Vol. 21 No. 4

TECH BRIEFS

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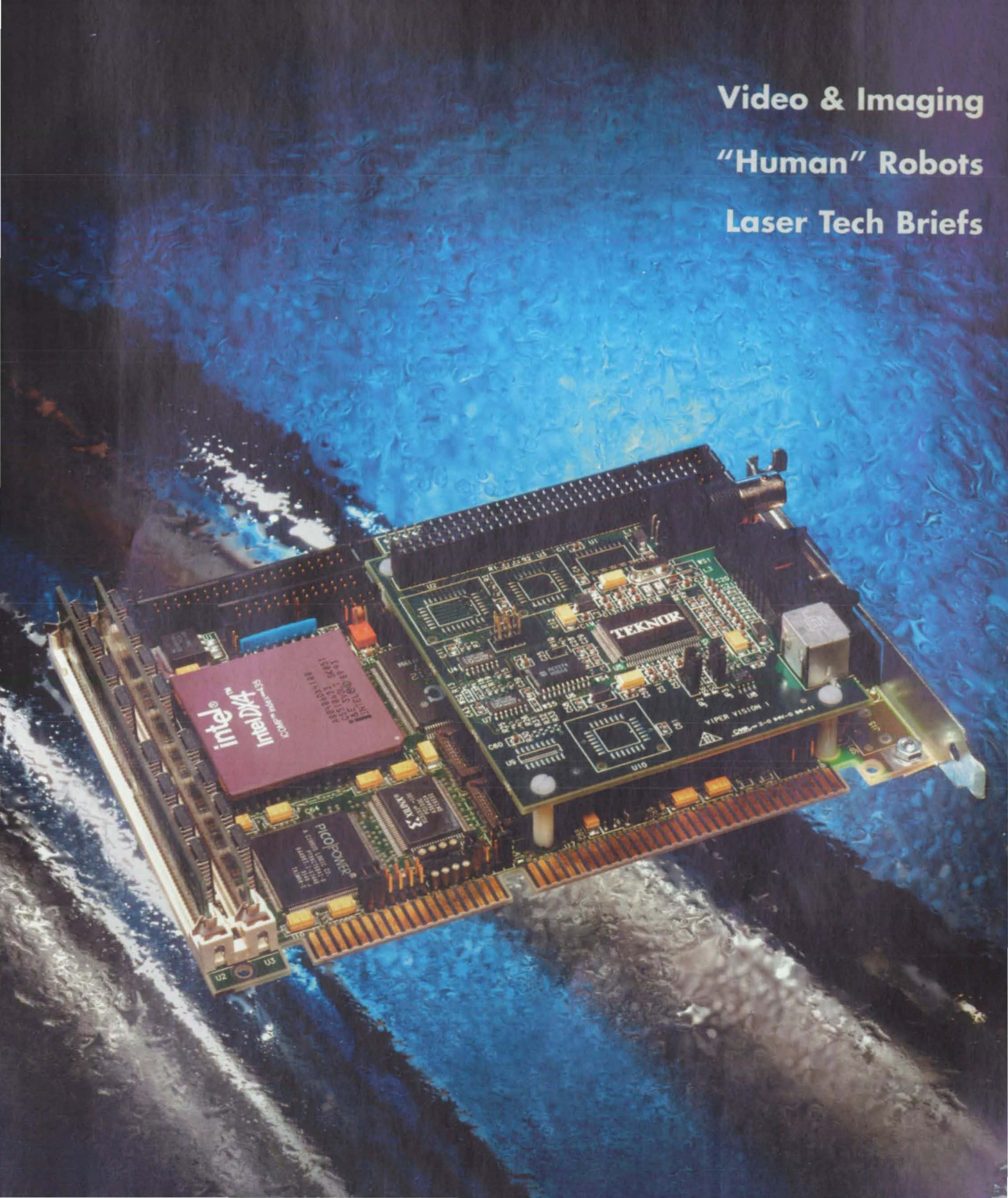

