top dielectric Si_3N_4 sublayer (2 µm thick). The recesses in the dielectric SiO_2/Si_3N_4 layer are formed in the desired pattern by reactive ion etching all the way down to the silicon. Then the following layers are deposited: (1) a seed layer of GaAs 300 Å thick, (2) a 1,850-Å-thick superlattice comprising five 200-Å-thick layers of $(GaAs)_{0.8}(Si_2)_{0.2}$ alternating with five 170-Å-thick layers of GaAs, (3) a 0.2-µm-thick layer of GaAs, (4) a second 1,850-Å-thick superlattice, (5) a 1-µm-thick layer of GaAs, (6) a third 1,850-Å-thick superlattice, and (7) a 1-µm-thick layer of GaAs. The superlattices help to prevent the propagation of defects from the Si/GaAs interface to the top GaAs layer. On top of this structure, the desired electronic-device layers are deposited.

The portion of the final GaAs layer deposited over each of the dielectric SiO_2/Si_3N_4 strips is polycrystalline, but the portion deposited on the silicon in each recess between the SiO_2/Si_3N_4 strips is formed as a single crystal, as is necessary for fabrication of electronic circuitry. The polycrystalline material can be removed, with minimal damage to the single-crystal material, by selective chemical etching in an aqueous solution of ammonia and hydrogen peroxide.

This work was done by Susan R. Reinecke, Samuel A. Alterovitz, and John Dickman of **Lewis Research Center** *and Rainee N. Simons of NYMA, Inc. For further information,* ***write in 26*** *on the TSP Request Card.*

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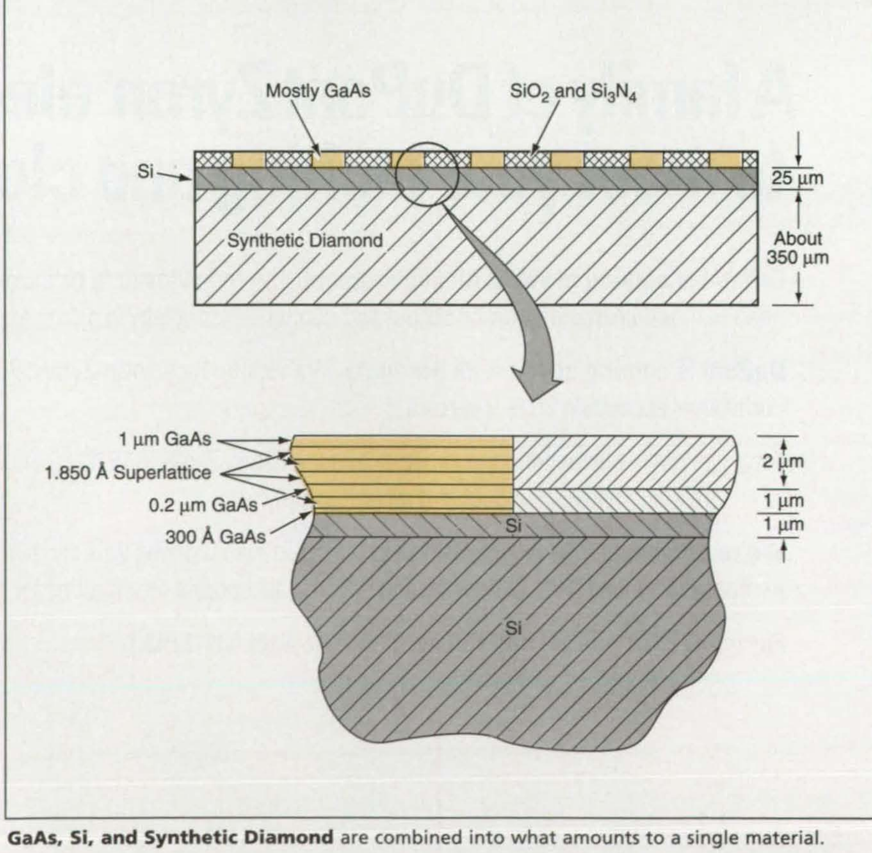


GaAs, Si, and Synthetic Diamond are combined into what amounts to a single material.

Accessories for Pulsed-Laser Deposition of Superconductors

Larger substrates can be coated without breaking vacuum before deposition is complete.

Lewis Research Center, Cleveland, Ohio

Three accessories have been developed to improve pulsed-laser deposition of epitaxial thin films of high-temperature superconductors (e.g., yttrium barium copper oxide) and other complex ceramic materials on sapphire, lanthanum aluminate, and other substrates. These accessories are designed to do the following:

- Enable the deposition of both an interfacial buffer film (e.g., cerium oxide or zirconium oxide in the case of a sapphire substrate) and a superconductor film in a single evacuation of a deposition-chamber system,
- Ensure uniform temperature (about 950 °C in oxygen partial pressure for depositing the buffer film and about 800 °C for depositing the superconductor film) across a substrate of area as large as 20 cm^2, and
- Enable deposition on both sides of a substrate of such large area.

In a typical older pulsed-laser deposition apparatus, the substrate was heated by direct contact with a heater plate, which could not maintain an acceptably uniform temperature (variation of no more than 10 °C) over an area larger than 1 cm^2. The apparatus included a holder for only one target (the source of material to be deposited on the substrate), making it necessary to cool the substrate and break vacuum to introduce different targets to form multilayer films; this extended the processing time and made the substrate and film vulnerable to airborne contamination. Moreover, it was not possible to deposit films on both sides of a substrate. The three accessories overcome some of these limitations.

One of the accessories is a multiple-target holder. This device holds as many as six targets and, at a given time, places one target in the path of the laser beam. During exposure to the laser beam, a motor and a planetary-gear mechanism rotate the target to ensure uniform ablation and a controlled deposition rate. The motor is located outside the deposition chamber and is sealed for high vacuum compatibility by use of stainless-steel welded bellows feed-throughs that permit sufficient motion for manipulating the targets.

The second accessory is a flat-plate heater, which is basically an extended version of the previous contact heater plate. It includes a relatively thick, flat plate to which a resistive heating element is brazed, forming a single heating unit. Although not applicable to deposition on both sides of the substrate, the flat-plate heater nevertheless provides an improvement in that it can maintain a very uniform temperature over an area as large as 20 cm^2.

The third accessory is a black-body type heater. This device is based on the concept of placing the substrate in a cavity, the interior walls of which are held at a uniform temperature. In principle, the substrate would equilibrate to a temperature close to that of the cavity. In practice, there must be an opening to admit the deposition plume, so that a perfect black-body cavity cannot be realized. An effective approximation to a black-body cavity can be obtained by judicious choice of the aperture, materials, and

other aspects of the design, as follows:

The practical black-body heater includes a double-walled nickel-alloy cylinder with inside diameter of about 7 cm and length of 10 cm, containing a cable heating element coiled within the double wall. The substrate is mounted within the cylinder and can be rotated during deposition to achieve higher thickness uniformity across the wafer. One end of the cylinder serves as the aperture for entry of the deposition plume. To reduce heating of nearby objects and make the interior temperature more nearly uniform, the heater is enclosed within a combination of concentric metal shields, the outermost one of which is cooled with water.

This work was done by Alberto Piqué and Steven Green of Neocera, Inc., and Xin Di Wu of Los Alamos National Laboratory for **Lewis Research Center.** *For further information, **write in 53** on the TSP Request Card.*

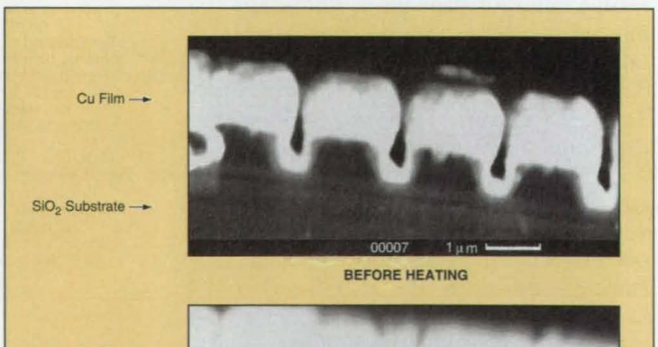
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-15873.

Selective Microwave Heating of Thin-Film Heterostructures

Highly microwave-absorbent thin conductive films are heated more strongly than are less-microwave-absorbent substrates.

NASA's Jet Propulsion Laboratory, Pasadena, California

Selective microwave heating of thin-film heterostructures shows promise as a technique for use in fabrication of integrated circuits. The basic idea is to take advantage of the properties of the materials in question when, as sometimes occurs, there is a need to heat (e.g., for annealing) a thin film of a relatively highly microwave-absorbent material (e.g., copper) that has been deposited on a less-microwave-absorbent substrate (e.g., silicon or silicon dioxide), and to minimize the heating of the substrate. Fortuitously, it is possible to achieve



Annealing by Selective Microwave Heating removed the voids from a copper film on a grooved silicon dioxide substrate. The flow of copper to remove the voids and fill the grooves has been conjectured to involve diffusion of the copper rather than melting, because the maximum measured temperature of the copper film was below its melting temperature.

the desired preferential heating of the copper or other thin film by suitable choice of the microwave power, frequency, and electromagnetic-field configuration.

The feasibility of the method was demonstrated in experiments. In a typical one of these experiments, a grooved silicon dioxide substrate coated with a copper film about 1 μm thick was placed in a cylindrical cavity and oriented so that the electric field in the TM010 mode of the cavity would be parallel to the outer surface of the film. The cavity was excited in its TM010 mode at a power of about 1.2 W for interval of about 30 s, heating the copper sufficiently to make it flow and fill in the voids that were present before heating (see figure). This is significant for the development of ultra-large-scale integrated circuits: heretofore, the presence of such voids and the lack of a suitable technique for eliminating them degraded the reliability of interconnections in such circuits.

This work was done by Martin B. Barmatz of **NASA's Jet Propulsion Laboratory,** *and Harry A. Atwater and Ruth A. Brain of Caltech. For further information,* ***write in 52*** *on the TSP Request Card.*

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

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

Refer to NPO-19402, volume and number of this NASA Tech Briefs *issue, and the page number.*

Narrow-Channel Fused Fiber Wavelength Division Multiplexers (WDM)

Fiber optic WDMs with closely spaced wavelength channels are mode to operate independently of the input light's polarization.

Naval Command, Control, and Ocean Surveillance Center, RDT&E Division, San Diego, California

Wavelength division multiplexing (WDM) is a technique whereby multiple laser signals, each at a distinctly different optical wavelength, are transmitted simultaneously over a single optical fiber. The method can be used to increase the overall capacity of a fiber link, or it can allow routing of signals in a fiber optic system based on the wavelength of the signal carrier.

WDMs made using the fused fiber technique are currently able to multiplex signals in the low-loss communications bands of single-mode fibers around 1300 nm and 1500 nm. But to more fully utilize the bandwidth made available by optical fiber, it is necessary to multiplex greater numbers of wavelengths within each of these low-loss bands. The fabrication technique described here allows the production of WDMs, using the fused fiber method, with the necessary small wavelength separations.

Fused fiber couplers are made by aligning two single-mode fibers side by side, fusing them together over a given length, and elongating and tapering the fused region. This process allows an optical mode field propagating in one fiber to interact with the guiding region of a second fiber, resulting in light being coupled from one fiber to the other.

Such coupling depends on several factors, including the effective length of the fused region, the cross-sectional shape and dimensions of the fused region, and most importantly the wavelength of light launched into the fused coupler. A properly designed fused fiber WDM will have a raised sinusoidal coupled-power dependence on the wavelength, ideally with a coupled power at one wavelength λ_1 of 0 (or 100) percent, while the coupled power at a second wavelength λ_2 will be 100 (or 0) percent. A coupler with these characteristics can perform the operations of multiplexing, demultiplexing, and bidirectional transmission of two optical signals at wavelengths λ_1 and λ_2.

The wavelength separation of a fused fiber WDM can be selected at the time of manufacture. This is done by launching light of a given wavelength into one of the optical fibers, and monitoring the output leads of both. As the fibers are fused and tapered, light will begin to couple over from the first fiber into the second. As the tapering continues, the light will begin to oscillate sinusoidally between the two fibers. This dependence of coupled power on the elongation of the coupled region is shown in the figure.

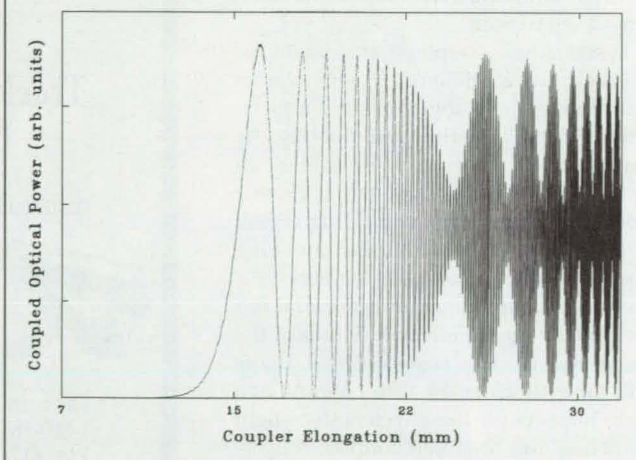
If the heating and pulling is stopped at any point where the coupled power is 0 or 100 percent, the device will be capable of operating as a WDM. The separation between the operating wavelengths depends inversely on the number of times the optical power has cycled back and forth between the fibers. Thus for closely spaced wavelength channels, the coupler must undergo many power-transfer cycles (and hence have a great elongation span).

The major impediment to manufacturing fused fiber WDMs with narrow channel spacings is the dependence of the coupling on the polarization state of the input light. Such dependence manifests itself in an envelope that can be observed in the coupled-power-vs.-elongation plot shown in the figure. For great lengths, this envelope can prevent the 0-or-100%-coupling condition necessary for the device to operate properly as a WDM. The researchers found, however, that if the elongation is stopped at one of the peaks of the envelope function, the operation of the resulting device is insensitive to polarization.

The approximate wavelength spacing can be chosen by stopping the manufacturing process at a particular peak in the polarization envelope. The desired wavelength spacing can then be fine-tuned by changing the degree of fusion of the two fibers. In the NCCOSC manufacturing station this was achieved by changing the distance that the heat source, an oxygen-propane microtorch, is toggled underneath the fibers. Using this method, polarization-independent narrow-channel (PINC) WDMs have been manufactured with wavelength spacings between 13 and 35 nm. With further refinements of the computer-controlled manufacturing station, it is expected that PINC WDMs with spacings of less than 10 nm will be readily achievable. The resultant couplers have very low loss (less than 0.2 dB) and low crosstalk (better than 20 dB of channel isolation with a 1-nm optical bandpass), and are environmentally stable.

This work was done by Richard Orazi and Matt McLandrich of the **Naval Command, Control, and Ocean Surveillance Center (NCCOSC)**, *Research, Development, Test & Evaluation Division.*

Inquiries concerning rights for the commercial use of this invention should be addressed to Commanding Officer, Att: Technology Transfer Liaison, NCCOSC RDTE DIV 0143, 53560 Hull St., San Diego, CA 92152-5001; (619) 553-2101.



Optical power coupled over into the second optical fiber as a function of the elongation of the fused region, for one input wavelength.

Computed Responses of Graded MMCs to Thermal Gradients

The micromechanical and macromechanical aspects are integrated into a single mathematical model.

Lewis Research Center, Cleveland, Ohio

A method of analysis has been introduced to compute stresses in functionally graded metal-matrix composites (MMCs) exposed to gradients of temperature. The term "functionally graded" characterizes an emerging class of materials, the microstructures of which are spatially graded to achieve specific thermal and/or mechanical properties. In the case of a composite material, functional grading can be effected by use of spatially variable spacing between individual inclusions (typically, the inclusions are fibers), and/or inclusions of different properties, sizes and shapes. One important class of applications involves grading to decrease thermally induced macroscopic bending moments in structural components, thereby decreasing thermal distortions of the components.

The method is best explained by use of the following example. The figure illustrates a mathematical model of a functionally graded matrix/fiber composite plate that is of thickness H along the x_1 axis and extends to infinity in the x_2–x_3 plane. The plate is subjected to temperatures T_T and T_B on its top ($x_1 = 0$) and bottom ($x_1 = H$) surfaces, respectively. The matrix is reinforced by periodic arrays of fibers in layers parallel to the x_2–x_3 plane. The grading in this case consists in variations in the distances along x_1 between the layers. The fibers can be either continuous or of finite length. Further, the fibers in each layer can have thermoelastic properties different from those of the fibers in other layers. Thus, the model admits a variety of materials with tailored microstructures, including metallic and ceramic phases sized, shaped, and functionally graded to obtain changing properties for applications that involve severe thermal gradients.

The mathematical model is subdivided into repeating unit cells, each consisting of eight subcells. Each subcell is designated by the triplet $(\alpha\beta\gamma)$, which indicates the relative position of the given subcell along the three axes. The dimensions of the subcells are h_1 and h_2 along the x_2 axis and l_1 and l_2 along the x_3 axis; these dimensions are fixed in the given configuration, whereas the interlayer distance $d_2^{(p)}$ can vary with p, where p is an index number that indicates the relative position of a unit cell along the x_1 axis.

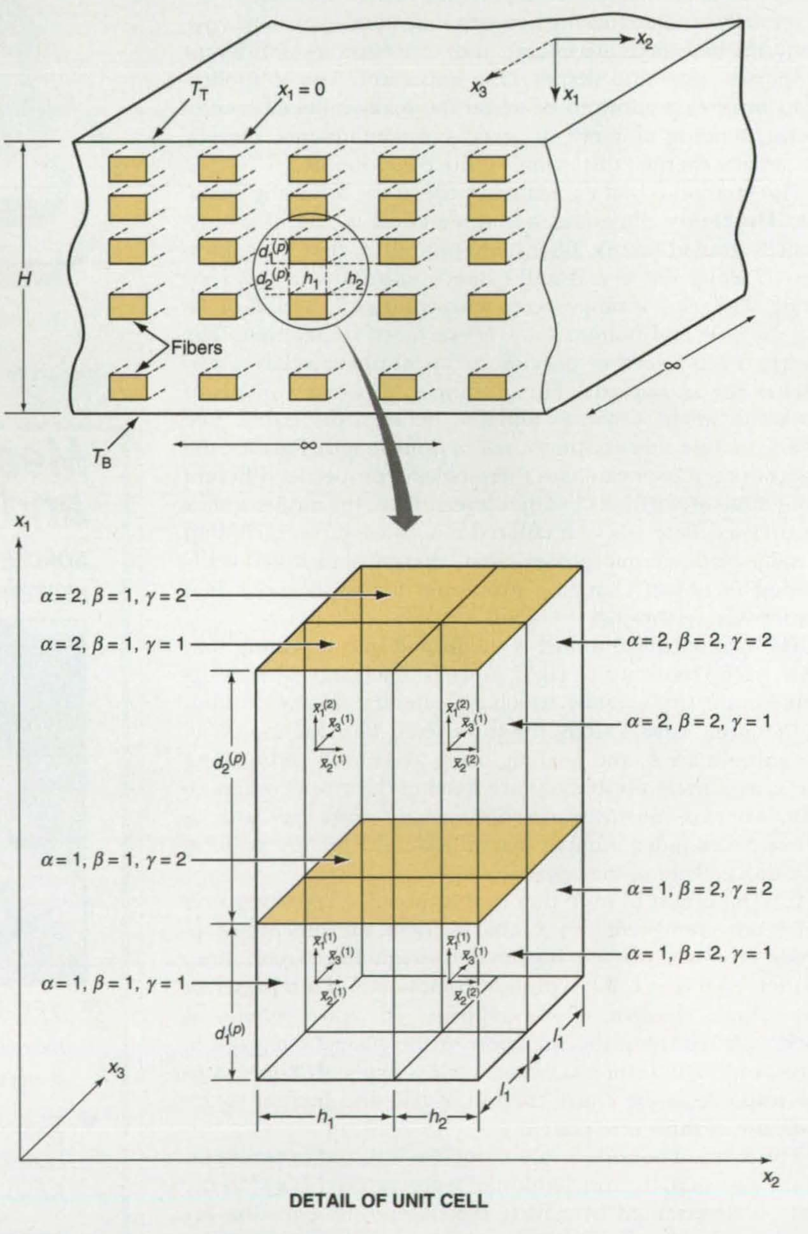
It is important to note that in this model, a repeating unit cell is not a representative volume element, the effective properties of which can be obtained through homogenization. Rather, each unit cell is a distinct component of a representative volume element, which comprises an entire column of such cells spanning the thickness of the plate (along the x_1 direction). The response of each cell is explicitly coupled to the response of the entire column of cells and thereby to the response of the entire plate.

The thermal boundary-value problem is solved in two steps. In the first step, the distribution of temperature $[T(x_1)]$ in the plate is determined by solving the differential equation for conduction of heat in a steady state in each cell. Because of the periodicity in, and infinite extent of, the x_2–x_3 plane, it suffices to determine the distribution of temperatures in a single column of cells. Given $T(x_1)$, and the resulting thermal components of strain, the stresses and strains in the cells and subcells are computed by solving the equilibrium differential equations for stresses and strains, subject to the applicable continuity and boundary conditions.

The method has been applied in the analysis of several versions of a conceptual composite plate made of nonuniformly spaced silicon carbide fibers embedded in a titanium aluminide matrix. The numerical results indicate that it is possible to alter the distribution of temperature, in a way that yields a more favorable distribution of stress, by grading of the microstructure of the composite. In designing the graded microstructure, one must take account of the sign of the gradient of temperature.

This work was done by Steven M. Arnold of **Lewis Research Center** *and Jacob Aboudi and Marek-Jerzy Pindera of the University of Virginia. No further documentation is available.*

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 Rd., Cleveland, OH 44135. Refer to LEW-16007.



A **Cellular Mathematical Model** is used to compute distributions of temperature and the resulting stresses and strains in a composite material that is functionally graded along the x_1 axis and is subjected to a gradient of temperature along that axis.

NEW PRODUCTS

Chip Filters for EMI Noise Suppression

AVX/Kyocera, Myrtle Beach, SC, introduces the KNF series of ceramic chip components that combine capacitor and inductor elements in a single distributed constant circuit filter for EMI noise suppression. The company says the filters are ideal for noise suppression for I/O and clock output lines in high-speed computer circuits. Specified by cutoff frequencies (25, 50, 100, and 200 MHz), each filter has typical attenuation of 20 dB over frequencies from 200-1100 MHz. The KNF series is rated at 25 V and 200 mA with capacitance ranges from 33-235 pF. Typical prices are from $0.20-0.25 in quantities of 100,000.

For More Information Write In No. 800

Precise Photoresist Measuring Tool

The Accudose 9000™ family of tools is called by Oriel, Stratford, CT, the most precise photoresist photospeed testing instrument in the world. The company says the exposure system offers significant advantages over an optical stepper, including superior dose resolution, a modest price, and a small footprint. Oriel says its precision makes it ideal for measuring photoresist batch-to-batch variability.

For More Information Write In No. 801

LED Lamps for High-Traffic Places

A new series of LED-based lamps from Ledtronics, Torrance, CA, is designed for high-traffic, high-vibration locations such as exit signs above automatic doors, in parking structures, schools, or theaters. Designated the EXL-R (for red) or EXL-G (green) series, the lamps fully comply with UL-924 standards. They are socket and circuit compatible with most standard exit signs. The LED row consumes less than 1 W per lamp. At 100-set (2 lamps) quantities, price for 120-V red is $18.50 and for 120-V green $37.00.

For More Information Write In No. 802

Biaxial Industrial Inclinometers

The SI-702B series biaxial electronic tilt sensors from Columbia Research Laboratories, Woodlyn, PA, use force balance accelerometer technology to produce a high-level, low impedance output proportional to the sine of the tilt angle. Electronic damping and desensitization circuitry allows measurements along two perpendicular axes in strong vibration and shock environments. The SI-702HP uses the company's HP suspension system for added accuracy and ruggedness. Applications include platform stabilization, surface mapping, and measuring tilt angles in remote locations.

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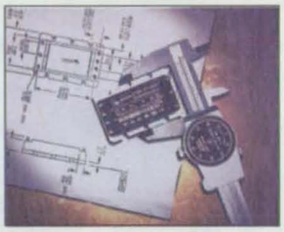

150-W Micro DC-DC Converter

The micro-size 150-W DC-DC converter module from Vicor Corp., Andover, MA, measures just 2.28 X 1.45 X 0.5 in., one third the size of the company's full-size package. It accepts a nominal input voltage of 48 VDC and provides a 12-V output with 86 percent efficiency, according to the company. Input range is 36-75 V, output is programmable from 1.25-13.2 V, and power density is 90 W per cubic inch. Single-piece price is $112.

For More Information Write In No. 804

6000-V Pulse Generator

Directed Energy Inc., Fort Collins, CO, says its new GRX-6.0K-H pulse generator produces clean, high-voltage pulses with amplitudes to 6000 V, with rise and fall times less than 65 ns. Optimized for driving capacitive loads, it is designed to pulse extraction grids and deflection plates in time-of-flight mass spectrometers and particle accelerators. The company says the device is well suited for driving Pockels cells and acoustic transducers, and for component testing. Pulse widths are less than 150 ns to DC and pulse recurrence frequencies from single-shot to greater than 10 kHz.

For More Information Write In No. 805

Surface-Mount Power Resistors

The MRC-1 series of high-power-density surface-mount resistors from IRC, Boone, NC, have resistance values as low as 0.05 ohm with a full 1-W rating at 70 °C. The company says the cylindrical resistors have a larger surface area for cooler operation than flat chips of the same 2010 footprint, and a higher surge-handling capability. The MRC-1 is available in values of 50-99 milliohms at ±2 percent tolerance. Maximum operating voltage is rated at 700 V and maximum operating temperature at 150 °C. Typical pricing is $0.25 for the 0.05-ohm in production quantities.

For More Information Write In No. 806

Ball Grid Array Inspection Package

Cognex Corp., Natick, MA, has introduced the BGA Inspection Package, a PCI-bus plug-in vision processor and application-specific machine-vision software package for the inspection of ball grid arrays (BGAs). Manufacturers of BGA assembly and test equipment can incorporate the package in machines to inspect BGA devices, an alternative to pin grid arrays and leaded devices for attaching IC chips to printed circuit boards, for defective solder balls at up to 4000 balls per second. With Windows™-based software, processor, on-line documentation, and two calibration plates, the package sells for $9,500-$12,500 depending upon quantity.

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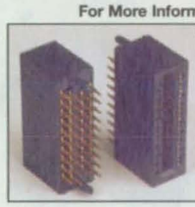

High-Speed Cardedge Connector

Thomas & Betts, Memphis, TN, says that its new one-piece fine pitch (0.050-in. centerline) cardedge connectors give designers an economical means of transmitting high-speed signals between daughtercards and backplanes with low signal distortion. The connector can simultaneously switch signals with 500-ps rise times, limiting near-end cross talk to 5 percent maximum (3 percent at 1.0 ns) and with 50-ohm impedance. The connectors are available with 30 to 150 dual rows of contacts in both surface-mount and through-hole configurations, with standard tail lengths of 0.100, 0.125, 0.155, and 0.190 in.

For More Information Write In No. 808

Narrow-Profile IC Test Clips

A new family of SOIC/SOJ test clips from ITT Pomona Electronics, Pomona, CA, is designed to simplify test access to 32-, 40-, and 44-pin devices. The company says the narrow body profile enables the clips to be placed on chips that are densely packed, end-to-end or side-to-side. Upper contacts are double rows of 0.025-in. square pins placed at 0.100-in. centers, allowing access with standard ribbon cable connectors of single-point clips such as Pomona's Grabber.® The one-piece gold-plated beryllium copper pins assure positive contact between the clip and the leads of the device under test.

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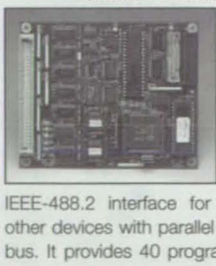

Digital Interface Board

The Model 4803 GPIB-controlled digital interface board offered by ICS Electronics, Milpitas, CA, is designed as a IEEE-488.2 interface for adapting instruments or other devices with parallel digital signals to the GPIB bus. It provides 40 programmable I/O lines that are user-configurable as inputs or outputs in 8 line groups. The lines use BCT-type drivers with high sink/source capability to drive digital signals, LEDs, relays, or other loads up to 48 mA. The 4803 is packaged on a 4.5-X-5.5-in. board that can be mounted almost anywhere in the host chassis and requires only 400 mA of +5 V DC.

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Encapsulants for Extreme Temperatures

Grace Specialty Polymers, Lexington, MA, introduces STYCAST® encapsulants for a broad range of applications with temperatures ranging from -65 to 230 °C. The company says the encapsulants have excellent chemical resistance, thermal shock, and electrical insulation characteristics, and adhere well to metals, plastics, ceramics, and glass. Typical dielectric strength and volume resistivity are >400 V/mil and 10^{14} ohm-cm respectively. Epoxy- or silicone-based, the materials come in one- or two-component systems.

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WORKBENCH DATA ACQUISITION SOFTWARE FOR WINDOWS OFFERS SUPERB GRAPHICS

WorkBench for Windows is a measuring process control and analyzing software package which takes full advantage of the features and graphical interface provided by Microsoft Windows. With WorkBench for Windows, a measuring process and control or simulation task can be set up directly on screen, freely and in any configuration of the integrated functional components, by selecting and connecting modular elements.

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EASY-TO-USE 180MM PANEL-MOUNTED CHART RECORDERS

Omega announces the RD1800 Series flexible, powerful, easy-to-use 180mm panel-mounted chart recorders. Models are available with 1-, 2-, 3-, or 4-pen continuous trace or 6-, 12-, 18-, or 24-channel dot printing. Universal inputs are completely scalable and can be programmed for thermocouples, RTDs, or voltages up to 20 VDC. A large, bright display, bar graph display, and printout of chart settings allow for quick interpretation of data.

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Omega introduces the new SPR101 Series non-contact speed sensor. The unit is ideal for RPM and speed measurement applications and is capable of sensing from absolute zero to 20 KHz. The SPR101 utilizes two hall effect sensors and will sense any ferrous metal object at a maximum distance of 0.5mm. PNP or NPN models are available and provide a square wave output with an amplitude equal to the applied voltage.

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The Model OMA-AVDS-4 serves as a reliable watchdog over site conditions when you can't be there. Featuring non-volatile speech recording, the OMA-AVDS-4 lets you record emergency and identification messages using your own voice. The unit can monitor the bell output of your alarm panel or dry contact and when an alarm condition occurs, automatically call up to eight phone numbers and deliver your emergency voice message.

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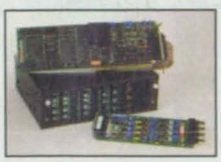

DATA ACQUISITION BOARDS FOR DESKTOP PCS

Omega is proud to introduce the new DAQBOARD Series of PC/AT-compatible data acquisition and control boards. The DAQBOARD Series offers more signal conditioning choices than any comparable product, while also offering high-speed performance and a low cost. The unit features A/Ds, D/As, digital I/O, and counter/timers. A wide range of input types are available from thermocouples to strain gages. The unit may be expanded from 16 to 256 input channels.

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DIN RAIL-MOUNTABLE SIGNAL CONDITIONERS

Omega is proud to introduce the CCT Series, an economical line of DIN rail-mountable signal conditioners. Available input types include RTD, thermocouple, strain, frequency, voltage, and current. The CCT easily conditions a wide range of signals into standardized formats. Signal conditioners feature isolation up to 2KVeff, both 20 mA and 10 VDC outputs. Units are powered by 120 VAC and mount on standard 35mm DIN rail.

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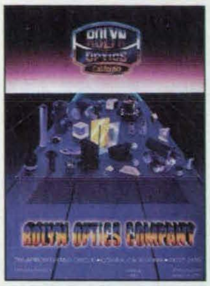

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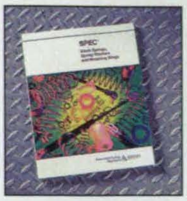

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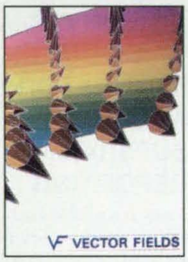

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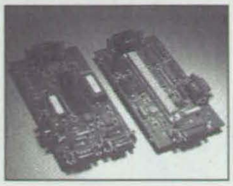

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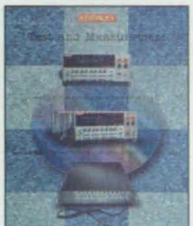

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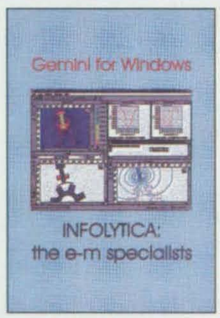

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Computer Programs

Interface Software for AIRSAR Imagery

The SearchAIRSAR computer program enables users of the World Wide Web to interactively search for, display, and order survey and frame images produced by the airborne synthetic-aperture radar (AIRSAR) group at NASA's Jet Propulsion Laboratory. A user can search for images of a site via a number of fields, including the name of the site, latitude and longitude, and/or the date of the AIRSAR scan. The results of a search are returned immediately, and the user can view the survey and frame images found in the search. The user can order an image that was found by filling out a Hypertext Markup Language (HTML) form. Confirmation of the order is sent by electronic mail. Written entirely in Applescript, SearchAIRSAR acts as a common gateway interface between WebSTAR 1.2.4 (a Macintosh Web-server program) and FileMaker Pro 2.1v3 (a relational-database program); both of these programs are commercially available. SearchAIRSAR has been implemented on a Power Macintosh 9500 computer with 80 MB of random-access memory and 4 GB of hard-disk memory, running Mac OS 7.5. SearchAIRSAR can be seen working at http://www-airsar.jpl.nasa.gov under the "Search Image Database" link.

This program was written by Alvin Wong of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 72*** *on the TSP Request Card.*
NPO-19930

NASA/MSFC Global Reference Atmospheric Model — 1995 Version

The NASA/Marshall Space Flight Center Global Reference Atmospheric Model (GRAM) was developed in response to the need for data on a design reference atmosphere that provides complete global geographical variability and complete altitude coverage (surface to orbital altitudes) as well as complete seasonal and monthly variability of the thermodynamic variables and wind components. A unique feature of the GRAM-95 computer program is that, in addition to providing data on the geographical, height, and monthly variation of the mean atmospheric state, it provides the ability to simulate spatial and temporal perturbations in these atmospheric parameters (e.g., fluctuations due to turbulence and other atmospheric perturbation phenomena).

Like earlier versions of GRAM, GRAM-95 provides complete geographical and altitude coverage for each month of the year. Individual years 1985 to 1991 and a period of record (1980 to 1991) can be simulated for the Global Upper Air Climatic Atlas (GUACA) height range (0 to 27 km). GRAM-95 uses a specifically developed set of data, based on Middle Atmosphere Program (MAP) data, for the height range from 20 to 120 km, and the NASA Marshall Engineering Thermosphere (MET) model for heights above 90 km. Fairing techniques assure a smooth transition in the overlap height ranges (20 to 27 km and 90 to 120 km).

In addition to the traditional GRAM variables of pressure, density, temperature, and wind components, GRAM-95 now includes water vapor and 11 other atmospheric constituents. A new, variable-scale perturbation model provides both large-scale and small-scale deviations from mean values for the thermodynamic variables and horizontal and vertical wind components. The perturbation model includes new features that simulate intermittency ("patchiness") in turbulence and small-scale perturbation fields. The density perturbations and density gradients (density shears) computed by the new model compare favorably in their statistical characteristics with observed density perturbations and density shears from 32 space shuttle reentry profiles. GRAM-95 provides considerable improvement in wind estimates from the new GUACA data set, compared to winds calculated from the geostrophic wind relations previously used in the height range from 0 to 25 km.

GRAM-95 is written in FORTRAN 77 to be machine-independent. A FORTRAN 77 compiler is required to build the executable code. GRAM-95 requires the use of an attached compact disk/read-only memory (CD-ROM) drive and the GUACA data base on CD-ROM for the 0-to-27-km atmospheric level. A copy of GUACA can be purchased via the Climate Services Division at the National Climatic Data Center [Room 468; 151 Patton Avenue; Asheville, NC 28801-5001; phone (704) 271-4800; fax (704) 271-4876]. GRAM-95 also requires approximately 20MB of disk space to prepare the code for execution and activate the resulting executable code. GRAM-95 has been successfully implemented on an SGI Indigo2 computer running IRIX 5.2, a Sun4-series computer running SunOS 4.1.3, and a Sun4-series computer running Solaris 2.3. GRAM-95 has been successfully compiled on a DEC ALPHA AXP computer 4000 running OSF/1, a DEC MicroVAX 3600 computer running VMS 5.5, and an IBM PC-compatible computer running MS-DOS 5.0. Sample input and output are included on the distribution medium. The standard distribution medium for GRAM-95 is a 0.25-in. streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. Alternate distribution media and formats are available on request. The original GRAM code was developed in 1976, GRAM-90 was released in 1991, and GRAM-95 was released in 1995.

This program was written by Dale L. Johnson of **Marshall Space Flight Center** *and C. G. Justus, W. R. Jeffries III, and S. P. Yung of Computer Sciences Corp. For further information,* ***write in 1*** *on the TSP Request Card.*
MFS-31105

Implementing Thermal Models via Spreadsheet Software

Mathematical models implemented in commercial spreadsheet software simulate the transient and steady-state thermal conditions that occur during the use of cryogenic liquids to cool scientific instruments housed in large Dewar flasks. These are nonlinear, self-consistent models based on the customary practice of modeling the thermal properties and behavior of an apparatus by analogy to an electrical network, wherein (a) electrical potentials represent temperatures, (b) electrical resistances represent temperature-dependent radiative and conductive thermal resistances, and (c) elec-

trical capacitances represent heat capacities (thermal masses). A simulation is conducted by running the software with the applicable model iteratively until the desired number of steps in simulated time (in a transient case) or convergence of subsequent iterations to within acceptably close values (in a steady-state case) is achieved. The matrix-inverting capability of the spreadsheet software is used to solve the network equations at each iteration. These thermal models in spreadsheet software can accommodate adjustment of model parameters, but unlike many of the large, commercial thermal-model programs, can be run on desktop computers. The spreadsheet implementation also costs less. Thus far, the models have been implemented in Excel spreadsheet software on a Macintosh Duo computer with 12MB of random-access memory, a 120MB hard disk, and a color monitor.

This work was done by Alfred E. Nash III of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 12*** *on the TSP Request Card.*
NPO-19760

Software for Estimating Costs of Developing Other Software

The COSTMODELER computer program provides a software framework for estimating the costs of developing and maintaining other computer programs. Mathematical models for use in estimating costs are defined to the program via data files instead of being directly implemented in the program. Several models are provided with the program. These models can be used in the forms in which they are provided or customized to better represent a particular software-development environment and the characteristics of particular software products. No programming is required to implement new theoretical models for testing and verification.

The size of the proposed software product can be described either in terms of the number of lines of code or function points. The number of lines of code can be estimated directly or specified as a range of probability. The function-point model is sufficiently generalized that it can be adapted to accommodate a feature-point model.

Any number of "cost drivers" may be defined. Cost drivers are those characteristics of a software-development team or software product that may affect the costs of development. A probabilistic range for the effects of these cost drivers can also be defined. The use of cost drivers facilitates "what-if" analysis to evaluate the predicted effects of a variety of management decisions.

A project can be decomposed to any level of detail in an inverted tree structure. Different cost drivers can be applied at any node in the tree structure. All attributes are fully inherited from one level of the tree to the next to minimize input requirements. Notes can be attached to any node to provide documentation for complex project decompositions. The tree structure can be fully edited at any time, with moving, copying, addition, or deletion of branches.

The project-development life cycle is completely user-definable. Life-cycle phases can be redefined and new phases can be added. Projects can be developed as sets of incremental deliveries. Graphical displays clearly show the relationships between life-cycle phases and increments and the cumulative total number of workers required. Each of the increments can utilize separate life-cycle phase definitions. Both schedule and personnel constraints can be

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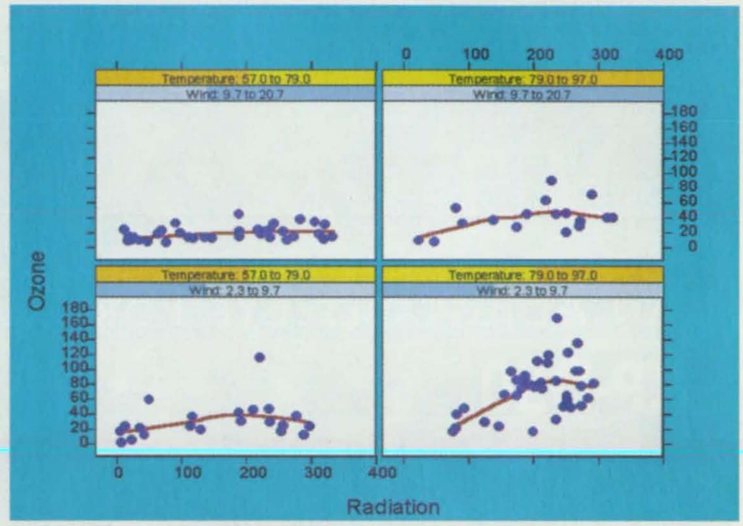

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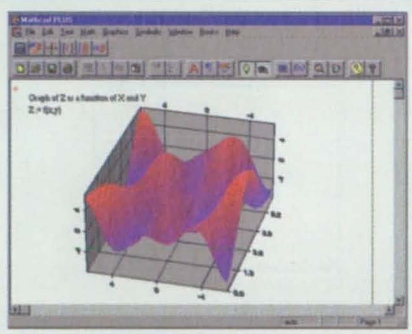

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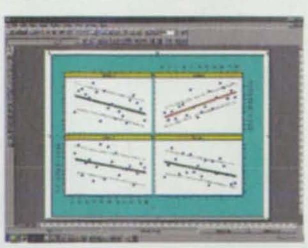

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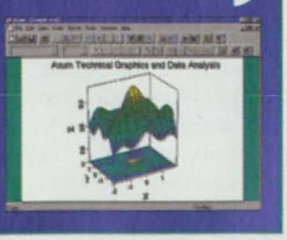

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applied. Comparative plots visually display the cost penalties resulting from a constraint of either type.

The members of the development team can be grouped into any number of classifications. These classifications can be assigned hourly compensation rates, and the percentage of the total effort to be performed by each classification for each development phase can be defined. These personnel classifications and life-cycle relationships can be related to the organization's personnel-cost-accounting systems so that actual expenditures can be compared to the estimates at any point during the development process. This comparative analysis capability is built into COSTMODELER, with a complete set of reports to assist in the identification of problems in real time.

A variety of output reports are provided. Each report can be configured by the user to include as much or as little detail as required. Several output graph formats are included.

COSTMODELER is written for IBM PC-compatible computers with a minimum of an 80386 processor. An executable code is provided on the distribution diskettes. COSTMODELER was developed in Pascal using Borland Pascal with Objects version 7.0. 2MB of random-access memory are required for execution. The standard distribution medium for COSTMODELER is a set of two 3.5-in. (8.89-cm), 1.44MB, MS-DOS-format diskettes. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. An electronic copy of the documentation in MS-Word for Windows 6.0 format is included on the distribution medium. COSTMODELER was released to COSMIC in 1995.

This program was written by George B. Roush of **Johnson Space Center.** *For further information, write in 40 on the TSP Request Card.*
MSC-22543

Software for Central Purchasing in a Large Organization

The Just-in-Time Material Acquisition System software implements most of the routine functions of a central purchasing system at NASA's Jet Propulsion Laboratory. This software automates the heretofore labor-intensive processes involved in selection, procurement, receiving, internal delivery, internal accounting, and payment involved in the acquisition of small items. The system is based on client-server architecture, with the system data base running on a Unix-based Sun SPARCServer computer and users accessing the system via graphical-interface software running on their personal computers. Authorized users order items from online catalogs of vendors with prearranged contracts, maintained by the procurement office. The system verifies a user's identity and purchasing authority, and electronically transmits the user's order to the vendor. Vendors package items and ship them with bar-coded labels, which are scanned into the system at the receiving dock, initiating the process of payment. The label on each package is further scanned at subsequent stages of internal delivery until final delivery to the addressee, thereby creating an auditable data trail corresponding to delivery events. To assist management oversight, the system generates reports, which it sends to system operators, managers, and users by electronic mail.

This work was done by David Werntz, Audrey Ridley, Steven Loyola, and Nilesh Patel of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, write in 10 on the TSP Request Card.*
NPO-19746

Cassini Management Information System

The Cassini Management Information System (CMIS) is a user-friendly, inexpensive, schedule-control program for IBM PC and Macintosh computers distributed across a local-area network. CMIS was developed to help keep the Cassini Project (a spacecraft mission to Saturn) within a fixed budget while preventing schedule slips. CMIS implements a distributed-planning method, which differs from the centralized planning methods of typical large projects; it thereby eliminates the need for a central planning staff and gives managers direct control of their plans. All Cassini Project management levels — assembly, subsystem, system, and project — use CMIS to identify, monitor, and control the schedule and flow of products between elements of the project organization. ("Products" as used here includes designs, components, parts, assemblies, and tests.) All managers identify their input and output products. Each product is defined in terms of its name, a customer's identification number, a supplier's identification number, a customer's required delivery date, and the supplier's available delivery date. Comparison of the CMIS data across the project yields planning and performance metrics that help managers at all levels to resolve schedule issues and identify problems and discrepancies (e.g., a product for which delivery dates conflict, the supplier is missing, or there is no customer.) CMIS has yielded useful results and gained acceptance on the Cassini project and is expected to be applied to other NASA projects. CMIS can also be used in private industry to control costs and maintain schedules in projects that involve flows of products among the elements of organizations.

This work was done by Michael Hughes, Glen Gira, and Reed Wilcox of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, write in 6 on the TSP Request Card.*

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Refer to NPO-19618, volume and number of this NASA Tech Briefs *issue, and the page number.*

Mechanics

Improved Adaptive-Grid Computation of Hypersonic Flow

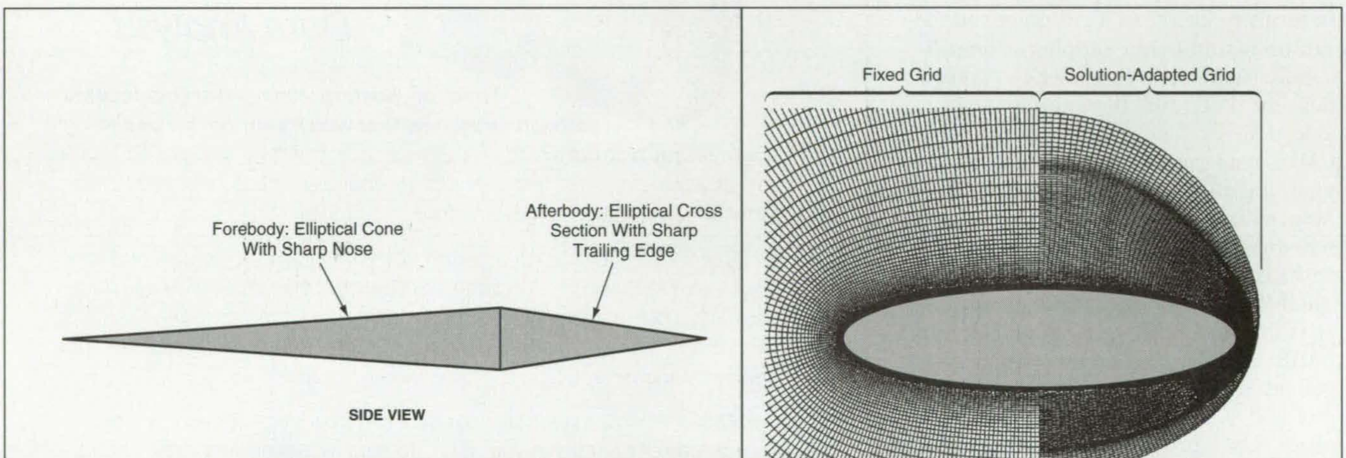
The position of the outer gridline is maintained beyond the outer shock.

Ames Research Center, Moffett Field, California

Improvements have been made in a method of iterative adjustment of the three-dimensional grids that are used to solve numerically the parabolized Navier-Stokes equations of flow. The method was developed especially to compute hypersonic flows about bodies that have complicated shapes. Methods of this type, called solution-adaptive grid methods, involve the refinement (or coarsening) of computational grids in regions of high (or low, respectively) gradients in computed flows. The purpose of such refinement or coarsening is to satisfy the competing requirements to (1) capture such features as shock waves, the accurate resolution of which typically requires fine meshes, and (2) prevent unnecessary refinement of the mesh elsewhere, thereby preventing undue increases in amounts of computation.