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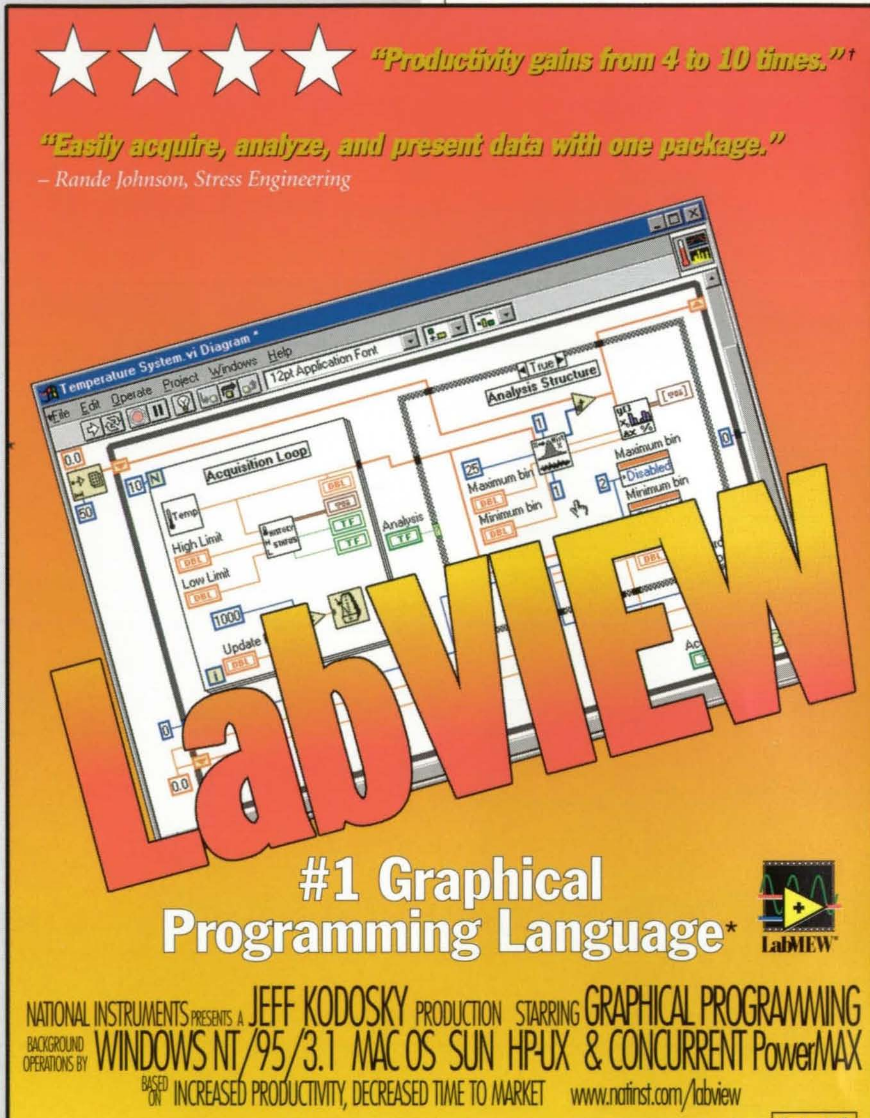

*As shown in T&M World Marketing Insight Study, 1995; Sensors Data Acquisition Survey, 1995; PE&IN Data Acquisition Survey, 1996
† "Telemetry Monitoring and Display Using LabVIEW" NI User Symposium Paper, George Wells & Ed Baroth, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

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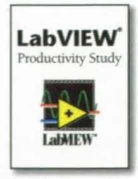