Previous versions of this solution adaptive-grid method were described in "Adaptive Grids for 3-D Parabolized Navier-Stokes Computations" (ARC-13073), *NASA Tech Briefs*, Vol.16, No.11 (November 1992), page 95, and "Adaptive Grids for Computations of Three-Dimensional Flows" (ARC-12479), *NASA Tech Briefs*, Vol. 15, No. 8 (August 1991), page 66. A special feature of this method is a grid-fitting algorithm that aligns the outer boundary of the grid with the flow field computed on the preceding iteration, in such a way that the resulting outer gridline lies just beyond the computed outer shock: by so doing, the algorithm minimizes that part of the

continued on page 78



Mach-Number Contours *in a mach-7.4 flow about the body illustrated at the left, at an angle of incidence of 5°, were computed by use of fixed and solution-adapted grids.*

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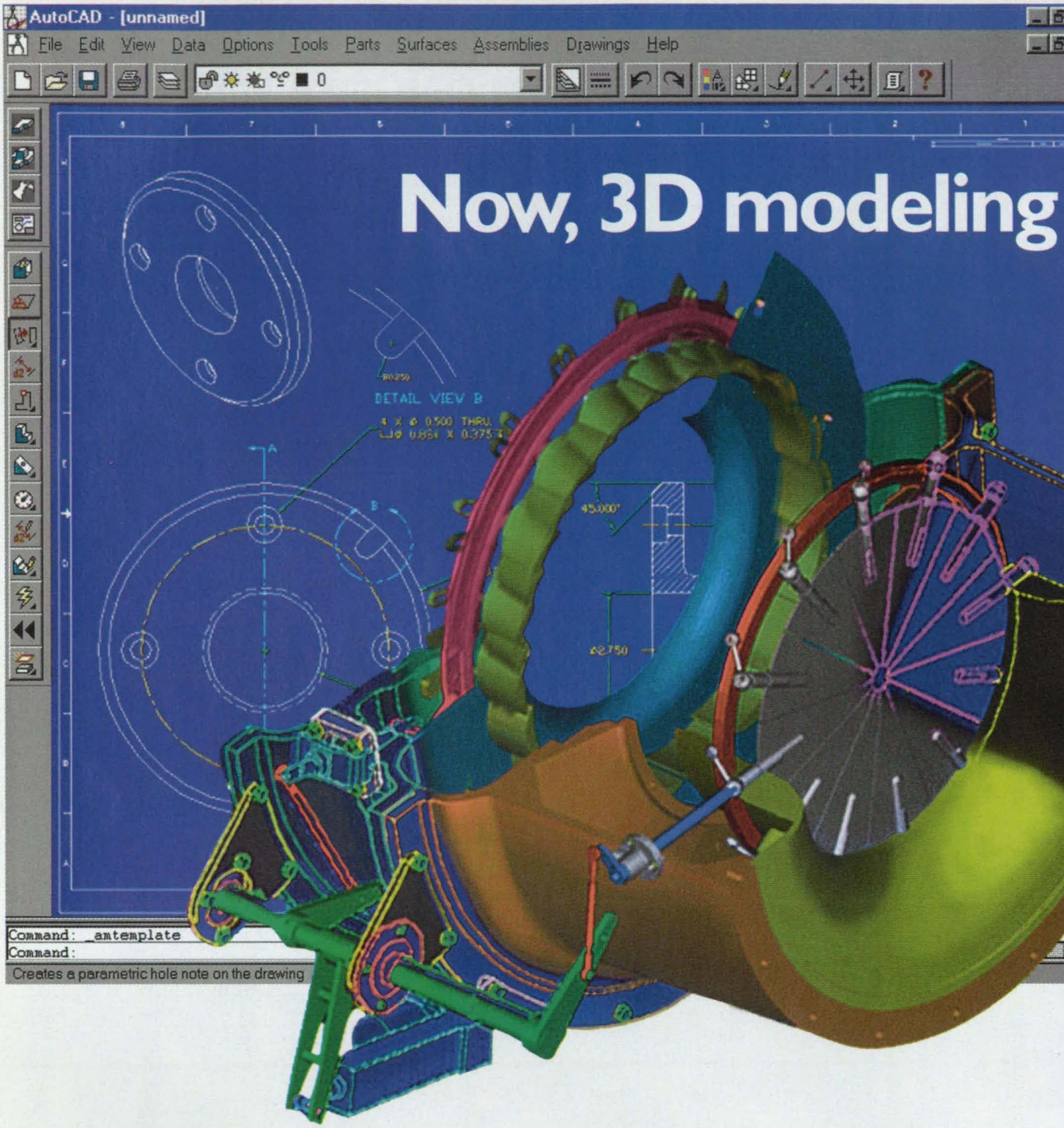

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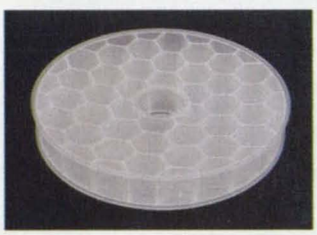
continued from page 74

computational domain that lies outside the region of interest and maximizes the density of the grid within the region of interest.

As explained in more detail in the noted previous articles in *NASA Tech Briefs*, the grid points are considered to be connected by fictitious tension and torsion springs; the configuration of the grid is essentially the equilibrium configuration of the interacting springs, and the spring stiffnesses used to compute the equilibrium configuration depend partly on gradients of selected dependent flow variables and/or on curvatures of streamlines and flow surfaces. The solution is marched spatially downstream. At each marching station, the position of the outer gridline is adjusted to be just beyond the outer shock. Also at each marching station, the grid points are redistributed line-by-line in both crossflow directions according to the updated tension and torsion quantities in the fictitious springs, the tensional forces being proportional to error measures or weighting functions. Weighting functions are selected by first normalizing gradients of dependent flow variables and/or curvatures of a number of dependent variables, then selecting the largest of these quantities at each point.

This solution-adaptive-grid method was tested by applying it to hypersonic flows about two bodies with simplified shapes that represent parts of generic hypersonic airplanes. Similar computations were performed on fixed grids. In both cases, the solution adaptive-grid method yielded better resolution of flow-field structures. In the case of one of the bodies (see figure), pitot-tube pressures computed by the solution-adaptive-grid method were found to agree with experimental values more closely than did those computed on a fixed grid.

This work was done by Scott Lawrence of **Ames Research Center** *and Albert Harvey III and Sumanta Acharya of Louisiana State University. For further information,* ***write in*** *83 on the TSP Request Card. ARC-13182*



Foam-Reinforced Inflatable Spacecraft

NASA's Jet Propulsion Laboratory, Pasadena, California

Use of open-celled polymer foams is proposed to strengthen and stiffen inflatable spacecraft structures. The inner surface of the membrane of an inflatable structure would be coated with open-celled polymer foam, which would effectively thicken the membrane without contributing much additional weight to the overall structure. Because the foam would expand upon deployment from compact stowage and thereby contribute to inflation of the structure, less gas would be needed to inflate the structure with foam reinforcement than would be needed to inflate the same structure without foam reinforcement. After initial inflation, the structure would be cooled to below the glass-transition temperature of the polymer, so that the foam lining would become rigid. Thus, the membrane and foam lining would become a stiffer, stronger structural component. The foam would also impart improved thermal properties and greater dimensional stability to the structure. Tests of open-celled foam and of an experimental inflatable structural unit lined with foam confirm the viability of the concept.

This work was done by Paul B. Willis of Caltech for **NASA's Jet Propulsion Laboratory**. *No further documentation is available. NPO-19913*

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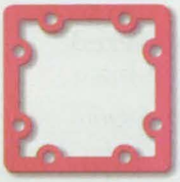

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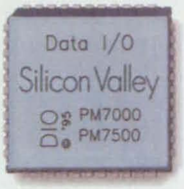

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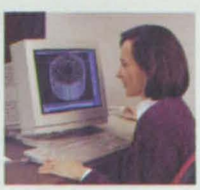

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Portable Tripod Rig for Erecting Dish Antennas on Posts

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Lewis Research Center, Cleveland, Ohio

A portable tripod rig facilitates the erection of dish antenna assemblies (reflector-support structures and reflector dishes) on posts in locations in which cranes are not available. The rig provides secure means for lifting a reflector-support structure onto the top of a post, then lifting the reflector over the support structure and adjusting its position relative to the support structure so that support bolts can be inserted easily. In the original application for which the rig was designed, the posts are about 2 m high, the antennas are designed for operation at frequencies from 20 to 30 GHz, the reflector dishes are 2.4 m in diameter, and the antenna assemblies weigh 396 lb (180 kg) apiece. The design of the rig can be readily modified to suit the weights and dimensions of other dish antenna assemblies.

The main structural members of the rig are standard 2 × 4 in. (5 × 10 cm) and 4 × 4 in. (10 × 10 cm) [actual dimensions somewhat smaller] wooden beams with steel-tubing couplings at their ends and other attachment points. The structural members are joined at attachment points by use of pins with cotter keys. The lifting mechanism of the rig includes a winch, a cable, pulleys, and a lifting-hook assembly that includes a split-sheath pulley.

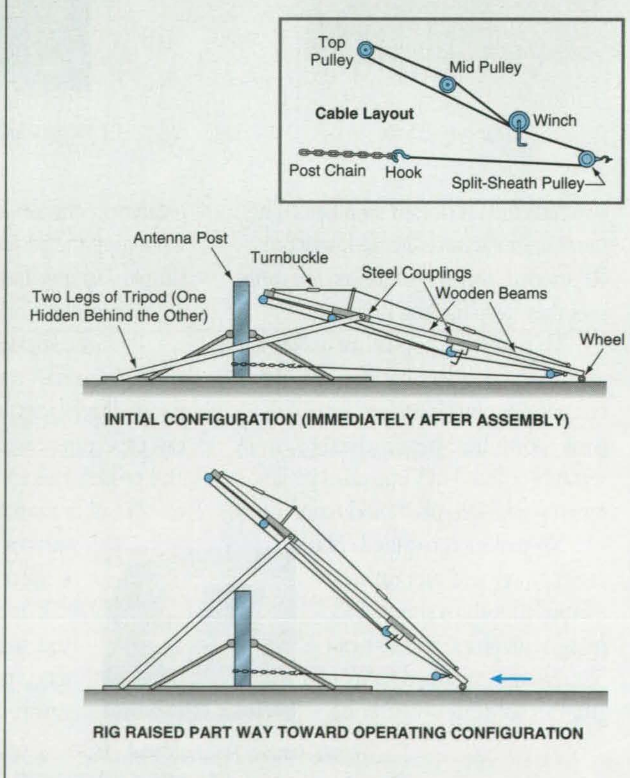

*Figure 1. The **Rig Is Used To Raise Itself** into the working configuration.*

Motion Control Tech Briefs

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Motion CONTROL Tech Briefs

Motion Control Tech Briefs Supplement to *NASA Tech Briefs* March 1997 Issue Published by Associated Business Publications

MOTION CONTROL TECH BRIEFS

DEPARTMENTS

On the cover:

The DeltaPro™ motion controllers from Industrial Indexing Systems of Victor, NY, integrate everything required for a motion system, including a positioner, amplifier, motor, operator interface, power supply, and cables. The systems were specifically designed for basic motion control applications where complex programming is not required.

Photo courtesy of Industrial Indexing Systems

Torque-Limiting Driver Based on Displaceable Bevel Gear

The use of multiple intermediate gears would contribute to reliability and long life.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed improved torque-limiting driver would act similarly to a number of other devices in that it would limit an applied torque to a preset value. Thus, a combination of this driver with an ordinary wrench would act as a conventional torque wrench. As in another proposed torque-limiting driver of the same type, the torque would be limited in this driver by the slippage of gears that would be spring-loaded against each other. Both proposed drivers are related to the driver described in "Tool for Driving Many Fasteners Simultaneously" (MSC-22386), *NASA Tech Briefs*, Vol. 19, No. 7 (July, 1995), page 24.

The other proposed driver of the same type (see Figure 1) would contain a single driving gear and a single driven gear, so that during a significant fraction of the time, a single tooth on each gear would bear the entire torque load. In the improved driver, the transmission of torque and the slippage would occur at multiple simultaneously meshing gears, so that no single gear tooth would have to bear the entire load. The reduction of the loads on individual gear teeth would reduce wear and reduce the probability of breakage of gear teeth, thus increasing the reliability and prolonging the useful life of the driver.

In the other driver, the input and output torque-drive axes would be offset from each other. As a consequence, the inadvertent application of an axial force during use would result in the application of a spurious and possibly damaging bending moment to the driven nut, bolt, or shaft. The improved driver would have an in-line drive configuration, which would eliminate this spurious bending moment.

In the improved torque-limiting driver, the spring loading and slippage of gears would occur in the axial direction, and all loads would be distributed symmetrically about the single drive axis (see Figure 2). The input torque would be applied by a wrench to the upper torque coupling, then transmitted through the torque-input shaft to the axially displaceable bevel gear, which would be axially spring-loaded against several intermediate bevel gears. Provided that the applied torque was less than the preset limiting torque, the intermediate bevel gears would transmit the torque to the output bevel gear.

Because of the inclinations of the gear teeth, the driving forces between engaged teeth would include circumferential, radial, and axial components. The circumferential force would produce the output torque, but in other situations, the radial and axial forces are often considered wasteful byproducts. In this case, however, the axial force would be used to control the output torque. When the transmitted torque reached the preset limit, the axial force at the engaged teeth of the displaceable bevel gear and the intermediate bevel gears would equal the axial load applied by the torque-control spring. An attempt to apply a greater torque would cause the axially displace-

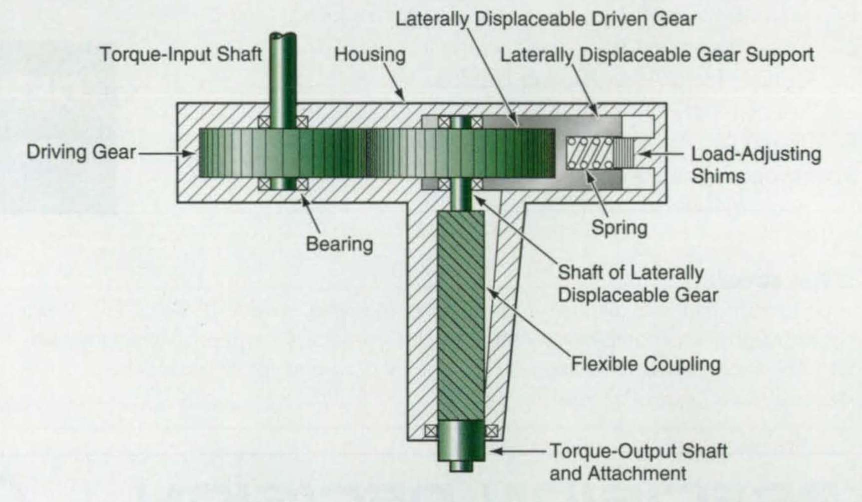


*Figure 1. This **Torque-Limiting Driver**, a predecessor to the present improved driver, would have a displaced-axis configuration that could give rise to a spurious bending moment.*

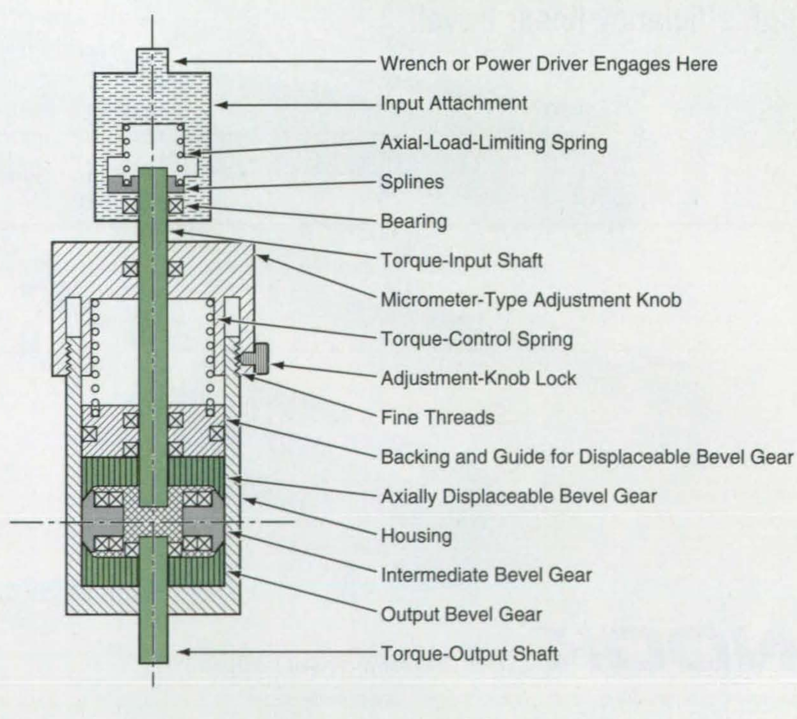


*Figure 2. The **Improved Torque-Limiting Driver** would have an inline drive configuration.*

able bevel gear to move away from the intermediate bevel gears. Continued turning in an attempt to apply a greater torque would cause the gears to disengage, slip, and re-engage repeatedly.

The axial force that pushed the gears apart against the torque-control-spring load would be proportional to the applied torque. The factor of proportionality would be a function of the geometrical relationships between the axially displaceable gear and the intermediate bevel gears. The torque-control spring and its adjustment would be designed according to this factor of proportionality. The spring preload load and thus the preset limiting torque would be adjusted by turning a micrometer-type adjustment knob to one in a set of calibrated torque-setting marks on the side of the housing.

The input attachment would contain a spring-loaded, splined coupling between itself and the torque-input shaft. The axial-load-limiting spring would be used to limit the amount by which the output torque could increase when the technician applied an axial load to the input attachment. When the applied axial load exceeded the preload on this spring, the spring would become compressed and the splines would disengage, so that no input torque would be transmitted.

This work was done by Joseph S. Cook, Jr., of **Johnson Space Center**. *For further information,* ***write in 44*** *on the TSP Request Card.*

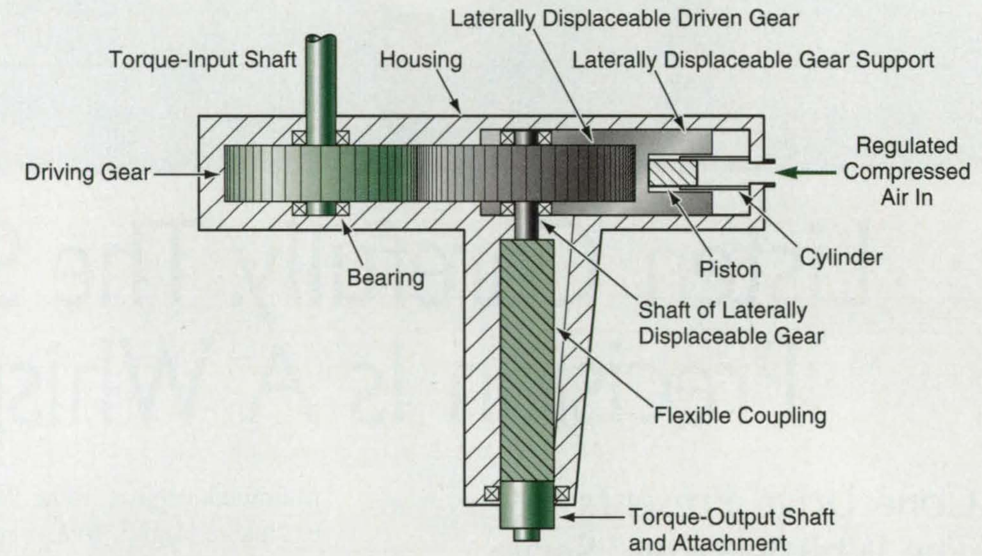
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22384.

Pneumatically Loaded Torque-Limiting Driver

The limiting torque would be a function of air pressure.

Lyndon B. Johnson Space Center, Houston, Texas

The figure illustrates a proposed pneumatically loaded torque-limiting driver related to the mechanism described in "Tool for Driving Many Fasteners Simultaneously" (MSC-22386), *NASA Tech Briefs*, Vol. 19, No. 7 (July, 1995), page 24. It is also related to the mechanisms described in the preceding article, "Torque-Limiting Driver Based on Displaceable Bevel Gear" (MSC-22384).



Compressed Air at Regulated Pressure *would be applied to the piston to push the gears together with a constant preload. The limiting torque would be the torque strong enough to force the gears to slip out of engagement at that preload.*

With the exception of the components used to set the limiting torque, the present mechanism would be nearly identical to the mechanism illustrated in Figure 1 of the preceding article. The driven gear would be connected to the output shaft via a flexible coupling and would be mounted in a gear support that was capable of sliding radially (laterally). As in other torque-limiting mechanisms based on the same principle, the gears would be pushed together with a preload that would define the limiting torque. This load would counteract the lateral repulsion between the gears. The lateral repulsion would be proportional to the applied torque, the factor of proportionality being a function of the gear-tooth geometry.

As long as the applied torque remained less than the preset limiting torque, the gears would remain in mesh and would thus transmit the torque from the input shaft to the output shaft. At the preset limiting torque, the lateral repulsion would equal the preload. Any attempt to apply a greater torque would cause the repulsion to exceed the preload, and the gears would be pushed apart. Continued turning in an attempt to apply a greater torque would cause the gears to disengage, slip, and re-engage repeatedly.

In the mechanism shown in Figure 1 of the preceding article, the preload would be applied by a spring. Unfortunately, deflection of the spring between the point of initial yielding and the point of slippage would result in an increase in preload and a concomitant increase in the limiting torque. The resulting torque range would constitute a band of uncertainty in the output torque. In addition, fatigue in the spring could decrease the stiffness of the spring, thus reducing the preload and adding another element of uncertainty to the torque setting.

In the mechanism proposed here, the preload would be applied to the laterally displaceable gear support by a piston sliding in a cylinder. Compressed air at regulated pressure would be sup-

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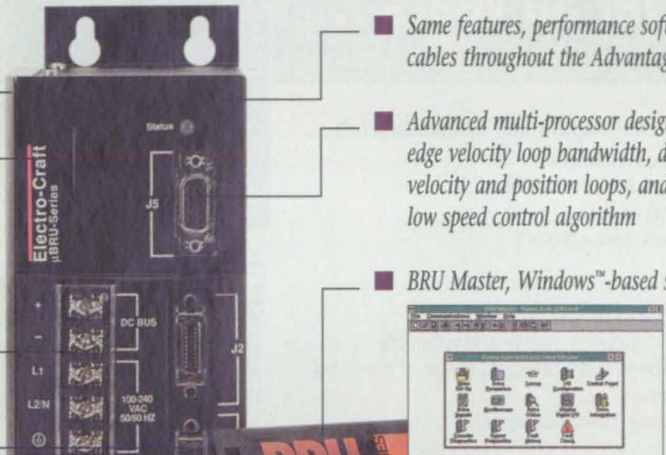

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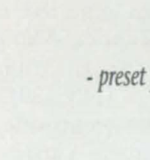

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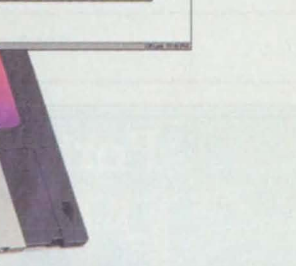

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plied to the cylinder. The preload would equal the pressure x the cross-sectional area of the piston. The preload would thus remain constant as long as the regulated pressure remained constant, resulting in more precise control of torque.

This work was done by Joseph S. Cook, Jr., of **Johnson Space Center**. *For further information,* ***write in 45*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center; (713) 483-4871. Refer to MSC-22385.

Simpler Power-Conserving Stepping-Motor Drive Circuit

Marshall Space Flight Center, Alabama

A stepping-motor drive circuit features a design that is a slightly simplified version of a design reported in "Power-Conserving Stepping-Motor Drive Circuits" (MFS-28854), *NASA Tech Briefs*, Vol. 18, No. 7 (July 1994), page 30. The previous version provided for the generation of drive currents with amplitudes proportional to

$$D + |C \sin \theta|,$$

where θ is the difference between the actual and commanded shaft angles at a given instant, D is a positive term set by a dc bias input, and C is a product of amplifier gains and current-drive parameters. The underlying idea is to use as little drive current as possible when the motor operates under a light load (for which $|\theta|$ is small) and to increase the drive current only to satisfy the need for increasing torque as the load (and thus $|\theta|$) increases. In the previous version, D was adjusted so that at minimum amplitude (at $\theta = 0$), the drive current would provide enough torque to overcome bearing friction and other losses. In the present version, the dc bias input is eliminated and, instead, C is increased to ensure sufficient torque for all $|\theta|$ above an acceptably small dead-band value. All appreciable filtering has been removed to produce a system that responds much faster. It is also important to note that the angle-command signals for circuits of this type are sine and cosine signals, which can be generated with high angular resolution from clock signals.

This work was done by Frank J. Nola and David E. Howard of **Marshall Space Flight Center**. *For further information, **write in 31** on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31158

Three-Dimensional Capaciflectors

Electrodes can be arranged to fit surfaces and/or define sensory regions.

Goddard Space Flight Center, Greenbelt, Maryland

An extension of the capaciflector concept provides for capaciflector electrodes in a variety of three-dimensional configurations (see Figure 1). Heretofore, only two-dimensional configurations have been reported.

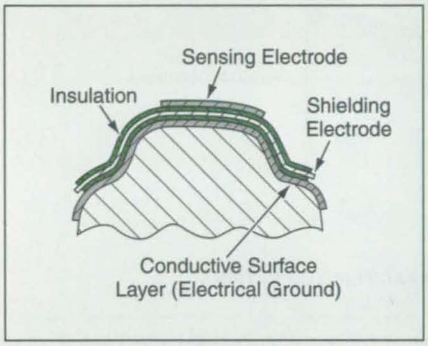


*Figure 1. **Capaciflector Electrodes** can be configured in three dimensions for a variety of purposes. In this example, they are shaped in three dimensions to conform to an irregular rounded surface.*

The capaciflector concept has been discussed in numerous previous articles in *NASA Tech Briefs.* To recapitulate: Like other capacitive proximity sensors, a capaciflector puts out a signal indicative of the capacitance between a sensing electrode and an object in the vicinity. A capaciflector as reported previously includes at least one planar sensing electrode laid out over at least one larger planar shielding electrode (reflector). By use of current-measuring voltage followers, the sensing and shielding electrodes are driven by alternating voltages of equal magnitude, frequency, and phase. The driven shield increases the range and spatial resolution of capacitive sensing by concentrating the sensing electric field into a narrower region according to established principles of electrostatics. The current in the sensing electrode is measured as an indication of the sensed capacitance. Optionally, the current in the shielding electrode is also measured as a less precise indication of sensed capacitance.

The present three-dimensional capaciflectors operate according to the same basic principles as those of the capaciflectors reported previously, except that the third dimension for configuring electrodes provides an additional degree of freedom for design. One can configure the electrodes to define sensory regions and/or make the capaciflectors conform to the surfaces of robot arms, tools, or other objects for which proximity sensing may be needed in specific applications.

For example, Figure 2 shows two of the many possible round cylindrical side-looking capaciflector arrangements. In the first example, a cylindrical sensing electrode is sandwiched axially between a cylindrical base shielding electrode and a rounded cap shielding electrode; this concentrates the sensing electric field into a roughly toroidal region around the sensing electrode. The second example is a cylindrical version of the planar capaciflector array described in "Capaciflector Camera" (GSC-13564), *NASA Tech Briefs*, Vol. 18, No. 10 (October 1994), page 58. As in the case of the planar capaciflector array, one can process the capacitance readings from the row and column electrodes (in this case, the circumferential and axial electrodes) into a three-dimensional capacitance image of an object within sensory range of the array. Of course, the capacitance-data-processing algorithm must be modified in accordance with the change of the capaciflector array geometry from planar to cylindrical.

For another example, a screw, pin, tool, or other three-dimensional object could be used as a sensing electrode.

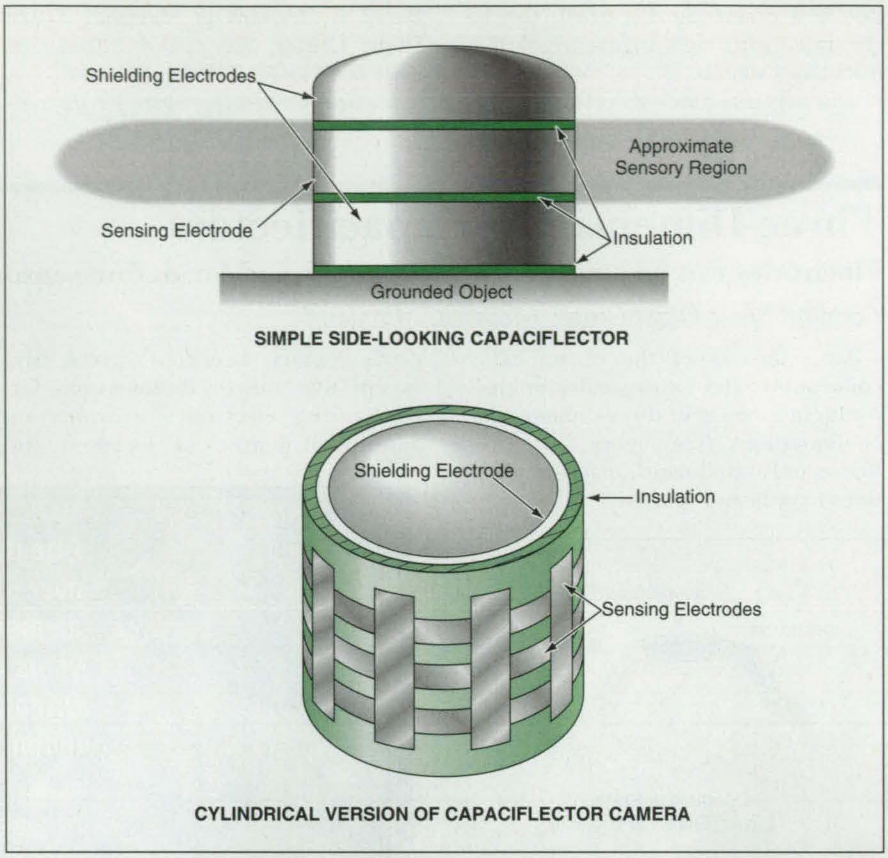


*Figure 2. These **Side-Looking Capaciflectors** are examples of two out of an almost unlimited number of three-dimensional capaciflector configurations.*

The object used as the sensing electrode would have to be electrically isolated from ground with the help of a relatively large driven shielding electrode in the same manner as in other capaciflector arrangements. The driven shielding electrode could also be a three-dimensional object.

This work was done by John M. Vranish of **Goddard Space Flight Center**. *For further information,* ***write in 18*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13701

Fixtures Help Align Mating Modules

Rugged, lightweight fixtures are suitable for robotic assembly operations.

Lyndon B. Johnson Space Center, Houston, Texas

Relatively simple, rugged, compact, lightweight fixtures facilitate the alignment of two modules of equipment that are to be fastened to each other. The fixtures ensure alignment along all three spatial axes, in three stages of successively increasing precision as the two modules are pushed together, and little visual or tactile feedback is needed; consequently, the fixtures are suitable for use where modules are to be put together by robots or by workers in heavy protective clothing.

Typically, three sets of the fixtures are needed to ensure complete alignment (see Figure 1, next page). Each set of fixtures includes parts that are mounted on the two modules and that mate with each other (see Figure 2, next page). Following initial coarse alignment, and as the two modules are pushed together, pins on module 1 make contact with shoehorn flanges on module 2: this is the first stage of alignment. As the two modules are pushed together further, the shoehorn flanges funnel the ends of the pins toward narrow openings, which are just wide enough to accommodate the pins.

As the modules continue to approach each other, the pins enter

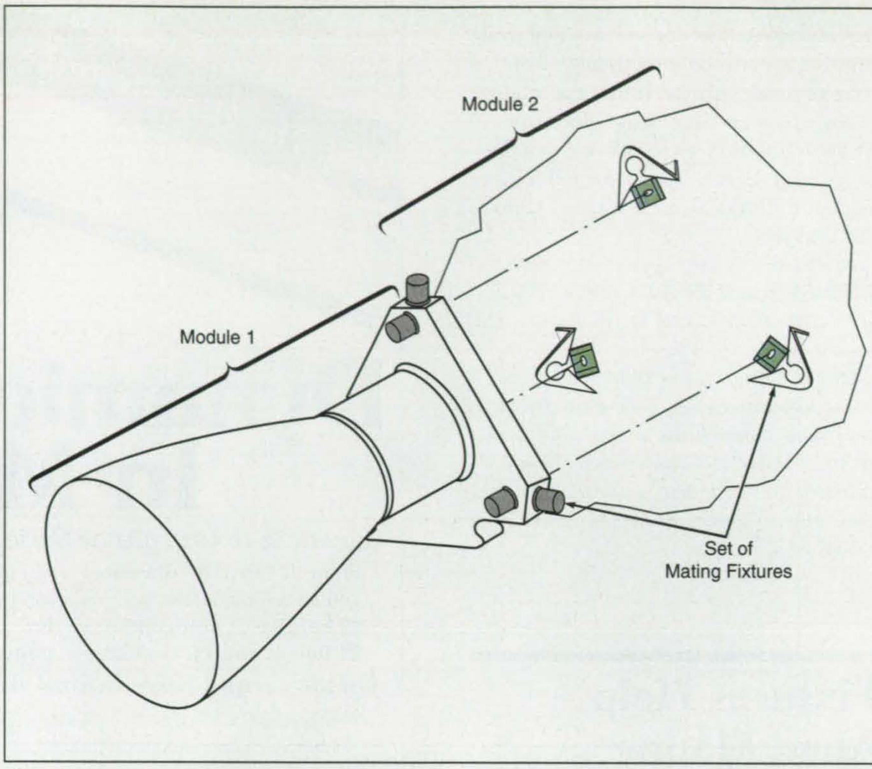


Figure 1. ***Three Sets of Fixtures*** *guide the two modules into precise alignment as they are pushed together.*

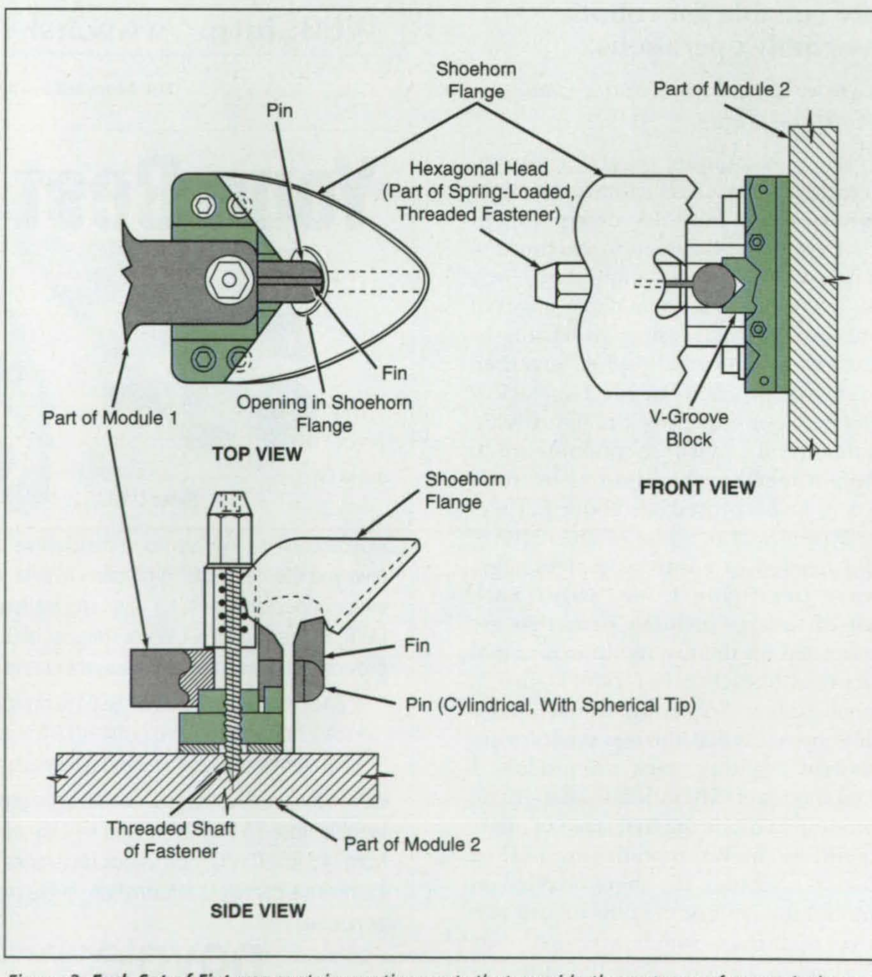


Figure 2. ***Each Set of Fixtures*** *contains mating parts that provide three stages of successively more precise alignment.*

the openings in the shoehorn flanges and thus become restrained against significant lateral motions: this is the second stage of alignment. Finally, the two modules are pushed into firm contact as the pins on module 1 come to hard stops in mating V-grooves on module 2. This is the third and final stage of alignment, in which all clearance is eliminated and the two modules can no longer move relatively to each other.

Each fixture on module 1 includes a spring-loaded, captive, threaded fastener that fits in a threaded hole in the V-groove block of the mating fixture on module 2. The spring-loaded fasteners are kept retracted during the alignment procedure to prevent mechanical interference. Then, while the modules are still being pushed together to maintain alignment, the spring-loaded fasteners are activated and threaded into engagement with the V-groove blocks. Then the robot or worker can release the modules, which remain fastened together.

A fin on top of each pin on module 1 prevents the pin from slipping under the opening in the mating shoehorn flange on module 2. This feature helps to maintain the alignment of each pin-and-shoehorn pair that has already been mated while one or both of the others have not yet been mated. This feature also facilitates unfastening of the two modules by ensuring that pins do not become jammed under the openings in the mating shoehorn flanges.

The fixtures can be fabricated fairly easily and inexpensively. The spring-loaded, captive, threaded fastener is a commercial product. The shoehorn flange can be formed from sheet metal. The pins and the V-groove blocks can be made to the necessary precision by standard machining techniques.

This work was done by Dennis R. Preston of Hughes Danbury Optical Systems, Inc., for **Johnson Space Center**. *For further information, write in 50 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to Hughes Danbury Optical Systems, Inc. Inquiries concerning licenses for its commercial development should be addressed to:

Mr. Robert A. Hays
Hughes Danbury Optical Systems, Inc.
100 Wooster Heights Rd.
Danbury, CT 06810-7589
(203) 797-6045

Refer to MSC-22130, volume and number of this NASA Tech Briefs *issue, and the page number.*

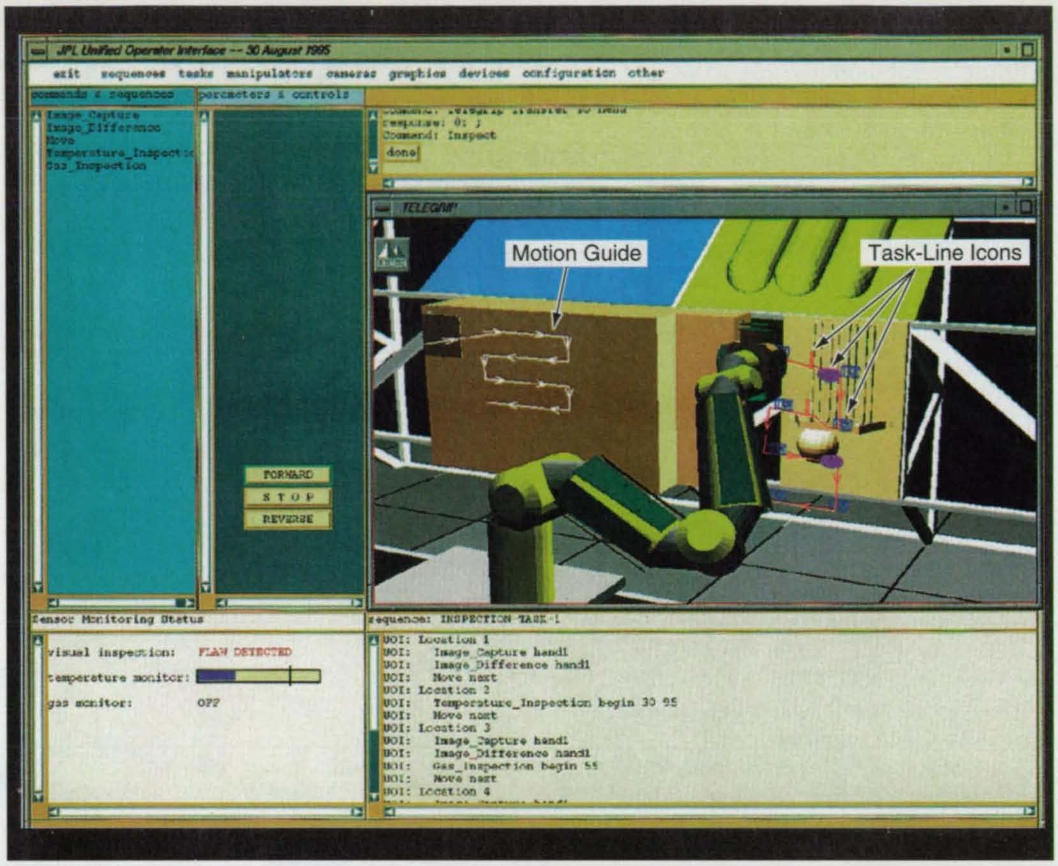
User-Friendly Graphical Aids for Telerobot Control

Embodied in an integrated software package, graphical tools make control safer and more flexible.

NASA's Jet Propulsion Laboratory, Pasadena, California

Computer-graphical constructs called "motion guides" and "task lines" have been developed to facilitate remote computer-based planning and control of the motions and tasks of robots in situations in which (1) there are significant signal-propagation delays between the robots and the control stations where human operators are located and/or (2) in a command-line programming environment, the robot trajectories and tasks cannot be easily visualized. The motion guides and task lines are presented as part of a graphical user interface to provide a more intuitive programming environment in which motions and tasks can be visualized more easily and thus modified more easily to achieve objectives and prevent collisions. The motion guides make it possible to plan safe (noncollisional) paths, even in the presence of signal-propagation delays; task lines facilitate the specification of tasks. The motion-guides/task-lines approach to telerobot control has great potential for application in manufacturing, underwater exploration, and handling dangerous materials.

A motion guide is a graphical representation of the path that a robot is required to follow (see figure). The operator can generate



The ***Unified Operator Interface*** *is a graphical user interface for remote planning and control of a robot. Motion guides and task lines in the display represent robot trajectories and robot tasks, respectively.*

or cause the generation of a motion guide by any of several alternative techniques; for example, sampling the path of a simulated robot trajectory, arbitrarily choosing path segments and allowing them to be joined by smooth computed transitional curves, or interpolating between specified locations. Regardless of the method of generation, the robot is constrained to follow the path. The operator can choose to drive the robot along the motion guide by pushing a spaceball; pushing the ball forward or backward drives the robot forward or backward on the path. The operator can easily change the path while the robot is moving along it.

Safety features to prevent collisions are planned but not yet incorporated into the robot-control and graphical-user-interface software. One such feature would provide for automatic detection of potential collisions at all points along a motion guide rather than only at the current position of the robot. The locations of potential collisions would be highlighted to alert the operator to the need to modify the planned robot trajectory. The operator could thus generate or modify a trajectory without going through a separate simulation step to verify the safety of the trajectory. Another such feature would provide for automatic modification of parts of the motion guide to prevent collisions, while preserving the other parts of the motion guide.

A task line is a graphical representation of a sequence of commands pertaining to a task. A task line includes an icon that represents a subtask and is attached to a motion guide at the location where the subtask is to be performed. The icon in a task line for a visual inspection appears as a video camera; that for measurement of temperature looks like a thermometer; and that for gas inspection looks like a cloud. When an icon is selected, a panel that describes the associated sequence of commands appears in the lower part of the display. The operator can use this panel to enter parameters and/or otherwise modify the subtask. A task line can also be used to provide for reactive sequencing of commands; for example, if a robot is commanded to perform a temperature inspection, it can also be commanded to react by scanning a camera over a spot where it detects a temperature greater than a specified threshold level.

This work was done by Paul G. Backes and Stephen F. Peters of Caltech and Linh Phan and Kam S. Tso of SoHaR, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, write in 30 on the TSP Request Card.*
NPO-19807

Thermally Actuated Release Mechanism

The mechanism holds a tang securely until thermally actuated.

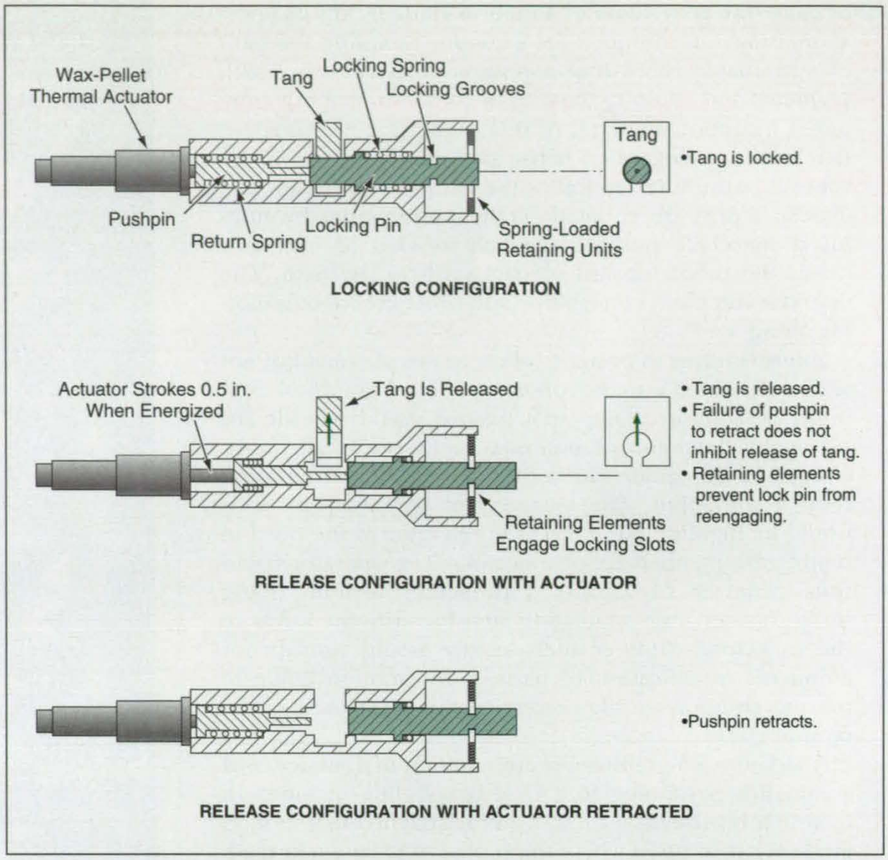
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates a mechanism that securely holds a tang until a thermal actuator in the mechanism is energized to release the tang. The mechanism can be reset and reused in subsequent release operations.

In the initial, locking configuration, a locking spring biases a locking pin leftward into a position in which it engages the tang. When the thermal actuator is energized, it pushes rightward against a pushpin, overcoming the leftward bias of a return spring. The pushpin, in turn, pushes the locking pin rightward into a position in which it no longer restrains the tang. Once this locking configuration has been attained, spring-loaded retaining elements engage locking grooves in the locking pin; this prevents the locking spring from pushing the locking pin back into engagement with the tang, thereby maintaining the release configuration.

When the thermal actuator is deenergized, the return spring forces the pushpin leftward, back to its initial position. The locking pin remains in its rightmost (release) position until and unless the retaining elements are withdrawn from the locking grooves in the locking pin. To reset the mechanism, the tang is inserted, then the retaining elements are withdrawn; this causes the locking spring to push the locking pin leftward into engagement with the tang in the original locking configuration.

This work was done by Richard E. Fleischner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 65*** *on the TSP Request Card.* *NPO-19665*



The ***Tang Is Released*** *when expansion of a wax pellet pushes the locking pin rightward. The locking pin thereafter remains in the release position until reset.*

Adaptive-Feature-Map Analysis of Bearing-Defect Vibrations

Defective bearings can be detected automatically during operation of a machine.

Marshall Space Flight Center, Alabama

A pattern-classification technique for automated early detection of faults in the bearings of a high-speed rotary machine (e.g., a turbopump) involves analysis of vibration spectra by use of a mathematical construct called an "adaptive feature map" (AFM). Like numerous other vibration-analysis fault-detection techniques, this technique is based on obtaining vibration data from accelerometers mounted on the machine, then processing the data in a way that reveals anomalous and/or changing patterns indicative of the existence and/or onset of faults. Some of these other techniques depend on "training" by use of comprehensive sets of vibration data acquired previously during operation with known faults. In the present technique, the AFM automatically classifies input data according to their patterns and updates its classification scheme as new data are acquired so that, in effect, the AFM "learns" patterns of normal and anomalous vibrations without supervision or prior training.

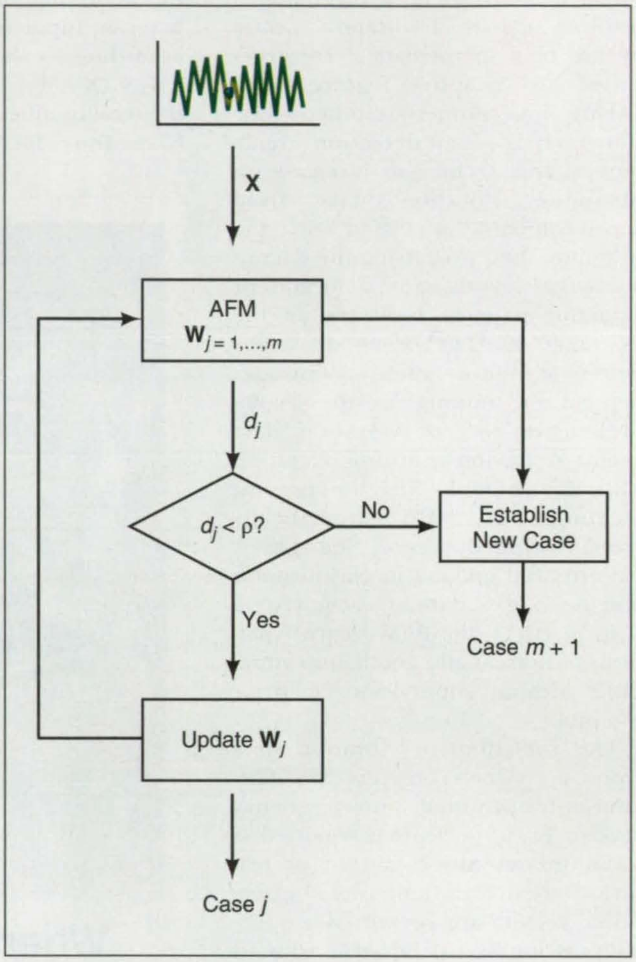
The time-domain vibration data from the accelerometers are fast-Fourier-transformed into frequency spectra. Each spectrum is regarded as a continuous-valued pattern or feature vector in an n-dimensional space. These vectors are presented sequentially as inputs to the AFM without specifying the desired outputs.

The functions of the AFM are implemented by an unsupervised-learning algorithm that can be represented graphically as shown in the figure and can be characterized further in terms of n input nodes and m output nodes. Each input vector $\mathbf{X}$ is compared with weight vectors $\mathbf{W}j$ ($1 \leq j \leq m$) associated with the output nodes.

Initially there is only one output node (j=1) that represents the normal (no-fault) case, and the initial weight vector ($\mathbf{W}_1$) for this case is arbitrarily set equal to the first input vector. Each succeeding input vector $\mathbf{X}$ is then utilized as follows: The Euclidean distance d_1 between $\mathbf{X}$ and $\mathbf{W}_1$ is computed, then compared with a quantity called the "vigilance factor" (ρ). If $d_1 < \rho$, then $\mathbf{X}$ is deemed to be close enough to $\mathbf{W}_1$ that it belongs to the normal case. Then the weight vector for the normal case is adapted to the accumulating knowledge of normal-case input vectors by adjusting it according to the recursive equation $\Delta\mathbf{W}_1 = (\mathbf{X} - \mathbf{W}_1)/N_1$, where N_1 denotes the total number of input vectors that have thus far been classified as belonging to the normal case.