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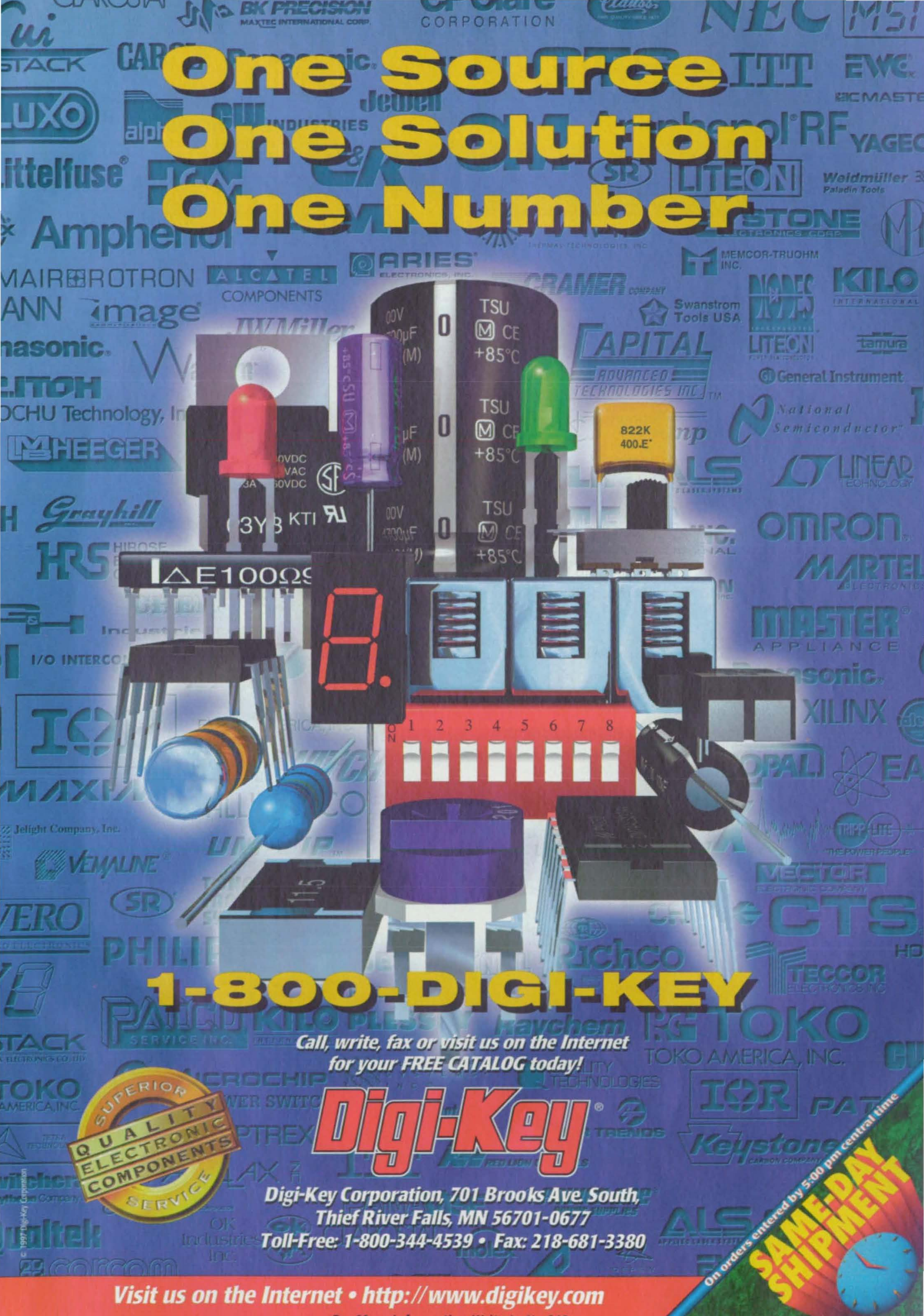

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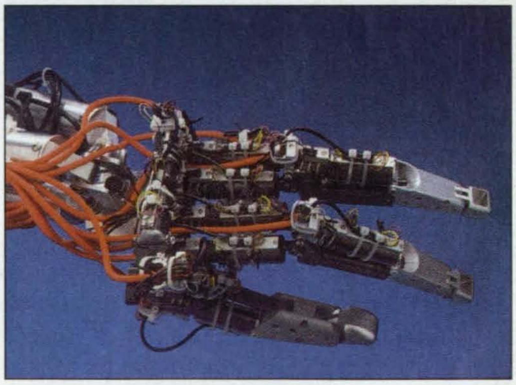