If $d_1 \geq \rho$, then $\mathbf{X}$ is deemed so far from $\mathbf{W}_1$ that it belongs to some other case, which could represent a fault. A new weight vector $\mathbf{W}_2 = \mathbf{X}$ is created for this case. Thereafter, each succeeding input vector is compared with $\mathbf{W}_2$ as well as with $\mathbf{W}_1$. The process is repeated, each time either updating one of the previously created weight vectors, $\mathbf{W}_j$, according to $\Delta\mathbf{W}_j = (\mathbf{X} - \mathbf{W}_j)/N_j$, or else creating a new weight vector $\mathbf{W}_{m+1}$.

After enough input vectors have been presented, the weight vectors become the centers of clusters of input vectors, and the point-density functions in these clusters approximate the probability-density functions of the input vectors. In addition, nodes that are close together can be expected to be sensitive to similar input vectors.



***Each Input Vector X** is compared with the m previously created weight vectors $\mathbf{W}_j$ and used either to update one of them or else to create a new weight vector $\mathbf{W}_{m+1}$.*

This AFM technique was tested by applying it to vibration data in the frequency range from 14 to 20 kHz from experiments on two turbopumps. For comparison, the data were also analyzed by another technique, called "envelope analysis," that had previously shown to provide early indications of faults. The results of these tests showed that the AFM technique is more capable of revealing subtle changes in signals and gives earlier warnings of faults.

This work was done by Harrison H. Chin of BF Goodrich for **Marshall Space Flight Center**. *For further information, **write in 27** on the TSP Request Card.*
MFS-26466

New Products

Imprimis Systems, San Diego, CA, has introduced the RatioBox™ series of **motor gearboxes** for use with any NEMA 17, 23, or 34 motors. The gearboxes change output speed, torque, and reflected inertia without producing backlash. A belt and pulley system makes the devices suitable for medical, instrumentation, semiconductor processing, and manufacturing applications. Constructed of die-cast aluminum with ball bearing support, the gearboxes mount to both motors and machines. They also increase motor torque and optimize load-to-rotor inertial ratios.

For More Information Write In No. 755

Parker Hannifin Corp., Compumotor Div., Rohnert Park, CA, offers the APEX-10 **analog servo drive**, which incorporates power electronics and can drive a variety of servo motors. Hall effect or brushless resolver commutation feedback is accepted and can be configured for different pole pair motors. Connections are on removable screw terminals for easy installation and cable routing. The drive operates in velocity or torque mode and can be matched with a servo controller for point-to-point positioning and contouring. Other features are 16 amps of peak current, standard ±10 V torque or velocity command input, 8 KHz PWM switching frequency, and nine diagnostic LEDs.

For More Information Write In No. 757

Industrial Indexing Systems, Victor, NY, has introduced the DeltaPro™ **motion controllers**, consisting of 19 models from 120 to 6500 watts. The lightweight systems integrate everything required for a motion system, including positioner, amplifier, high-power-density motor, operator interface, power supply, and cables. They are designed for basic motion control applications such as positioning, indexing, profiling, and electronic gear ratios. Features include dual 32-bit RISC processors, flash ROM and NOVRAM memory, a five-digit driver, and all-digital electronics. Programming is performed through a touchpad operator interface or a PC connected using an RS-232 port.

For More Information Write In No. 759

The Model 200N **pneumatic positioner** from W.E. Anderson Div., Dwyer Instruments, Michigan City, IN, features a transparent cover and colored indicator for visual verification. It allows access to span and zero adjustments, as well as direct or reverse action with no additional required parts. The device incorporates no external springs and is vibration-resistant. It operates over a temperature range of -21°C to 71°C. NPT mounting threads of 1/4" and 1/8" provide supply and instrument connections, respectively.

For More Information Write In No. 761

The escap® P850 **microstepping system** from Portescap U.S., Hauppauge, NY, features point-to-point movement without ringing at the final position. The low-inertia stepper motor can target 12,800 positions per revolution (at 64 microsteps/step), and delivers holding torque up to 189 oz-in. High speeds of more than 1,500 RPM can be reached for longer trajectories. Electronic damping control reduces low-speed and mid-range resonances and eliminates overshoot at the end of a movement.

For More Information Write In No. 756

The MC/DNET-1000 DeviceNet **motion controller** from Motion Engineering, Santa Barbara, CA, is DSP-based and provides single-axis standalone motion control. It can be programmed directly from a PC or PLC attached to a DeviceNet network. The unit controls point-to-point motion and trapezoidal, S-curve, and parabolic motion profiles. It features dual processors that enable storage and execution of up to 256 DeviceNet program blocks, and 4 KHz servo update rate motion control with three modes of operation: position, velocity, and torque control. The 2.5" x 3" x 6" enclosure can be panel-mounted.

For More Information Write In No. 758

Polytec PI, Auburn, MA, offers a line of **DC motor controllers** for use in micropositioning, micromanufacturing, optics, and precision mechanics applications. The controllers enable simultaneous operation of up to 16 DC servo motors and can be controlled manually via a joystick or keypad, or by computer. They feature external power amplifiers; macro programming language; IEEE 488, RS-232, and PC-BUS interfaces; I/O lines for flexible automation tasks; and LabVIEW™ drivers for programming. Benchtop and PC plug-in versions are available.

For More Information Write In No. 760

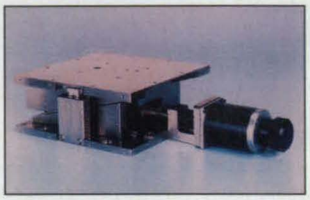
API Deltran, American Precision Industries, Amherst, NY, has announced the SB Series of **motor brakes** for integration into NEMA- and metric-dimension step and servo motors. Seven models of spring-set, electrically released brakes are available with holding torque ratios from 10 to 1,200 lb-in and diameters from 1.8" to 7.25". The brakes feature a low backlash rotor-to-stator design for motor holding position accuracy, and an operating temperature to 180°C. Standard coil voltage ratings are 24 and 90 VDC; non-standard voltages are available.

For More Information Write In No. 762

New Products

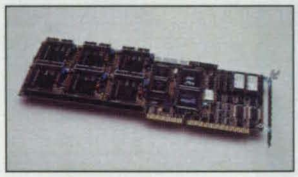
The DR-4M and DR-4MPS **microstepping drivers** from Advanced Micro Systems, Nashua, NH, operate NEMA 23 frame size and smaller stepping motors. The 4-amp per-phase, bipolar, chopper drivers have eight resolution settings from 1/2 step to 1/256 step, all user-selectable via a modular connector. Features include step resolution to over 50,000 steps per revolution, operation from a single power supply, up to 1 MHz step clock rate, and automatic current reduction and boost mode. The driver package includes a finned heat sink with channel mounts for an optional cooling fan (standard on the DR-4MPS).

For More Information Write In No. 763



The Z8 Z-axis **positioning stage** from Anorad Corp., Hauppauge, NY, is a vertical travel axis based on a three-piece wedge design. Both horizontal and vertical motions are guided by crossed roller bearings. The stage design provides an unobstructed mounting surface, allowing access from the top and all sides. The 8" square stage has a nominal height of 3" and is constructed of anodized aluminum. Nominal travel is ±0.5"; accuracy and repeatability range from 0.25μm to 10 μm and are drive- and feedback-independent.

For More Information Write In No. 764



Precision MicroControl Corp., Carlsbad, CA, offers the DCX-AT **digital motion and I/O control card** for installation in an AT/ISA bus or for standalone operation. It provides one to six axes of servo and/or stepper motion control with 26 dedicated I/O lines for each axis and 16 to 96 undedicated digital I/O lines. Multiple controllers can be joined to provide up to 96 axes of control and 1,536 undedicated digital I/O lines. Capabilities include multi-tasking, complex contouring, S-curve velocity profile, and continuous path motion with cubic spine interpolation.

For More Information Write In No. 765

Motran Industries, Valencia, CA, has introduced a line of linear electromagnetic **inertial force actuators** for active vibration control applications and for use as vibrators over a range of frequencies and forces. The actuators are designed to actively produce mass reaction forces onto the surface on which they are mounted. The sealed units have no external moving parts and are tolerant of high temperatures. Actuators are available with output from 1 to 300 pounds; custom designs also are available.

For More Information Write In No. 766

The rig is shipped to the antenna site dismantled and assembled there at a comfortable working height. Then the rig serves to erect itself to a working configuration: First, the cable from the winch is strung as shown in Figure 1, with its tip attached to the antenna post via a chain. The winch is turned by hand to raise the rig until the region between the two up-permost pulleys is positioned over the antenna post. The winch is self-locking, so that there is no danger to the operator when the handle is released.

Next, a chain is attached between the lower end of the large rig member and the base of the antenna post to provide a stable base. Finally, the cable is strung as shown in Figure 2 and used to position the reflector-support structure and the reflector.

This work was done by Karl F. Reader of Analex Corp. for **Lewis Research Center**. *For further information,* ***write in 56*** *on the TSP Request Card.*

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 Rd., Cleveland, OH 44135. Refer to LEW-16262.

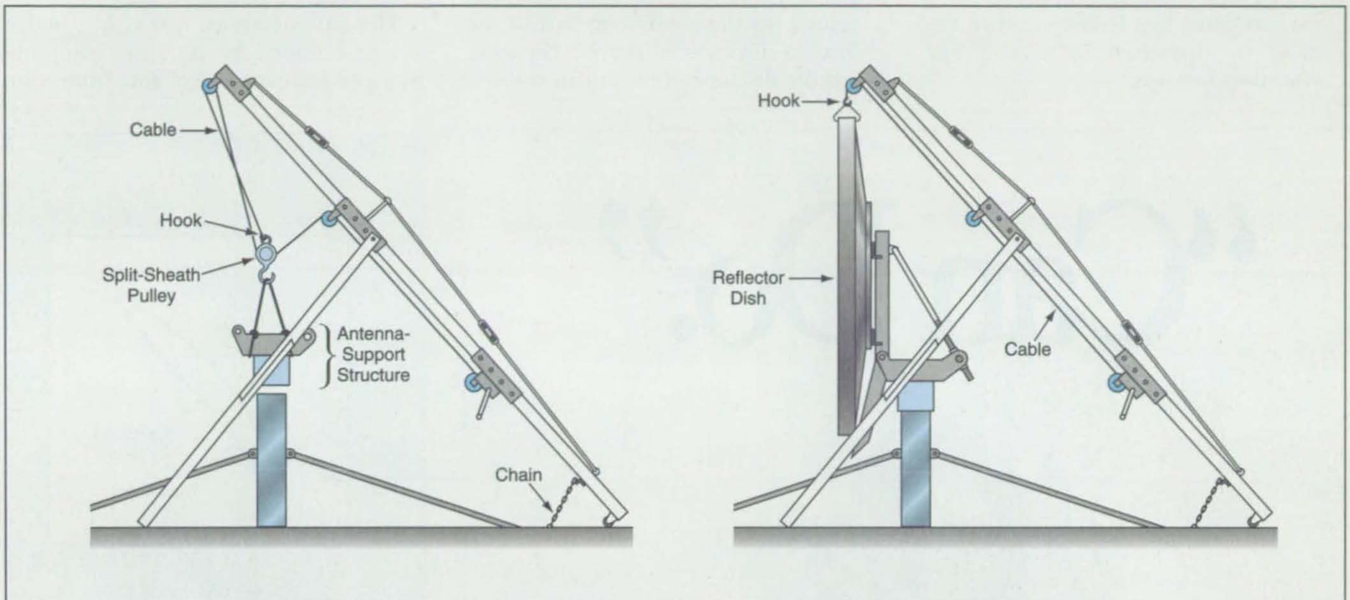


Figure 2. The ***Rig Lifts*** *the antenna-support structure onto the antenna post, then lifts the reflector dish onto the antenna-support structure. The split-sheath pulley enables the use of alternative lifting configurations.*

Mathematical Modeling of Wire-Rope Vibration Isolators

A nonlinear model fits experimental data fairly well.

Marshall Space Flight Center, Alabama

A semiempirical mathematical model has been developed to represent the dynamics of wire-rope vibration isolators (see Figure 1). Heretofore, the design of wire-rope vibration isolators has been based on experiments rather than on fundamental understanding of the dynamics. Although the semiempirical mathematical model does not address the fundamentals directly in that it does not represent the detailed dynamics of interactions among individual wires in cables, it nevertheless contributes to understanding of gross dynamic phenomena like damping, hysteresis, and variable stiffness.

The model includes terms for nonlinear stiffness, *n*th-power velocity damping, and variable Coulomb-friction damping. It fits experimental data fairly well (see Figure 2), and in doing so, it is consistent with the notion that damping is caused mainly by sliding friction among cable wires. It is also consistent with tightening and loosening of different numbers of wires during positive and negative displacements and the consequent asymmetry in the gross dynamics.

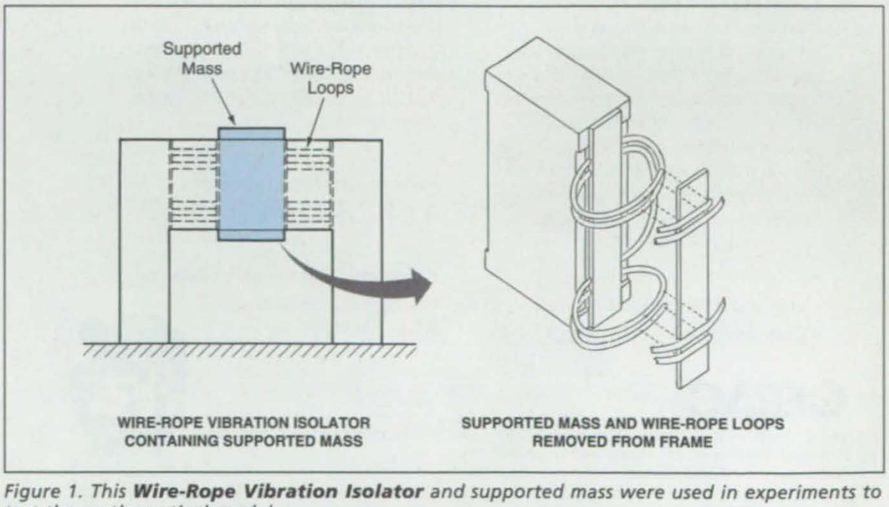


Figure 1. This ***Wire-Rope Vibration Isolator*** *and supported mass were used in experiments to test the mathematical model.*

The basic equation of the model is

$$m\ddot{z}+r\left\{k\left[(z-u)\pm\varepsilon^2(z-u)^3\right]+b\right\}+$$
$$c(\dot{z}-\dot{u})^n\ \mathrm{sgn}\ (\dot{z}-\dot{u})+$$
$$f\left[1-a(z-u)^2\right]\mathrm{sgn}\ (\dot{z}-\dot{u})=0.$$

The terms in this equation are defined as follows:

a. $z–u$ denotes the displacement of a mass relative to a frame in which the mass is supported by a wire-rope vibration isolator,

b. z is the position of the mass in the corresponding inertial coordinate system,

c. m is the effective value of the supported mass,

d. r is a nondimensional factor that equals 1 to a first approximation and is used to account for the approximation of dynamic stiffness,

e. k is a spring-stiffness parameter that represents the linear part of the force-vs.-displacement spring behavior,

f. ε is a spring-stiffness parameter that represents the nonlinear part of the force-vs.-displacement spring behavior,

g. b is the distance of the stiffness curve above the origin when the displacement is zero,

h. c is the nth-power-damping coefficient (approximated as a constant although in practice, it varies with time),

i. f is the friction force at small displacement, and

j. a is a parameter that accounts for the observed decrease in friction with increasing displacement as wires become tighter against each other and are thus less free to slide.

The parameters m, r, k, ε, b, c, and a are determined by iterative computation and comparisons of data from computed and experimental trajectories. The value of n has been assumed to be 2 in studies conducted thus far. Some additional refinement of the model may be needed: Under some circumstances, the model unrealistically predicts instability (negative damping or self-excitation); however, the instability can be eliminated by suitable choice of parameter a or by choosing nth power velocity damping as the sole damping mechanism ($f = 0$).

This work was done by M. L. Tinker of **Marshall Space Flight Center** *and M. A. Cutchins of Auburn University. For further information,* ***write in 84*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26358.

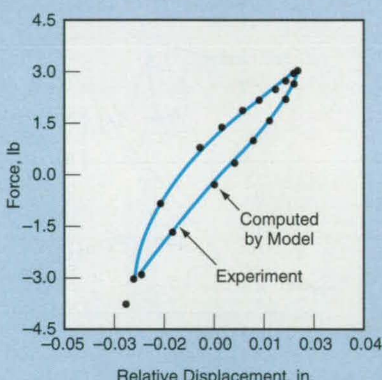


Figure 2. This ***Hysteresis Curve*** *for the vibration isolator of Figure 1 was computed and measured at an excitation frequency of 100 Hz and excitation amplitude of 0.0125 in. (0.32 mm). Other frequencies and amplitudes yielded similar results.*

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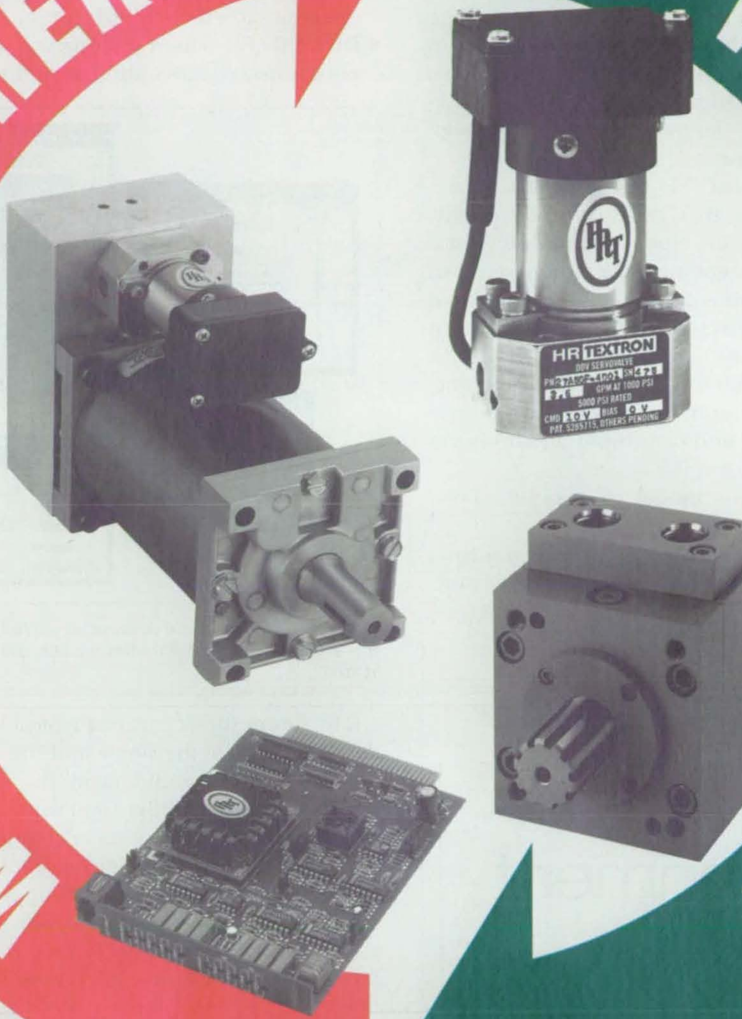

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Software for Teaching Aerodynamics

Interactive graphical displays help students visualize results of flow calculations.

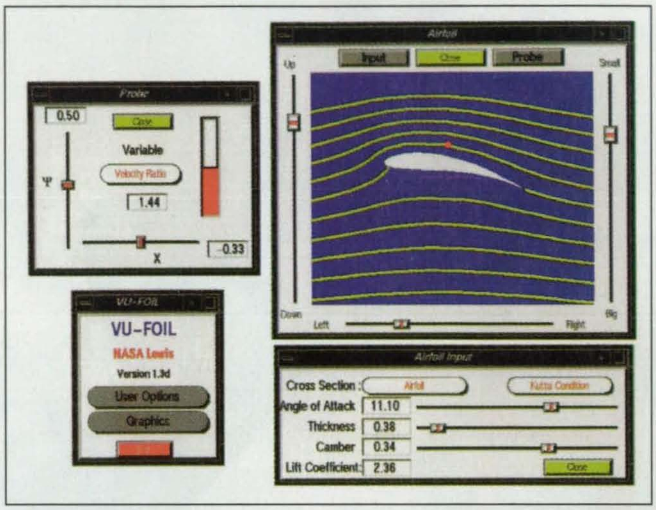
Lewis Research Center, Cleveland, Ohio

Six computer programs solve various aerodynamical problems, accepting inputs and presenting outputs via interactive graphical displays. These programs are designed to help undergraduate students visualize the results of their calculations and thereby gain deeper understanding of principles of aerodynamics. These programs can also be used in preliminary, approximate design analyses, enabling engineers to quickly explore the effects of variations in design parameters. Similar programs that mathematically model different phenomena could be used for similar purposes in other engineering and scientific disciplines.

These programs model classical flow phenomena as represented by simplified equations that can be solved rapidly enough for interactive analysis on modern computer workstations. As a student varies the geometry or flow conditions for a given flow problem, the new conditions are calculated immediately and the results presented to the student in graphical and numerical formats.

The programs and the problems they solve are the following:

- VU-TURBO performs design and off-design Brayton-cycle analysis for a turbojet engine with or without an afterburner, or for a two-spool turbofan engine.
- VU-FOIL uses a potential-flow model to compute flows around airfoils of various shapes.
- VU-SHOCKS computes supersonic flow past multiple wedges, producing graphical displays of the shock fronts that occur in such flows.
- VU-INLET computes supersonic flow through an external- or mixed-compression inlet.
- VU-DUCT implements a one-dimensional model of incompressible, inviscid flow, based on simple conservation of mass and momentum, to compute the flow through an open- or closed-circuit wind tunnel.
- DUCTSIZER is used to design or study flows through multiply connected air-conditioning ducts.



***VU-FOIL Computes Flow Around an Airfoil,** enabling the user to explore the effects of design parameters like thickness, camber, and angle of attack.*

The figure shows part of a typical VU-FOIL display. The student can change the shape and the angle of attack of the airfoil by use of the sliders in the lower right window. The streamlines in the upper right window are immediately updated to show the effects of these changes, and the lift coefficient is recalculated. The student can move a probe that samples the pressure and velocity; this amounts to doing a simulated wind-tunnel experiment in which probe measurements are taken at various locations to map the flow field. The student moves the probe by use of the sliders in the upper left window, the location of the probe is indicated by a red dot, which, in this case is located on the first streamline above the airfoil. The value of the flow variable being "measured" is indicated both numerically and graphically in the upper left window.

The programs have been tested on a variety of UNIX computers, including SGI, IBM, HP, DEC, and Sun. They can also be executed on personal computers running Linux with an X graphics emulator. The programs can be run in either stand-alone or client/server mode. Additional features of the programs include on-line help screens, optional printed output, restart capability, on-line references, and examination software tools.

This work was done by Thomas J. Benson of **Lewis Research Center** *and C. Fred Higgs III of Rensselaer Polytechnic Institute. For further information,* ***write in 21*** *on the TSP Request Card.*

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 Rd., Cleveland, OH 44135. Refer to LEW-16298.

Evaluation of Agility Metrics for Fighter Airplanes

Computer simulations have been used to devise optimal test maneuvers.

Dryden Flight Research Center, Edwards, California

In support of recent flight-test programs that have involved such high-performance fighter airplanes as the X-31 (see figure), Dryden Flight Research Center has participated in studies to validate some of the many proposed measures, called "agility metrics," for quantifying the performances of these airplanes. Previous research had shown that some of the proposed measures were sensitive to the test methods used to acquire data for calculating those measures. This is specifically true for performance measures that concentrate on maneuvers that take several seconds to perform and involve large changes in the position, orientation, and/or energy state of an airplane.

Optimal-trajectory-analysis methods were used in a study that was performed to quantify the sensitivities of some of these performance measures to test technique or pilot technique. Optimal test trajectories for the X-31, X-29, and F-18 airplanes were identified by using an optimal-trajectory-analysis computer code and simulations of the three aircraft. These maneuvers were used to calculate the agility metrics in question and quantify the effects of maneuver techniques on these metrics. These studies showed that when an aircraft is tested in a maneuver that is optimized to exploit the maximum performance of the airframe for a given task, great improvements in performance are possible.

From a long list of dozens of proposed performance measures from many industry sources, three agility metrics were chosen for this study on the basis of the observation that all three had shown mixed results in preliminary studies and all three were variations on measures of standard level-turn performance and energy maneuverability. The first, called the "combat cycle time," is a measure of the time taken to turn through a specified change of heading and then regain the energy lost during the turn. The second, called "dynamic speed turn

continued on page 90

*The **Performances of Fighter Airplanes** in test maneuvers are quantified by use of agility metrics.*

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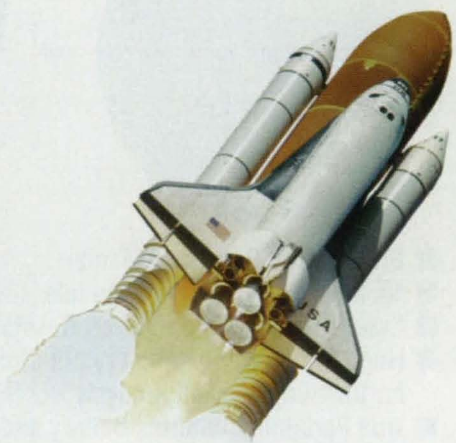

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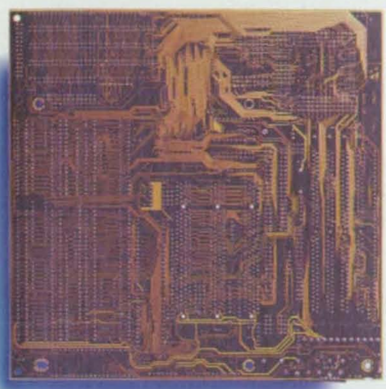

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For More Information Write In No. 648

continued from page 86

plots," quantifies the ratio between the rate of change of energy and the translational or rotational speed. The third, called the "relative energy state metric," is a measure of the speed of an airplane during a turn, relative to its ideal turning (corner) speed.

All three of these metrics were found to be very sensitive to the type of turning maneuver used to acquire data to calculate them for a given airframe. Some of the metric values varied as much as 60 percent for the F-18 airplane in preliminary studies. If a turn was flown at maximum angle of attack to exploit nose-pointing capability, huge energy losses were incurred. The proposed agility metrics and traditional measures of performance concentrate on energy loss during the turn and they rate this type of maneuver as less desirable. Fighters with flight-control limiters that keep angles of attack low rated much higher. Thus, it was desirable to determine the best, or optimal, test maneuver to measure the performance capabilities of each fighter performing a given task; this would provide for a more valid comparison of the performance of the three aircraft.

The optimal-trajectory computer program used to calculate optimal test trajectories for the X-31, X-29, and F-18 airplanes is called "OTIS" (Optimal Trajectories by Implicit Simulation) and was written by the Boeing Co. The program uses a nonlinear-sequential-quadratic-programming technique to solve for an optimal turning maneuver that is resolved into a simple two-point boundary-value optimization. Limits specific to each airframe to be tested were incorporated into the program to focus on maneuvers that represent actual capabilities of each airframe.

Basic differences among the configurations of the three airplanes caused each to have a different angle of attack where the maximum lift was produced. They also had different acceleration capabilities, though all are powered by the same type of engine. Despite this, the resulting optimal maneuvers had the common characteristic of including quick nose-pointing maneuvers during the last few seconds of turns to acquire final heading angles. All three aircraft conserved energy during the first halves of turns by turning at lower than their maximum turn rates. The nose-pointing maneuver at the end exploited the quick-turning capability of each aircraft while bleeding energy at a high rate for a short time only. The result was that all the aircraft were capable of completing 180° turns and regaining all energy lost during the turns in 5 to 20 percent less time than in nonoptimal pull-and-hold maneuvers, without significant increases in turn radii.

Further research is planned to look at other agility metrics and to relate these metrics to exchange ratios in air combat, which is where the real performance and agility of a given airframe is tested. Also, there is need to determine how the proposed metrics rate poststall maneuvers, which have proven to be quite effective when used properly in simulated air combat.

This work was done by Wes Ryan of PRC, Inc., for **Dryden Flight Research Center**. *For further information,* ***write in 17*** *on the TSP Request Card.*
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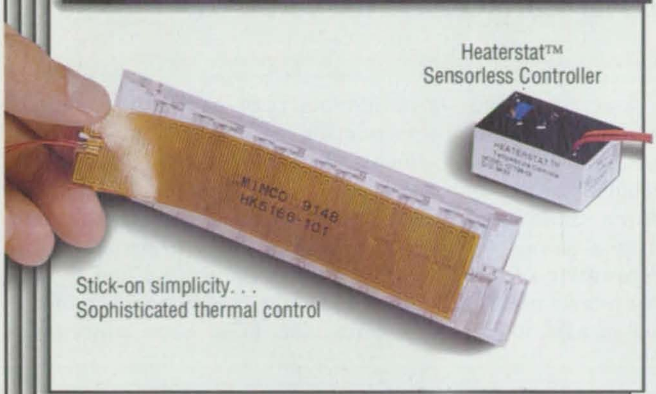

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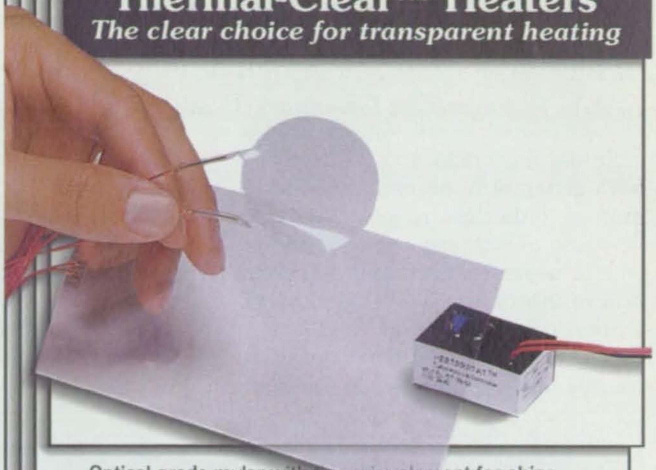

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For More Information Write In No. 513

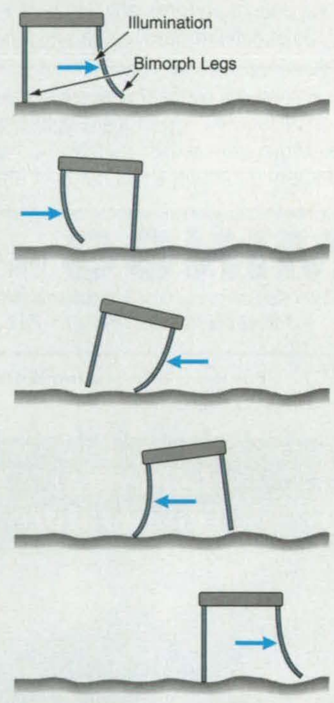
Tetherless, Optically Controlled Nanorovers

Applications as diverse as exploration, surgery, and law enforcement are foreseen.

NASA's Jet Propulsion Laboratory, Pasadena, California

Efforts are under way to develop a new generation of extremely small, mobile, tetherless robots, each type designed to perform a specific sensory and/or actuation function or combination of functions. Called "nanorovers," these robots would weigh as little as 10 mg apiece and would be mass-producible and expendable. Some would be controlled and/or powered remotely via artificially generated beams of light; others would be autonomous and powered either by artificial beams of light or by sunlight. A few examples of the diverse potential applications for nanorovers include exploration of narrow crevices and inhospitable terrain on the Earth and other planets, micropositioning, precise gripping in surgery, inspection in hazardous environments, law-enforcement inspections, and search-and-rescue operations.

Nanorovers would exploit the emerging technology of micro-electromechanical structures in general and of thin-film, light-energized bimorph actuators in particular. [The basic concept for actuation in nanorovers was described in "Thin-Film, Light-Energized Bimorph Micromechanical Actuators" (NPO-19607), *Laser Tech Briefs*, Vol. 20, No. 8 (August 1996), page 11a.] Bimorph actuators for nanorovers would typically comprise thin films of the ferroelectric/piezoelectric material lead lanthanum zirconate titanate (PLZT) deposited on thin silicon substrates and suitably polarized. When illuminated, such a film of PLZT generates a large photovoltage along its length; by the inverse piezoelectric effect, this voltage



A ***Device Containing Two Bimorph*** *legs could be made to walk in inchworm style by alternately illuminating the legs from opposite directions.*

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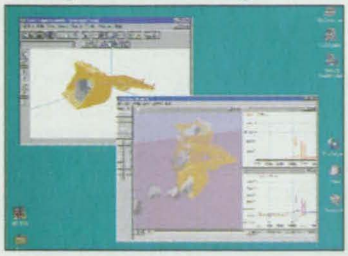

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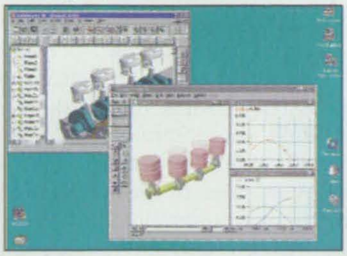

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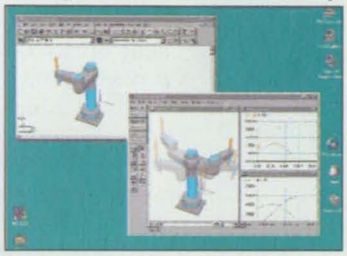

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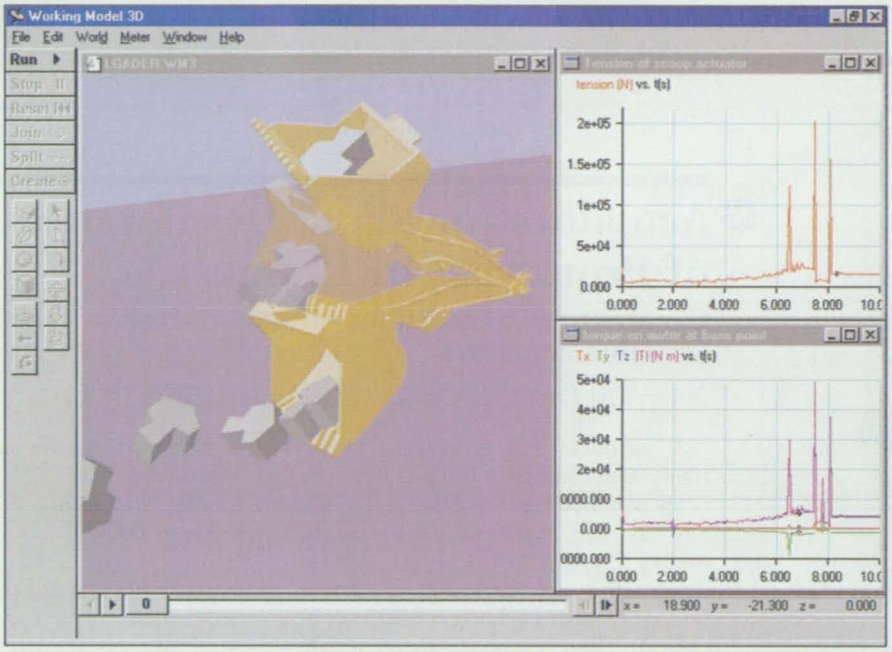

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causes the bimorph to deflect away from the source of light. The figure illustrates a simple walking device based on this concept. Enhancement of the efficiency of the optical-to-mechanical energy conversion would be a key step in the development of nanorovers to exploit this concept.

By designing nanorovers to rely on light (instead of electricity supplied via conductors) for actuation, one would not only eliminate external wires that act as tethers but would also eliminate much of the weight and bulk of conventional electrical power supplies. By making electrical control and power lines unnecessary, this approach would eliminate concerns over electrical noise and electromagnetic interference at suboptical frequencies. This approach would also facilitate unprecedented microminiaturization, leading to ultra-low-mass packaging, high operating speeds, and integration of finely tailored sensors and communication circuits onto single or few substrates. The combination of expendability and microminiaturization raises the possibility of deploying nanorovers in large numbers, reminiscent of many ants crawling around to sniff, look, and report their observations; indeed, some nanorovers might walk on multiple bimorph legs extending from thumbnail-sized bodies and could thus even resemble ants.

This work was done by Sarita Thakoor of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 89*** *on the TSP Request Card. NPO-19606*

Actuators for Rapid Development of Prototypes of Robots

Capabilities exceed those of commercially available actuators.

NASA's Jet Propulsion Laboratory, Pasadena, California

A product line of gearmotor-type rotary electromechanical actuators has been designed to accelerate and facilitate the development of prototype robots. These actuators feature generic designs that are amenable to adaptation or modification for specific applications. These actuators are generally more versatile and capable than are commercial off-the-shelf gearmotor-type actuators, which are often unsuitable for use in prototype robots for various reasons that can include limits on speed and torque capacities, limits on load-bearing capacities, lack of passages in shafts to accommodate wiring to be connected to other equipment, inadequacy of angle-measuring capabilities, and geometric configurations that can be unsuitable for use with or attachment to other mechanical components.

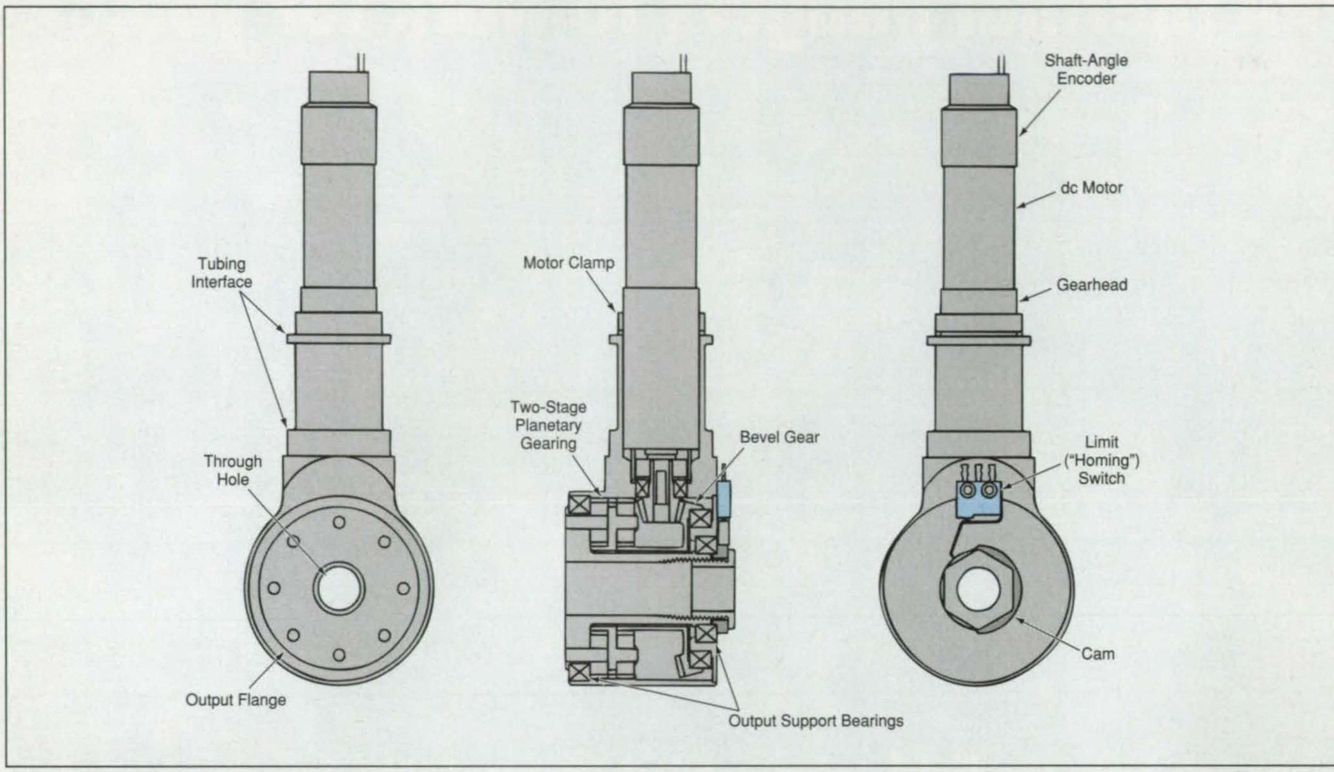
The approach taken in designing these actuators involved building on a commercial line of miniature dc gearmotors with motor, gearhead, and shaft-angle-encoder options that span wide ranges of torque, speed, and angle-measuring capability. The approach involved designing a highly versatile gearbox to (1) accept the maximum speed and torque that could be supplied by the chosen gearmotor and produce output speed and torque to satisfy any reasonable speed and torque requirement and (2) overcome the common limitations of commercial off-the-shelf actuators.

A typical actuator of this type (see figure) includes a dc motor equipped with a shaft-angle encoder and gearhead oriented perpendicularly to an output shaft. The motor and gearhead drive a bevel gearset with a torque rating equal to that of the gearhead connected to the motor. The axis of the bevel gearset is coincident with that of the output shaft. The bevel gearset drives a planetary gear train, which can have whatever number of stages is needed to effect the desired speed reduction. A single clamp retains the shaft-angle-encoder/motor/gearhead assembly in the gearbox housing. Bearings for the bevel and planetary gears and for the output provide support against all rated loads.

The output shaft is hollow to accommodate wiring. An output flange on one end of the output shaft contains eight holes; this output configuration provides the capability to transmit high output torque. A cam is attached to the other end of the output shaft. A switch triggered by the cam can be used for "homing" the output shaft to specified limiting angles. The cam can be shaped to trigger the switch at specific desired

angles. The cam can be adjusted to a desired angle setting by loosening a nut that holds it in place.

This work was done by Timothy Ohm and Jack A. Frazier II of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 25*** *on the TSP Request Card. NPO-20054*



This ***Electromechanical Actuator*** *features a generic design that imparts a wide range of capabilities and adaptability for specific applications.*

Manufacturing/Fabrication

Improved Electrode for Vacuum Arc Vapor Deposition

Redirection of arc and arc gas reduces exposure time and increases electrode life.

Marshall Space Flight Center, Alabama

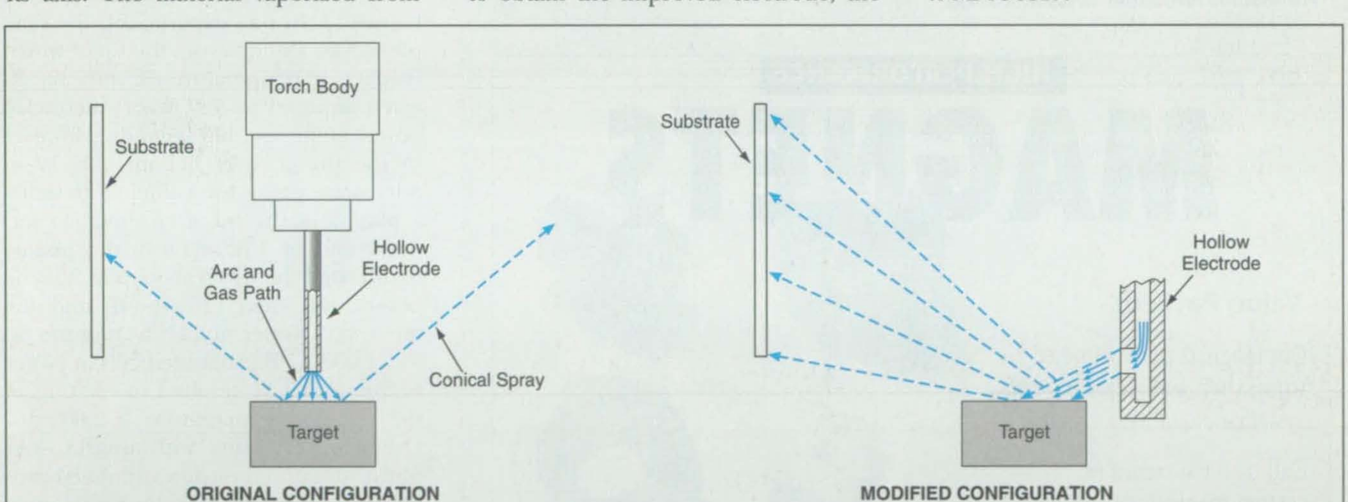
An apparatus for vacuum arc vapor deposition (VAVD) features an electrode configuration that has been modified to redirect the arc and arc gas to obtain a spray of vaporized material that is more concentrated in one specific direction. As a result, the rate of deposition is increased and the time of exposure of the substrate material to deposition conditions is correspondingly reduced. Furthermore, the arc-emission area is increased, with a consequent increase in the longevity of the electrode.

Control over vapor direction has been a problem during the development of VAVD. In its original configuration, the VAVD torch includes a hollow cylindrical electrode with a hole along its axis. The material vaporized from the target is accelerated into the vacuum in a conical spray with a half-cone angle of about 45° with respect to the axis of the electrode (see figure). The conical spray is fairly efficient for coating the inside of a ring, hole, or other surface that circumferentially surrounds the electrode and target, but is less efficient for coating a substrate that does not surround the electrode and target in the case of a substrate that must be positioned on one side of the axis; some of the spray heads for the substrate as desired, but most goes off in other directions and is thus wasted. Thus, the rate of deposition is not as great as it could be if more of the spray could be utilized.

In modifying the original electrode to obtain the improved electrode, the bottom end was welded closed and a port for the arc and gas was opened on one side. The arc-emission area in the improved electrode is located on the inside of the electrode near the side hole, and the arc and gas are directed out through the hole obliquely towards the surface of the target.

This work was done by Jack L. Weeks and Douglas M. Todd of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 24*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-30119.



A Greater Fraction of the Vaporized Target Material *is directed toward the target in the improved configuration.*

Plasma-Enhanced Microwave Heating

Heating is effected first by a microwave plasma torch, then by microwaves alone.

NASA's Jet Propulsion Laboratory, Pasadena, California

Plasma-enhanced microwave heating is an improved hybrid technique for heating materials to high processing temperatures. This technique can be used in such fabrication processes as joining ceramic rods, drawing ceramic fibers, sintering, igniting combustible materials, and joining ceramics to metals.

The need for a hybrid heating technique arises as a result of the temperature dependence of the microwave-absorption characteristics of ceramics. In general, the degree of absorption of microwave power by a dielectric material increases with temperature, such that most materials absorb with reasonable effectiveness at temperatures ≥ 800 °C. However, at lower temperatures, typical ceramics that one seeks to process absorb microwaves too weakly for practical microwave heating. Therefore, prior to heating a sample of ceramic with microwave power, it is usually necessary to use another heating technique to preheat the sample. In an older hybrid heating technique, the sample is preheated in a conventional radiant furnace; this technique is too expensive and slow and thus uneconomical for commercial production purposes. Plasma-enhanced microwave heating is expected to be more commercially viable.

In preparation for plasma-enhanced microwave heating, the sample is placed in a resonant microwave cavity in air. For preheating, a suitable gas (e.g., helium) that can be dissociated easily in the microwave electric field is pumped through the cavity and microwave power at the frequency of resonance of the cavity is used to generate a plasma in the gas. Ordinarily, the plasma is ignited at a position of intense electric field. Initially, the plasma heats the sample much more effectively than does the microwave radiation, so that the sample becomes preheated. Once the sample has reached the desired preheat temperature, further use of the plasma would waste energy and the plasma would shield the sample from the microwave radiation. Accordingly, the flow of gas is stopped to turn off the plasma, and the sample is then heated further by microwave irradiation alone. Alternatively, the microwave-generated plasma can be used as a plasma torch to heat objects that cannot be heated effectively by microwaves.

The position(s) of high electric field depends on the electromagnetic mode of the cavity as modified by the sample. In general, the unmodified electromagnetic mode of the cavity features one or more position(s) of highest electric field. In addition, high electric fields occur at sharp edges and narrow ends of objects placed in the cavity. One can exploit these effects to maximize the capability to generate a plasma on a sharp edge or narrow end of a sample; this can be done by placing a sample with the affected edge or end at the maximum-electric-field position of the cavity electromagnetic mode.

The feasibility of plasma-enhanced microwave heating was demonstrated in an experiment in a rectangular waveguide cavity excited in the TE_{102} mode, using helium as the plasma gas and various rod samples. In each case, the rod was oriented along a maximum-electric-field line with its tip positioned at the point of maximum electric field (see Figure 1). In one experiment, the sample was an alumina rod, the tip of which reached a temperature of only 65 °C when exposed to 500 W of microwave power alone for 400 seconds. However in the presence of helium, 200 W of microwave power was sufficient to ignite a plasma at the tip after about 45 seconds, and by 120 seconds, the plasma had heated the tip to about 900 °C. The plasma was then turned off, and the microwave power quickly heated the tip to > 1,600 °C. Further increases in power to about 300 W resulted in melting of the tip at a temperature ≥ 2,000 °C. Other experiments with quartz, sapphire, aluminum nitride and metal rods have also demonstrated the feasibility of this technique.