The Omni-Hand robotic hand module with an opposable thumb and interchangeable digits can accommodate a variety of tools. Built for NASA for space applications such as equipment maintenance, the module was designed by Ross-Hime Designs of Minneapolis, MN through an SBIR grant. For more information on the Omni-Hand and other robotic joints originally designed for NASA, see Mission Accomplished on page 18.

Photo courtesy of Ross-Hime Designs

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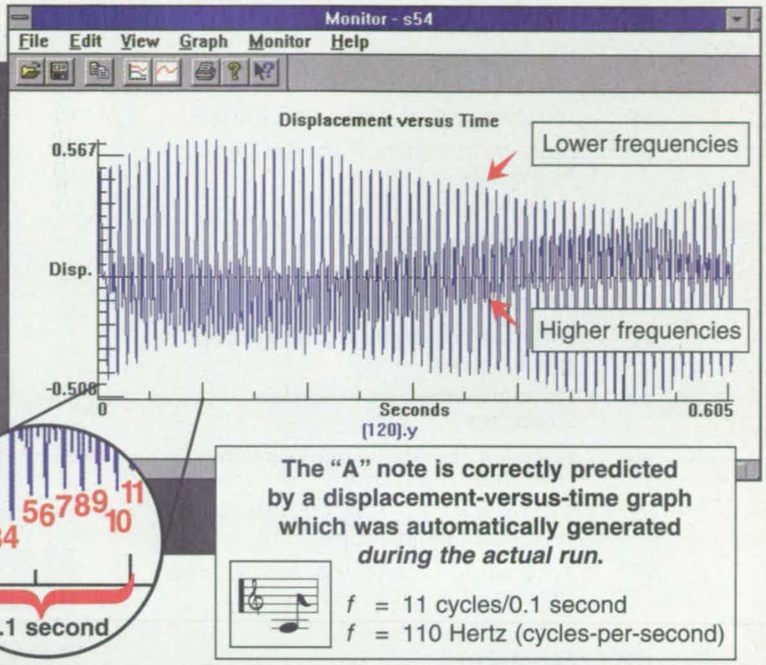

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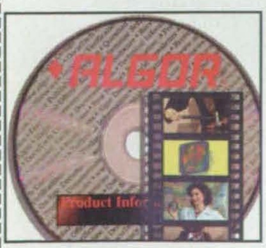

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Contents *continued*

Special Supplement

Laser Tech Briefs

Follows page 80 in selected editions only.

On the cover:

Real-time video for LCDs and analog CRT screens is produced with the VIPer Vision TEK-380 video interface module from Teknor Industrial Computers of Montreal, Canada. The module is one of the new Video & Imaging products and technologies described in the Special Focus beginning on page 24.

Photo courtesy of Teknor Industrial Computers

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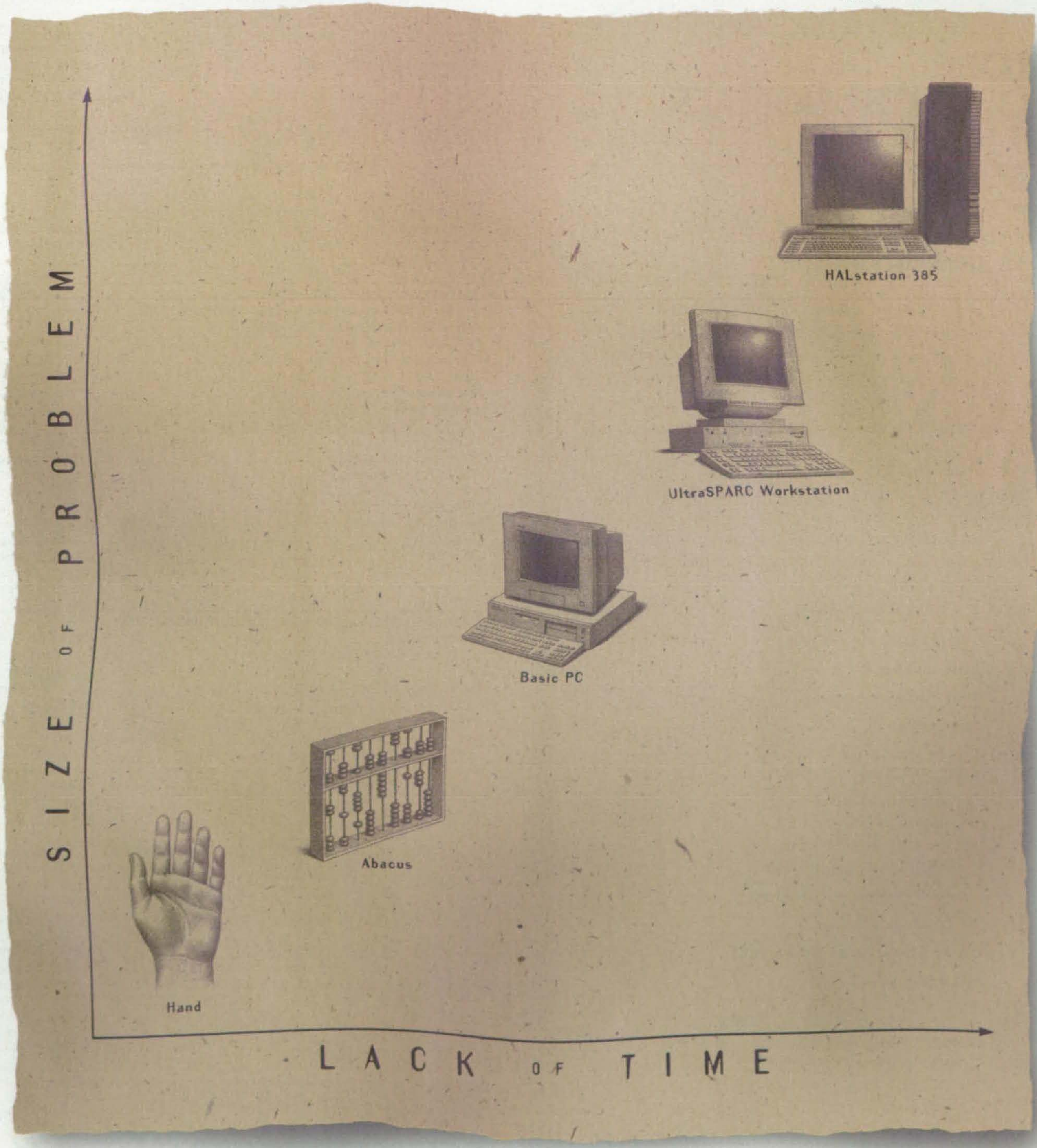