Figure 2 illustrates the use of plasma-enhanced microwave heating to join two ceramic rods end-to-end. First, a rod is inserted from the top of the cavity as in Figure 1 and a helium plasma is ignited at its tip. Then a second rod collinear with the first rod is inserted from the bottom and positioned to leave a gap of < 1/2 in. (< 12.7 mm) between the tips of the two rods. Because of the concentration of microwave electric field in the gap, the plasma becomes locked in the gap. The plasma quickly preheats both tips. Once the preheat temperature has been reached, the plasma is turned off and the

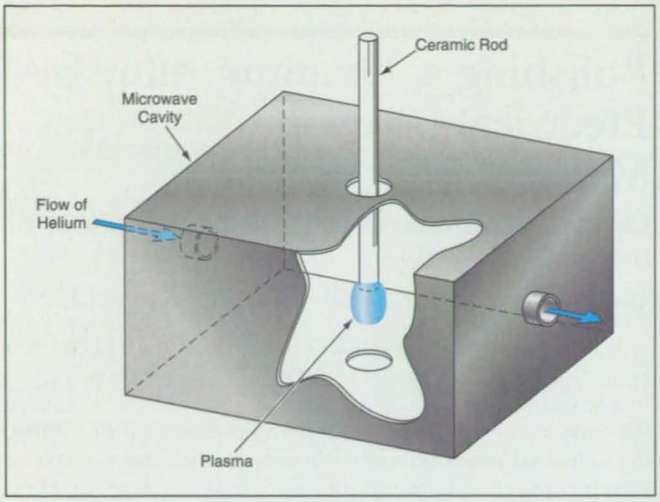


Figure 1. ***A Plasma Is Formed*** *at the lower tip of the ceramic rod at the position of maximum electric field in the microwave cavity. The plasma can be used to preheat this rod for subsequent heating by microwave power alone. The plasma could also be used as a torch.*

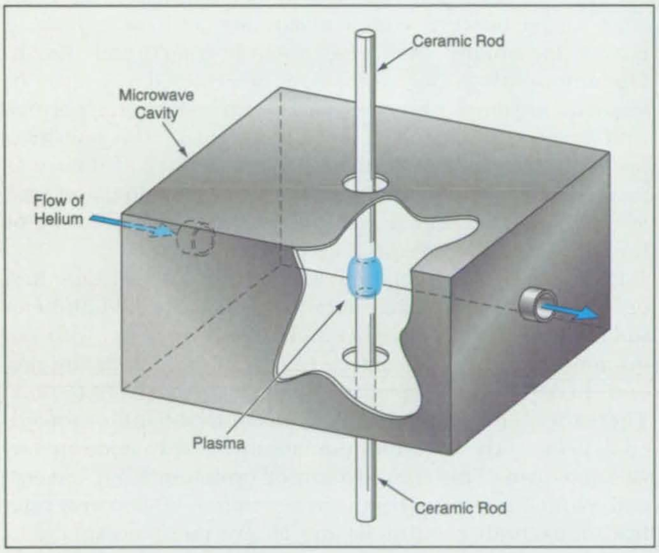


Figure 2. ***Two Ceramic Rods Can Be Joined*** *tip-to-tip by plasma-enhanced microwave heating of the tips, then pushing the tips together.*

tips are heated to melting temperature by microwave power alone. The rods are then pushed together to form a joint.

A modified version of the arrangement of Figure 1 can be used to draw a fiber of the rod material. Once the tip of the rod has been melted in the microwave-only processing stage, a fiber is inserted from the bottom of the cavity. The tip of the fiber is placed in contact with the molten tip of the rod, then pulled down to draw a fiber from the molten tip material.

This work was done by Tzu-Yuan Yiin, Martin B. Barmatz, and Henry W. Jackson of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 28** on the TSP Request Card.*

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

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Technology Transfer
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Refer to NPO-19483, volume and number of this NASA Tech Briefs *issue, and the page number.*

Polishing a Titanium Alloy by Electrical-Discharge Machining

Optimum EDM settings yield a relatively high finish.

Goddard Space Flight Center, Greenbelt, Maryland

A traveling-wire electrical-discharge machine (EDM) has been found to produce a superior intermediate finish on one surface of a titanium-alloy workpiece, thereby reducing the time that must be spent in manual polishing to achieve the required ultimate surface finish. Before the workpiece was thus processed, generator control parameters for EDM polishing of the alloy were not available and had to be determined experimentally.

The alloy in question was Ti/6Al/4V (the numbers indicate weight percentages). The workpiece had a thickness of 3.5 in. (8.89 cm). Generator parameter settings on the EDM were varied between rough machining and two polishing passes to obtain the best possible machined finish. Optimum settings (see table) were determined in a series of test cuts in scrap. Reverse polarity (wire electrode positive with respect to the workpiece) was used in the polishing passes to reduce the granularity of the surface of the workpiece. Flushing pressure was set as low as possible, and wire tension was set as high as possible to reduce the vibration of the wire, thereby improving the surface finish.

If previously documented EDM generator settings had been used, a finish of 125 microinches (3.2 μm) root mean square (rms) would have been obtained. However, with the optimum settings, the surface finish achieved after the second EDM polishing pass was 32 microinches (0.8 μm). Thereafter, only 15 minutes of polishing by hand was needed to achieve the required ultimate finish of 16 microinches (0.4 μm) rms. This combination of optimum EDM settings and manual polishing results in a saving of 80 percent, relative to machining and polishing by previously documented methods.

This work was done by N. Grant Piegari and Dewey Dove of **Goddard Space Flight Center.** *No further documentation is available.*
GSC-13723

Parameter	Rough Machining to 125 μin. rms	Polishing to 73 μin. rms	Polishing to 32 μin. rms
Machining Mode	1	7	7
Machining Potential, V	–3	+3	3
Maximum Current, A	11	9	7
Pulse Duration, μs	4	2	1
Pulse Frequency, kHz	55	125	250
Reference Speed, m/min	0.172	0.911	0.911
Wire Speed, m/min	9.2	7.2	7.2
Wire Tension, kg weight	1	1.2	1.2

These ***Generator Parameter Settings*** *for an electrical-discharge machine (Charmilles Model 600 or equivalent) were found experimentally to be optimum for rough machining followed by polishing to the indicated surface finishes.*

Improved Fabrication Technique for Submillimeter Split-Finger Backshorts

Fabrication time is reduced and quality is enhanced.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved process for fabrication of split-finger, contact-type backshorts for millimeter- and submillimeter-wavelength waveguide components has been developed. A split-finger, contact-type backshort (see Figure 1) is made from a strip of beryllium copper with thickness and width chosen for a close fit inside a waveguide of rectangular cross section. Slots perpendicular and parallel to the broader sides of the strip are machined into one end to split that end to form the contact fingers, and the contact fingers are bent outward slightly to ensure spring-loaded contact with the interior of the waveguide in the presence of geometric imperfections.

Because of the small dimensions of the slots and fingers, it is difficult and time-consuming to make backshorts by conventional machining of individual units, the quality of the resulting fingers tends to be poor, and the fingers are often weakened and damaged by the machining process itself. The improved process enables mass production of backshorts of better quality, greater uniformity, and greater reliability, and it costs less than conventional machining does. In the original laboratory setting in which the improved process was developed, it was possible to fabricate 640-GHz backshorts like that of Figure 1 at the rate of three per day by conventional machining. The rate of production increased to 100 per day when the improved process was introduced.

The raw material for the improved process is a cold-rolled, unhardened beryllium copper sheet with a thickness about 0.001 in. (about 0.025 mm) less than the smaller of the two inside cross sectional dimensions of the waveguide. In the first step of the process, the sheet is cut to a length of about 1 in. (25 mm) long and width of about 1/4 in. (6 mm). The long edges of the sheet are rounded by a few strokes with an Arkansas stone. The sheet is rigidly clamped between two aluminum plates (see Figure 2) with one of its rounded long edges protruding slightly, then the protruding edge is lapped flush with the clamp.

The clamp holding the beryllium copper sheet is mounted on a vacuum chuck on the translation table of a high speed saw of the type ordinarily used to dice wafers (e.g., integrated-circuit wafers). Initially, the clamp is aligned so that the saw cuts along the sheet in the plane located halfway through the thickness, and the sheet is thus slit along its full length to the required depth. The clamp is then rotated 90°, and multiple cross cuts are made at specified intervals to form the fingers of multiple backshorts that

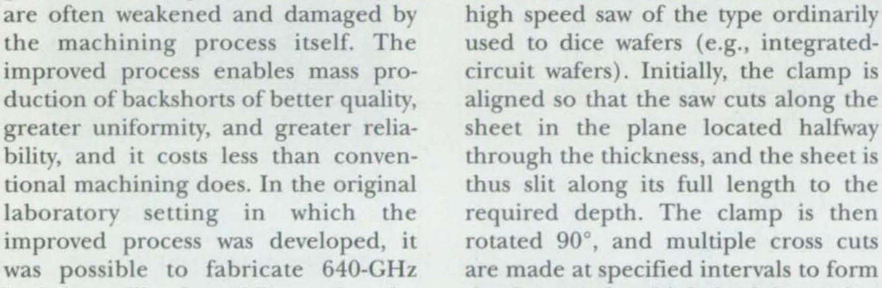

*Figure 1. **This Contact Tip of a Typical Backshort** is dimensioned for use at a frequency of 640 GHz in a waveguide with an interior cross section of 0.00625 by 0.0125 in. (0.159 by 0.318 mm).*

are to be made from the sheet. Of course, the thickness of the blade determines the thickness of the slots. Because the saw operates automatically, intensive oversight by a technician is unnecessary.

Once all the slots have been cut, the sheet is removed from the clamp and affixed to a silicon wafer by use of a commercially available clear wafer wax. The wafer and sheet are positioned for cross cutting by the dicing saw, and the saw is set to cut through the thickness at multiple specified positions along the length to separate the sheet into multiple backshorts. In the case represented by Figure 1, it was possible to obtain more than 60 backshorts, each 0.25 in. (6.35 mm) long and 0.0120 in. (0.305 mm) wide from a single sheet. [The maximum height of the backshorts is limited by the maximum cutting height of the dicing saw. The authors have recently discovered that their saw is capable of producing backshorts up to 0.700 in. (17.78 mm) in length.]

The wax is dissolved to release the backshorts. Each backshort in turn is set in a vice, slit side up, and a scalpel is used to pry the fingers apart, thickness-wise, to a distance of about 0.002 in. (0.05 mm) greater than the smaller interior dimension of the waveguide. Although this prying operation involves manual piece work, it takes little time (less than 2 minutes per piece).

The backshorts are then hardened in an argon oven at a temperature of 600 °F (318 °C) for 3 hours to impart springiness to the fingers. Finally, each backshort is soldered into place on a brass holder attached to a micrometer drive, which is used to adjust the position of the backshort along the waveguide.

This work was done by Peter H. Siegel and John E. Oswald of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 49*** *on the TSP Request Card.*
NPO-19809

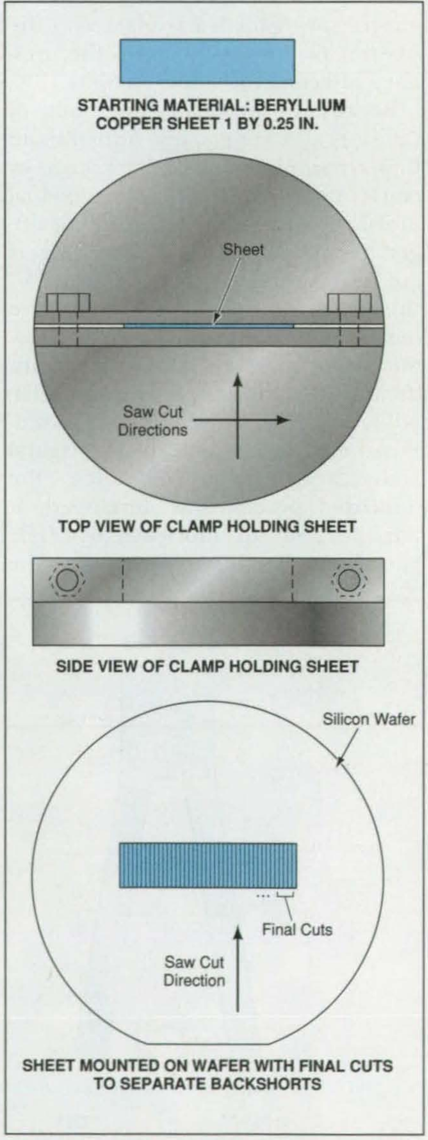

Figure 2. A ***Sheet of Beryllium Copper*** *is clamped rigidly to enable a dicing saw to cut narrow slots along and across one edge to make contact fingers, then the sheet is held by wax on a silicon wafer and diced to obtain multiple backshorts.*

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Incremental State Saving in SPEEDES Using C++

Improved state-saving techniques prevent overloading of computer memories.

NASA's Jet Propulsion Laboratory, Pasadena, California

The incremental state-saving capability of the object-oriented Synchronous Parallel Environment for Emulation and Discrete Event Simulation (SPEEDES) operating system has been extended to encompass general incremental state-saving methods. [SPEEDES and an adaptive, parallel, discrete-event-simulation-synchronization algorithm called "Breathing Time Buckets" developed in SPEEDES were described in "Synchronization of Parallel Discrete Event Simulations" (NPO-18414), *NASA Tech Briefs*, Vol. 16, No. 9 (September, 1992), page 129.] The present improvements have been accomplished through the use of a rollback queue and through inheritance using a base-class rollback item. An additional feature of the improved operating system is the use of a new technique for supporting lazy cancellation. ("Lazy cancellation" denotes a concept for avoiding the need to cancel or roll back events that are simulated out of chronological order but produce the same results as if simulated in chronological order.)

The greatest challenge in the field of parallel discrete-event simulation is to provide general mechanisms for current-event processing, for example, processing time-tagged events for simulated objects in their ascending time order, while simultaneously achieving high parallel performance. It is difficult to ensure correctness (in the sense of preserving causality) in a parallel simulation in which objects are distributed among multiple processors because each processor tends to advance at its own rate. Because of the different rates of advance, an event simulated on a slow node (processor) can sometimes result in scheduling of an event in the simulated past of another object that resides on a faster node; this violates causality, potentially rendering invalid all events simulated on the faster node back to the event in question.

Optimistic parallel discrete-event simulation engines require rollback mechanisms to restore the states of simulation objects to those of earlier times when events are accidentally processed out of time order. Traditional approaches involve saving the entire state of an object before its next event is processed, so that its original state can be restored. However, this approach can very quickly use up all of the available memory in a processor. In addition, the overhead for copying large amounts of memory can be quite high. Thus, there exists a need for a reversible incremental state-saving technique.

EVENT

```
Variables
int input1;
double input2;
double output;

Methods
//......Process Event Phase 1
void C_Event::Phase1() {
//......get inputs
  input1 = object->get_input1();
  input2 = object->get_input2();

//......process stuff
  output = input + 2.0 * input2
}

//......Delta Exchange
void C_EVENT::exchange() {
  object->exchange_output(output);
}

//......Check Lazy
int C_EVENT::check_lazy() {
  If (input1 I = object_>get_input1())
    return 0;
  If (input2 I = object_>get_input2())
    return 0;
  return 1;
}
```

SIMULATION OBJECT

```
Variables
int input1;
double input2;
double output;

Methods
//......get input1
int C_OBJECT::get_input1() {
  return input1;
}

//......get input2
double C_OBJECT::get_input2() {
  return input2
}

//......exchange output
void C_OBJECT::exchange_output(double o) {
  EXCHANGE(output, o);
}
```

***These Samples of Code** show how a user can participate in a lazy cancellation in SPEEDES.*

The present improvements fill this need. These improvements are based partly on the recognition that events can store important input information in their internal data structures to support sophisticated optimization techniques. For example, the user can specify lazy cancellation for specific events — hopefully, the ones most likely to benefit from lazy cancellation, while using aggressive cancellation as the default mode of cancellation for the rest.

One of the most efficient ways to handle incremental state saving in parallel discrete-event simulations is an algorithmic mechanism called "Delta Exchange." In the SPEEDES implementation of Delta Exchange, an event changes the state of a variable in a simulation object by exchanging this variable with a similar variable that is stored in the data structure of the event. State changes of this type can easily be accomplished by dividing the processing of each event into two steps. The first step is the basic processing of the event, while the second step is the Delta Exchange, in which the new state values are exchanged with the old state values. After the Delta Exchange, the simulation object has the new state values, and the event has the old values. If the Delta Exchange is performed

again, the variables are restored and the simulation object returns to its original state.

In addition to the Delta Exchange, another mechanism is needed to save the state of the object incrementally as it is modified by the processing of an event. This is accomplished by use of a SPEEDES construct called the "Rollback Queue." When an event does something to change the state of its simulation object, a rollback item is pushed onto the top of the Rollback Queue. Specific rollback items, which are C++ objects, inherit from the base class Rollback Item object. The base-class Rollback Item defines three virtual functions that make it easy to store values, roll back an event, or clean up the rollback queue, respectively. The incorporation of new types of rollback items into the SPEEDES programming environment becomes very easy in this approach.

Rollback of an event is accomplished by popping rollback items out of the Rollback Queue, then calling their rollback virtual function to undo whatever was done. The rollback items are then stored in reverse order in another list called "qreverse." This provides the rollforward capability needed for lazy cancellation. After an event is successfully processed, its rollback information must be cleaned up. This is accomplished by popping the rollback items out of the Rollback queue, then calling its cleanup virtual function. Some of the rollback items do not require any work for cleanup. In these cases, the base-class virtual cleanup function is called, but does no processing.

Lazy cancellation helps to prevent the wasteful processing that would occur in rolling back events that produce the same results. Lazy cancellation in SPEEDES follows an object-oriented approach that produces results quickly, with less overhead than in other approaches. Because events are represented as objects in SPEEDES, the inputs from a simulation object that are required for processing an event can be saved in the data structures of the event object. Before reprocessing the event (after it has been rolled back), a virtual function called "Check_Lazy" is called. This virtual function, which is supplied by the user, (see figure) compares the previous inputs from the simulation object still stored in the event object with the new values in the simulation object. If they are the same, or if it is determined that the event would still produce the same result, then this virtual function returns a 1. Otherwise, it returns a 0. If the Check_Lazy virtual function returns a 1, the event is rolled forward. Otherwise, antimessages are sent, and the event is reprocessed.

After an event has been rolled back, SPEEDES checks a flag stored in the event object that tells whether the event is participating in lazy cancellation. This enables events to participate on a selective basis in lazy cancellation. When it is time to process that event again, SPEEDES checks whether the event would have produced the same result.

Lazy cancellation may be performed in a very efficient manner in which event-processing inputs from the simulation object are saved in the event object, and then later before reprocessing the event, the simulation object is checked to determine whether the values corresponding to these inputs have changed or would produce a different result. This approach is much more efficient than are most other approaches which involve byte-for-byte comparisons of the old state of the simulation object with its new states, The present approach is also more flexible.

This work was done by Jeffrey S. Steinman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 41 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-19424.

A Remote Agent Prototype for Spacecraft Autonomy

Tasks would be communicated to a system at a high level of abstraction.

NASA's Jet Propulsion Laboratory, Pasadena, California

The New Millennium Remote Agent (NMRA) architecture is a prototype architecture for artificial-intelligence systems that would govern the functions of nearly autonomous robotic systems. In the original intended application, the robotic systems would be small exploratory spacecraft now undergoing development in NASA's New Millennium Program. Scientists would communicate high-level scientific goals to a spacecraft, and the NMRA hardware/software system aboard the spacecraft would then work out the lower-level details; it would plan and schedule scientific observations by on-board instruments, translate schedules into sequences of operations, verify that the operations would not damage the spacecraft, execute the operations, and respond to errors and equipment failures (responses could include rescheduling), all without routine human intervention. The NMRA architecture might also prove adaptable to other, terrestrial robotic systems for which there is a need to implement semiautonomous operation with only occasional high-level, possibly non-real-time human intervention.

The NMRA architecture integrates the following concepts:

- Traditional real-time monitoring and control;
- Constraint-based planning and scheduling to ensure achievement of long-term mission objectives and effective allocation of scarce resources;
- Robust multi-threaded-execution software for reliable execution of planned sequences under uncertain conditions, for rapid response to failures and other unexpected events, and for management of concurrent real-time activities; and
- Model-based diagnosis to confirm successful execution of plans and to infer the functionality of all equipment on the basis of inherently limited information from sensors.

Continuous autonomous operation would involve the following cycle:

1. High-level goals (e.g., to take more pictures) would be retrieved from a database.
2. Planning and scheduling software would be asked to generate a schedule, given such input data as the available time and the actual or anticipated state of all relevant hardware. The resulting schedule would be represented as a set of tokens (relatively abstract commands) placed on various state-variable time lines, with temporal constraints between tokens.
3. The schedule would be sent to executive software, which would act at the designated times to translate the tokens into sequences of lower-level (less abstract) commands subject to the temporal constraints. For each token, the executive software would then attempt to execute the lower-level commands and either (a) verify successful execution, (b) retry in case of failure to execute, or (c) generate alternate low-level commands to achieve the goal represented by the token. Hard failures to execute commands could necessitate modification of the schedule, in which case the executive software would coordinate the actions needed to keep hardware systems in a safe state and would request a new schedule from the planning and scheduling software.
4. The cycle would be repeated from step 1 whenever (a) execution reached the applicable time horizon or (b) the executive software requested a new schedule as a result of a hard failure.

The executive software would constitute one of four layers of the NMRA architecture. Execution of a schedule would be achieved through cooperation of the executive software with the three other layers. The executive software would reason about the overall hardware system in terms of a set of component modes. From inputs that would include sequences of commands and observations from sensors, a mode-identification layer would generate component-mode information; that is, information about the current mode (nominal or failed) of each hardware component. The mode-identification layer would receive its inputs from a monitoring layer, which would take the raw sensor-data stream and discretize it to the level of abstraction required by the mode-identification layer. A control-and-real-time-system layer would take commands from the executive layer, implement low-level control of the state of the hardware, and provide low-level sensor data to the monitoring layer.

This work was done by Nicola Muscettola, P. Pandurang Nayak, and Brian C. Williams of Recom Technologies at NASA Ames Research Center; Barney Pell of Caelum Research at NASA Ames Research Center; Michael D. Wagner of Fourth Planet; and Douglas E. Bernard, Steve A. Chien, Erann Gat, Kim Gostelow, and Robert Rasmussen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 8*** *on the TSP Request Card.*
NPO-19992

Punctured Convolutional Codes for Seamless Data-Rate Changes

Fewer changes in symbol rates (with possible loss of symbol lock) would be necessary.

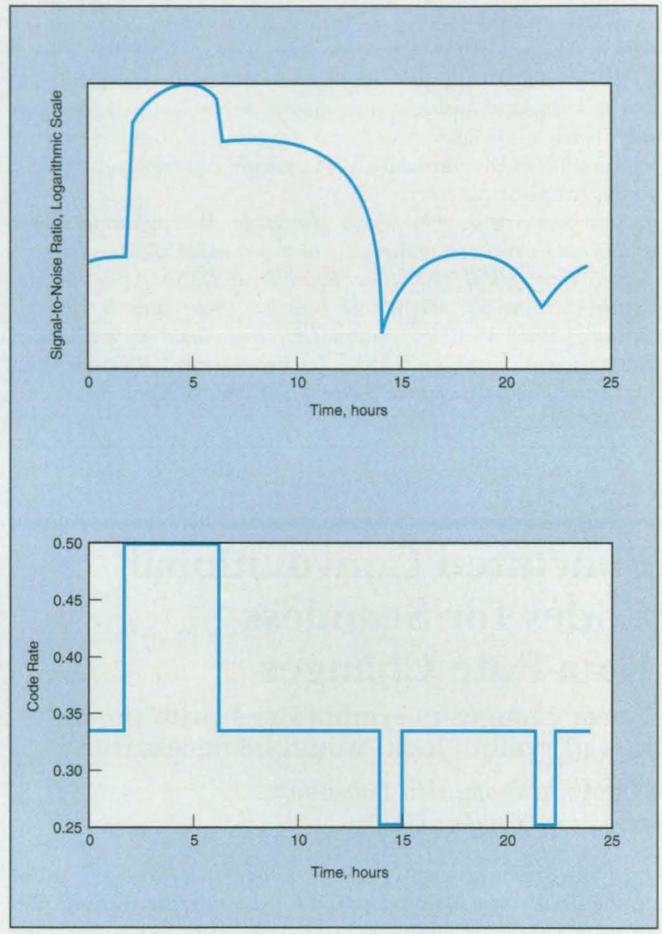
NASA's Jet Propulsion Laboratory, Pasadena, California

Error-correcting convolutional codes that are said to be "punctured" have been proposed for use in radio transmission of a binary data signal over a channel with a signal-to-noise ratio (SNR) that is low and that fluctuates during the day. The basic task is to maximize the data return by use of the highest practicable data rate without exceeding a given bit-error ratio (BER) at the given SNR. Heretofore, this task has been accomplished by changing the symbol rate (the rate at which the code is transmitted in the channel) to suit the changing SNR. Unfortunately, changing the symbol rate causes undesirable side effects; it changes the transmission bandwidth, and it can make the receiver temporarily lose its lock on the symbol phase and thus lose some data.

The proposed punctured convolutional codes offer an alternative that could reduce the need for changes in symbol rates: the transmission would continue seamlessly because the symbol rate would be kept the same and when the SNR changed, the data rate would be changed accordingly at the coding stage (see figure) instead of at the transmission stage. Increases in symbol rates would be reserved for instances where SNR was high enough to provide ample BER margin; decreases in symbol rates would be reserved for instances where SNR was so low as to cause the receiver to lose symbol lock.

To change the data rate at the coding stage, one must switch to a code that features the corresponding new rate. (The rate of a code is defined as the ratio between the number of information bits and the number of bits in the code symbols that convey that information). The advantage of using punctured convolutional codes (as distinguished from other convolutional codes) is that one can change to a code of a different rate without changing the basic structures of the encoder in the transmitter and the decoder in the receiver.

A regular convolutional code of rate $1/N$ generates N binary code symbols per information bit. It has been found that one can generate a convolutional code of higher rate by periodically and systematically refraining from transmission of some of the code symbols; this periodic, systematic omission of symbols is what is meant by "puncturing" in this context.



*A **Hypothetical System Would Switch** among available codes with rates of 1/4, 1/3, and 1/2, according to the SNR and the achievable BER.*

Let the code be characterized by a period that contains L information bits, which are conveyed by NL code symbols. One can define a puncturing pattern, P, in the form of a codelike right-to-left chronological sequence of L groups of N binary symbols each. A "1" at a given location in this sequence denotes that the code symbol in the corresponding time slot is to be sent, whereas a "0" at a given location denotes that the symbol in the corresponding time slot is to be deleted. If there are m zeros in P, the resulting punctured code has a higher rate; namely, $L/(NL - m)$, where $0 < m < (N - 1)L$.

For example, consider a code with $N = 4$ (rate = $1/4$) and $L = 4$. One puncturing pattern for this code is $P = \{0111\ 1110\ 1011\ 1101\}$, for which $m = 4$. The rightmost digit corresponds to the first code symbol and the rightmost group of four digits corresponds to the four code symbols of the first information bit. This puncturing pattern indicates that the second symbol in the first bit, the third symbol in the second bit, the first symbol in the third bit, and the fourth symbol in the fourth bit in a period are deleted. The rate of the resulting punctured code is $4/(4 \times 4 - 4) = 1/3$.

Once having chosen to puncture a code to achieve a given rate, the problem is to find the puncturing pattern that gives the lowest BER for the given rate and the given range of SNR values. The search for the best puncturing pattern is rather complex, involving consideration of a number of factors from code theory, computational simulation, and practical implementation.

This work was done by Ying J. Feria and Kar-Ming Cheung of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 68 on the TSP Request Card. NPO-19555*

Software Produces SAR Image Data Products

NASA's Jet Propulsion Laboratory, Pasadena, California

"SIR-C GDPS" denotes a set of computer programs that generate image data products from raw data acquired in synthetic-aperture-radar (SAR) scans of the Earth performed during two missions of the space shuttle. SIR-C GDPS is divided into the following five software packages:

- The Catalog Subsystem package contains programs that enable the user to search for available data and request data products.
- The Control Processor Executive package contains a task-manager, a remote-task-manager, and a graphical-operator-interface program.
- The Data Transfer Subsystem package contains programs that control the readout of the specified SAR data from high-density digital cassettes.
- The programs in the SAR Correlator Subsystem package process the raw SAR signal data into image data. These programs estimate Doppler centroids and rates, perform radiometric and polarimetric calibrations, produce single-look complex SAR imagery, generate geometrically rectified and reduced-data multilook SAR imagery, and generate byte image files for display and printing.
- The Output Products Subsystem package contains programs that produce compact-disk read-only-memory (CD-ROM) files, annotated printed images, and tapes containing the processed SAR data.

These programs were written by Chi-Yung Chang, David Perz, Jeffrey Levison, Patricia Barrett, Tracy Clark, Dieuthuy Nguyen, Quyen D. Nguyen, Shirley Pang, Theresa Wright, Howard Yun-Howe Chu, and Sam Southard of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 33 on the TSP Request Card. NPO-20005*

Self-Regenerating Water Iodinator

This unit can function automatically for years.

Lyndon B. Johnson Space Center, Houston, Texas

A regenerable water iodinator can operate for many years without replacement or human intervention. The regenerable water iodinator, also called a "regenerable microbial check valve," (RMCV), is used to kill bacteria to make reclaimed water potable.

The RMCV was developed to replace expendable flow-through iodination canisters or microbial check valves of a type that have been used in space shuttles and that must be replaced after 30 days' use. Intended for use on Space Station Freedom, the RMCV is expected to match the 30-year life expectancy of that spacecraft. It will thus eliminate the maintenance time and materials that an expendable purifier would necessitate. Terrestrial versions of the RMCV could be useful in portable emergency or shipboard water-purification systems, or in stationary systems that are required to operate unattended for long times.

The RMCV includes an iodinated ion-exchange resin bed that kills microbes on contact and imparts a residual iodine content to the water flowing through it. In the normal mode of operation, water flows directly through the resin bed (see figure). The effluent from the resin bed flows through an on-line iodine monitor, which measures the residual iodine in the stream and passes the information to a control computer.

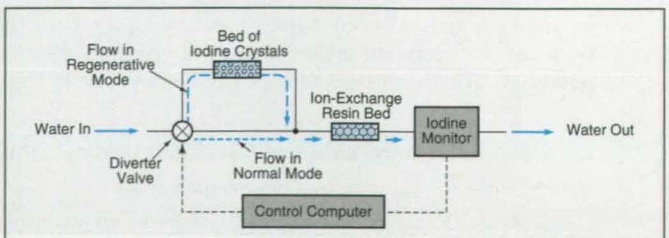
The computer performs a running integration of the iodine levels to determine the mass lost from the resin. When the residual iodine concentration falls below a preset value — for example, 2 mg/L — the computer switches the apparatus to the regenerative mode. It switches a diverter valve to reroute the flow of water through a packed bed of iodine crystals before entering the ion-exchange resin bed. In the iodine-crystal bed, the stream acquires an iodine concentration of 200 to 300 mg/L. The water then enters the ion-exchange resin bed, where the high concentration of iodine recharges the iodine-depleted resin.

When the computer, operating in conjunction with the iodine monitor, determines that the ion-exchange resin bed has been exposed to the high concentration for enough time to replenish the iodine in the resin completely, the computer switches the apparatus back to the normal mode. It switches the diverter valve so that the water stops flowing to the iodine bed and starts flowing directly to the resin bed. The cycle of depletion and regeneration then repeats indefinitely.

In a demonstration, four RMCVs were tested by using them to treat water containing artificial mixes of contaminants designed to simulate the effects of reclaimed wash water, humidity condensate, and urine. After a year of operation, the units were still producing adequate concentrations of iodine in the effluents, although the times between regenerations were slowly decreasing. The results of the demonstration have been extrapolated to a useful life expectancy of 19 years. With further refinement, a regenerable microbial check valve should be able to function automatically for at least 30 years.

The highly concentrated iodine solution from the iodine bed could also be extracted directly, with the resin bed bypassed, to provide a strong disinfectant for treatment of biofilms and other microbial growths. Disinfection with the iodine solution is more energy-efficient than is disinfection with steam or hot water. Unlike such disinfectants as quaternary ammonium salts, alcohol, or chlorine, the iodine stream can be produced at the time and place of use without need for storage.

This work was done by Richard L. Sauer of **Johnson Space Center** *and James E. Atwater and Richard R. Wheeler, Jr., of Umpqua Research Company. For further information,* ***write in 15*** *on the TSP Request Card.*



*The **Control Computer** switches the diverter valve to route the flow of water through an iodine-crystal bed when the iodine monitor detects a low concentration of iodine in the effluent.*

Books & Reports

Planetary Microrover

A brief report presents drawings for a conceptual design of a proposed vehicle that would traverse the surface of Mars or another remote planet, finding its way across rough, unknown terrain. The drawings show some dimensions and depict the general appearance of the vehicle, including notably six wheels on a unique suspension mechanism. This design presents significant licensing opportunities in the toy and model industries.

This work was done by Donald B. Bickler, Kenneth A. Jewett, Howard J. Eisen, and Lee F. Sword of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Mars Microrover,"* ***write in 87*** *on the TSP Request Card.*

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

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

Refer to NPO-19840, volume and number of this NASA Tech Briefs *issue, and the page number.*

Micromachined Tunable Optical Interference Filters

A report expands upon the concept of using micromachined two-stage Fabry-Perot interferometers as rapidly and repeatably tunable color filters and/or as fast shutters in miniature color television cameras and other optoelectronic instruments. The concept was described previously in this issue in "Micromachined Opto/Electro/Mechanical Systems" (NPO-19467). As described in both the report and the noted prior article: (1) the partially reflective optical flats of a two-stage Fabry-Perot interferometer would be micromachined integrally with flexible supports, along with electrodes for electrostatic control and measurement of deflection; (2) by controlling the deflections, one would control the transmission and reflection wavelength bands of the two filters; (3) by making one transmission band of one stage overlap one transmission band of the other stage, one would obtain a narrow-band-pass filter; (4) by making none of the transmission bands of both stages overlap, one would obtain a closed shutter; and (5) because these adjustments could be made at frequencies of the order of several kilohertz, one could obtain nearly simultaneous images at different wavelengths in one instrument. Thus for example, it would become possible to construct a color television camera with only one imaging detector and one color filter that would be repeatedly tuned to all required colors (e.g., red, green, and blue) in sequence at the image-repetition rate. In addition to discussing the foregoing issues, the report briefly explains the principle of operation of Fabry-Perot interferometers and the advantages of the proposed micromachined versions over traditional macroscopic versions and over liquid-crystal-filled versions.

This work was done by Benjamin P. Dolgin and Frank T. Hartley of Caltech and Paul Zavracky of Northeastern University for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Micromachined Tunable Filters for Optical Applications," **write in 3** on the TSP Request Card.*
NPO-19456

Integrated Pump Assembly for Active Cooling of a Spacecraft

A conference paper describes an integrated pump assembly (IPA) that constitutes a major subsystem of an active mechanical cooling system on the Mars *Pathfinder* spacecraft. The IPA pumps and controls the circulation of a chlorofluorocarbon refrigerant liquid to transfer excess heat from electronic and other equipment in the spacecraft to an external radiator. This is the first time such a mechanically pumped cooling loop has been used on a long duration spacecraft. The IPA contains centrifugal pumps, electronic control circuits, valves, and an accumulator. One of its novel components is a wax-actuated thermal-control valve for bypassing the radiator when the temperature of the fluid goes below 0 °C. The IPA features a modular design that made it relatively easy to test its various electronic and mechanical components independently and expeditiously during the development process. The design and fabrication of the IPA and the integration of the IPA with the rest of the cooling system and the spacecraft were accomplished in less than 18 months under severe constraints on cost and time. The IPA and the rest of the cooling system have performed well in a terrestrial laboratory solar vacuum test under flightlike conditions. The Mars *Pathfinder* was launched on December 3, 1996, and the IPA has been operating continuously and maintaining the spacecraft equipment temperatures at the right levels.

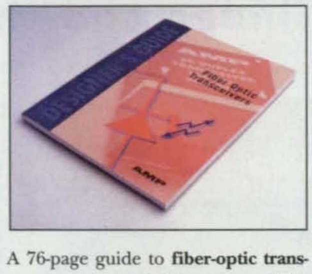
This work was done by Gajanana C. Birur, Pradeep Bhandari, and Marshall B. Gram of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the paper, "Integrated Pump Assembly — An Active Cooling System for Mars Pathfinder Thermal Control," **write in 37** on the TSP Request Card.*
NPO-20055

Development of a Mercury-Ion Frequency Standard

A continuously operating, high-reliability, ultra-stable frequency standard has been developed using ^{199}Hg ions confined in a linear ion trap (LITS). The standard is based on the physical principle described in "Linear Ion Trap for Atomic Clock" (NPO-17758), *NASA Tech Briefs,* Vol. 14, No. 9 (September 1990), page 44. The LITS includes a 10-MHz voltage-controllable quartz-crystal local oscillator or can operate with other high-performance local oscillators. The local-oscillator output is multiplied to ≈40.5 GHz and stabilized by comparison with the frequency of a ground-state hyperfine transition of $^{199}Hg^{+}$ ions. The comparison involves a combination of optical and microwave excitation and interrogation of the ions in a linear ion trap. The use of an ion trap enables the achievement of long interrogation times and a high resonance quality factor. In the LITS, a ^{202}Hg lamp provides the optical excitation at a wavelength of 194.2 nm to excite the ground-state transition, which is characterized by a frequency of about 40.5 GHz. The $^{199}Hg^{+}$ ions in the trap are cooled to near room temperature by helium at a low background pressure in the ion-trap vacuum system. Data from tests of the LITS indicate a short-term frequency stability of $2 \times 10^{-14}/\tau^{1/2}$, where τ is the averaging time in seconds. The long-term fractional variation in frequency is estimated to be less than 10^{-16} per day.

This work was done by Robert L. Tjoelker, Charles B. Bricker, William A. Diener, Robert L. Hamell, Albert Kirk, Paul F. Kuhnle, Lute Maleki, John D. Prestage, David G. Santiago, David J. Seidel, David A. Stowers, Richard L. Sydnor, and Thomas K. Tucker of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the paper, "Mercury Ion Frequency Standard Engineering Prototype for the NASA Deep Space Network," **write in 11** on the TSP Request Card.*
NPO-20012

New Literature

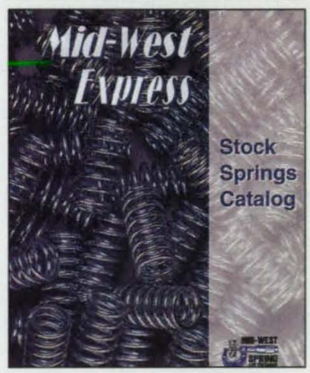


A 76-page guide to **fiber-optic transceivers** is available from AMP, Harrisburg, PA. Included are transceiver components and functions, specifications and standards, and qualification testing information for electronics designers.

For More Information Write In No. 700

Jonard Industries, Tuckahoe, NY, has released a 40-page catalog of **tools** for electronics, computers, and aerospace. Connector tools, tool kits, drivers, screws and nuts, and assembly tools are featured.

For More Information Write In No. 701



Springs are described in a 60-page catalog from Mid-West Spring Manufacturing, Romeoville, IL. Included are die, extension, torsion, and rolled wire compression springs; nitrogen cylinders; spring washers; and wire and metal custom forms.

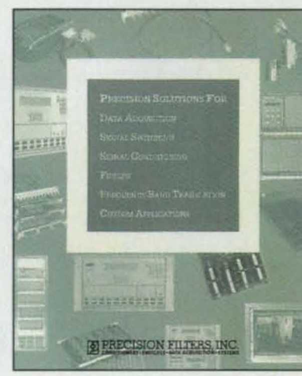
For More Information Write In No. 702

Datel, Mansfield, MA, offers a 20-page brochure on **converters, instruments, and data acquisition boards.** Products include switching DC/DC power converters, digital panel instruments, sampling A/D converters, and analog I/O boards.

For More Information Write In No. 703

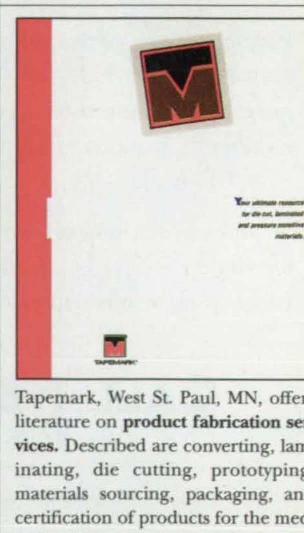
The Kimco Magnetics Div. of BEI Sensors & Systems, San Marcos, CA, has released a 16-page applications guide on **brushless DC motors** for medical, industrial, aerospace, and analytical instrumentation applications. A new section covers two-wire brushless DC motors.

For More Information Write In No. 704



A six-page brochure from Precision Filters, Ithaca, NY, describes **signal conditioning, filtering, and switching equipment.** Included are preamplifiers, transducer amplifier/filters, VME-based filters, and frequency-band translation equipment.

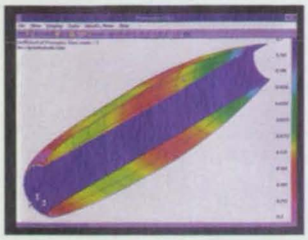
For More Information Write In No. 705



Tapemark, West St. Paul, MN, offers literature on **product fabrication services.** Described are converting, laminating, die cutting, prototyping, materials sourcing, packaging, and certification of products for the medical, electronics, computer, and industrial fields.

For More Information Write In No. 706

New on Disk

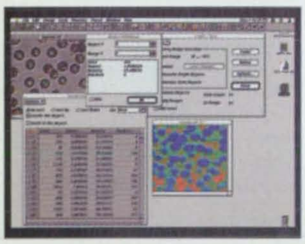


AeroLogic, Los Angeles, CA, has released Personal Simulation Works **3D computational fluid dynamics software** for Windows. The postprocessor provides graphic visualization, point-and-click streamline generation, and forces and moments for the complete model or selected patches. The program costs $2,500.

For More Information Write In No. 715

Mathcad® PLUS 6 for Macintosh **technical calculation** software from MathSoft, Cambridge, MA, features a live document interface that allows users to integrate text, calculations, and graphs, and document and share results using built-in Internet connectivity. New formatting capability; the ability to create and embed animation within a worksheet; improved editing; and direct graphing of formulas and expressions are included. Designed for PowerMac, the program supports 68030- and 68040-based systems and sells for $349.95.

For More Information Write In No. 716



Media Cybernetics, Silver Spring, MD, has released Image-Pro Plus Version 3.0 **image analysis software** for researchers and technicians who use microscopes and other image-acquisition devices. Designed for Windows 3.1, 95, or NT, the program contains a database that allows the acquisition, organization, retrieval, and exporting of images obtained from image-generating lab devices.

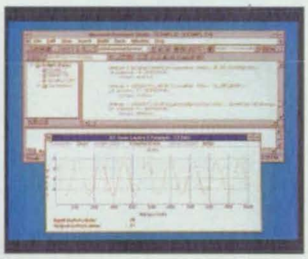
For More Information Write In No. 710

Analog Circuit Master **circuit simulation and analysis software** from Sagebrush Systems, Keizer, OR, provides simulation tools based on SPICE technology. Users can manage, operate on, and display the information generated by the circuit simulation program. The Windows 95-based software costs $1,250.

For More Information Write In No. 711

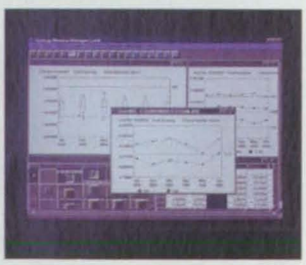
Integral Vision, Farmington Hills, MI, offers VisionBlox 2.0 **machine vision software,** which allows developers to acquire and grab live images using minimal Visual Basic or Visual C++ programming. It can design a machine vision application with a Windows graphical user interface by drawing the object onto the application platform. The software ranges in price from $1,600 to $3,600 and operates with Windows NT.

For More Information Write In No. 713



DataAcq SDK for Windows NT **data acquisition software developer's kit** from Data Translation, Marlboro, MA, allows users to create board-independent applications for Windows NT, 3.1, and 95. It includes various programmer's libraries and provides continuous throughput to or from memory at speeds greater than 950 kSamples/second using a high-speed board. Users can create memory buffers of any size within 16-Mb system memory. It is priced at $150.

For More Information Write In No. 714



Synergy Maestro Release 4.1 **statistical process control software** from Zontec, Cincinnati, OH, enables quality control managers to obtain instant reports of process improvements on a monthly basis. The Windows-based program supports direct input from gages and scales, and communications and messaging.

For More Information Write In No. 712

New on the Market

Product of the Month

Gage Applied Sciences, South Burlington, VT, has introduced the CompuScope 8500/PCI, a PCI-based multi-megahertz **data acquisition system** capable of transferring A/D data to PC memory at speeds up to 100 MB/s. It features a sample rate of 500 million samples per second for on-shot signals, storing the digitized data in onboard memory. PCI bus interface, including Bus Mastering; eight-bit vertical resolution; up to 2 megasamples of onboard memory; and drives for DOS, QNX, and Windows 3.1, 95, and NT are featured. It is capable of writing the A/D data directly to the PC's DRAM instead of storing it in the onboard memory.

For More Information Write In No. 720

Chemically vapor deposited beta **CVD silicon carbide material** from Morton Advanced Materials, Woburn, MA, offers 99.9995% purity, chemical resistance, thermal conductivity of >300 Wm-1K-1, stiffness, and polishability of <Å RMS. Fabricated parts are available up to 40" OD and 1" thick for applications in semiconductor processing, optics, wear components, and electronic packaging.

For More Information Write In No. 721

Cooper Power Tools, a division of Cooper Industries, Lexington, SC, offers the APEX K Series **swivel sockets,** which tighten metric and SAE fasteners from an offset angle of 30°. Available with either a square or hex drive, they feature a two-pin design. Standard and extended lengths are available up to 12"; extended models feature a tension sleeve that locks the socket to the desired operating angle.

For More Information Write In No. 722

Galil Motion Control, Mountain View, CA, has introduced the DMC-1411 **motion controller card** for one-and-a-half axes in the PC/104 form factor. It uses a 32-bit microprocessor and controls both servo and stepper motors. The unit controls jogging, point-to-point positioning, electronic gearing and CAM, and contouring. Multiple arrays enable real-time data capture of up to 1,000 elements.

For More Information Write In No. 732

NAC Visual Systems, Simi Valley, CA, offers the Image Intensified Lens System (ILS) for low light and UV high-speed photography. The **lens system** provides high-speed imaging to the far blue and UV spectrum. It is compatible with virtually all 16- and 35-mm film cameras, as well as video and image converter cameras. The system is used in studies of combustion, high-voltage discharge, and ballistic applications.

For More Information Write In No. 727

The Expert™ microprocessor-based dc **fiber-optic sensor** from Banner Engineering Corp., Minneapolis, MN, optimizes its sensitivity adjustment by differentiating between two received light levels. It features a seven-segment, moving dot bargraph display; and a single, sealed button for programming. It operates from 10 to 30VDC, and includes both reverse polarity and transient voltage protection.

For More Information Write In No. 723

American Linear Manufacturers, Port Orange, FL, has announced **rotary tables** in 4" and 6" diameters with preloaded, crossed-roller radial bearings, AGMA 10 gearing with several available ratios, and gear/worm drive mesh. They feature a sealed and lubricated gear and bearing cavity, and standard NEMA motor mounts and couplings.

For More Information Write In No. 725

New on the Market

Anritsu Wiltron, Morgan Hill, CA, offers the MS2653A and MS2663A **spectrum analyzers,** which cover the 9 kHz to 8.1 GHz frequency range. Results are shown on a color CRT display; a two-screen display is available for analysis of separate signals or measurements. Both models weigh 26 pounds, feature a built-in controller, and offer a PCMCIA interface.

For More Information Write In No. 724

Linear motor-driven free piston **air compressors and vacuum pumps** from Medo U.S.A., Hanover Park, IL, convert electrical energy into a pulsating magnetic field, which moves the piston through its stroke. Weighing as little as 1.5 pounds, the compressor/pump features controlled air generation, a single moving part, oil-free operation, and low noise and vibration.

For More Information Write In No. 726

The ICC-6000 Industrial Control Computer™ from Nematron Corp., Ann Arbor, MI, is a NEMA 4-rated **flat-panel computer** with an Intel Pentium processor. It offers a hinged chassis design that swings open for easy access, a 12.1" flat panel display, and SVGA resolution of 800 x 600 pixels. The electrical chassis can be changed without tools.

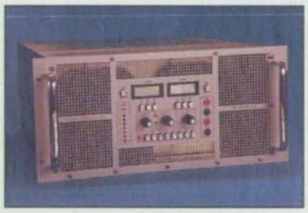
For More Information Write In No. 728

OMEGA Engineering, Stamford, CT, offers the CL506 portable **calibrator,** which features a long-life battery for field applications, and digital interfacing and I/O capabilities for laboratory usage. Features include simulation and measurement for PT 100 NI 100 RTDs, and 15 thermocouple types, as well as generation and measurement of mA, mV, V, and ohm signals.

For More Information Write In No. 729

The Series 96 1/16 DIN dual-display **controller** from Watlow Electric Manufacturing, St. Louis, MO, performs temperature measurement, event switching, remote set point input, heating, boost heating, cooling, alarms, digital communications, and retransmit. It features two inputs and four outputs, 10Hz sampling, and a NEMA 4X front panel. Hardware modules are pluggable and exchangeable; software menus can be self-programmed.

For More Information Write In No. 730



The RBL Series of **electronic loads** from Dynaload, a division of Transistor Devices, Randolph, NJ, features an adjustable slew rate to achieve rise times between 10 μs and 10 ms. Full-scale range switching provides selectable full-scale ranges for current and/or voltage, synchronized paralleling, and functionality in four modes of operation: constant current, constant resistance, constant voltage, and constant power. Standard units include 400V and 100V models.

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The Han Q5/O Han®-Drive compact **connectors** from Harting Elektronik of North America, Hoffman Estates, IL, allow quick three-phase motor interchange. They are designed for a working voltage of 400V contact-to-contact and 230V from contact to ground. The connectors feature glass-fiber reinforced polycarbonate insulators.

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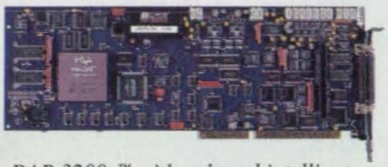

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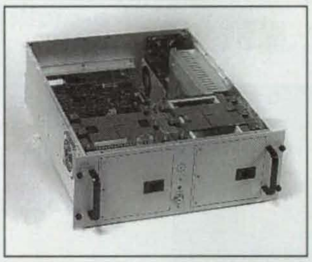

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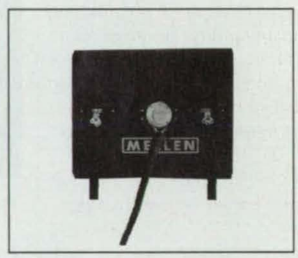

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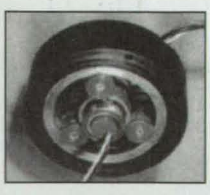

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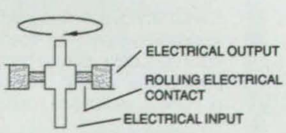

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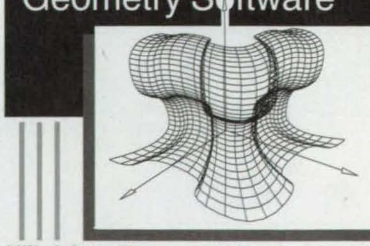

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