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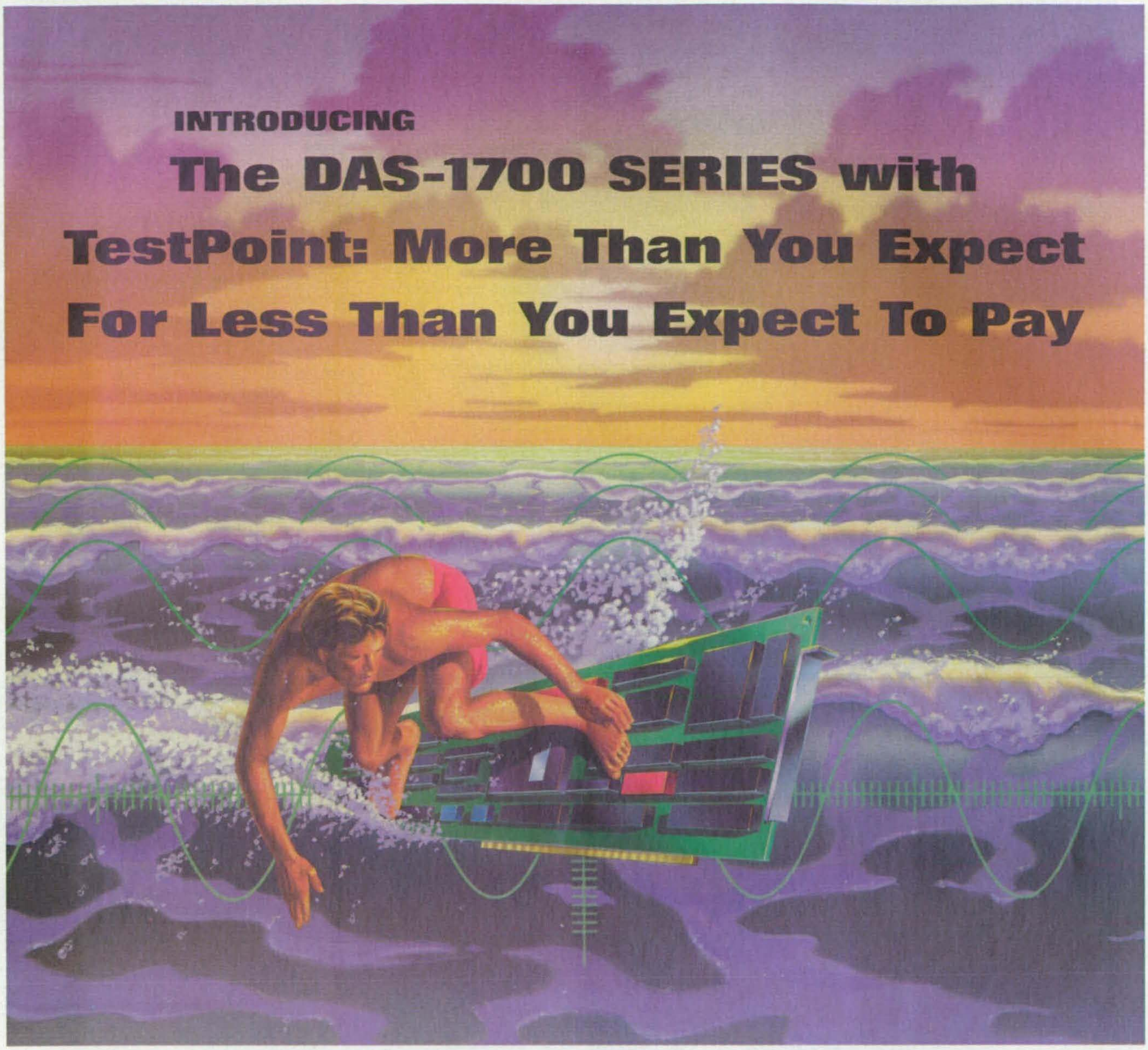

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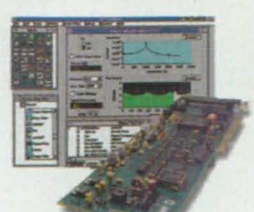

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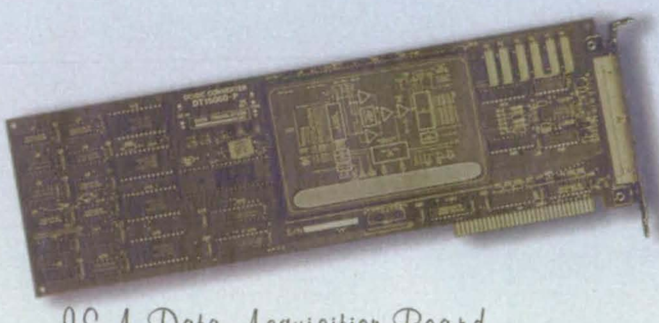

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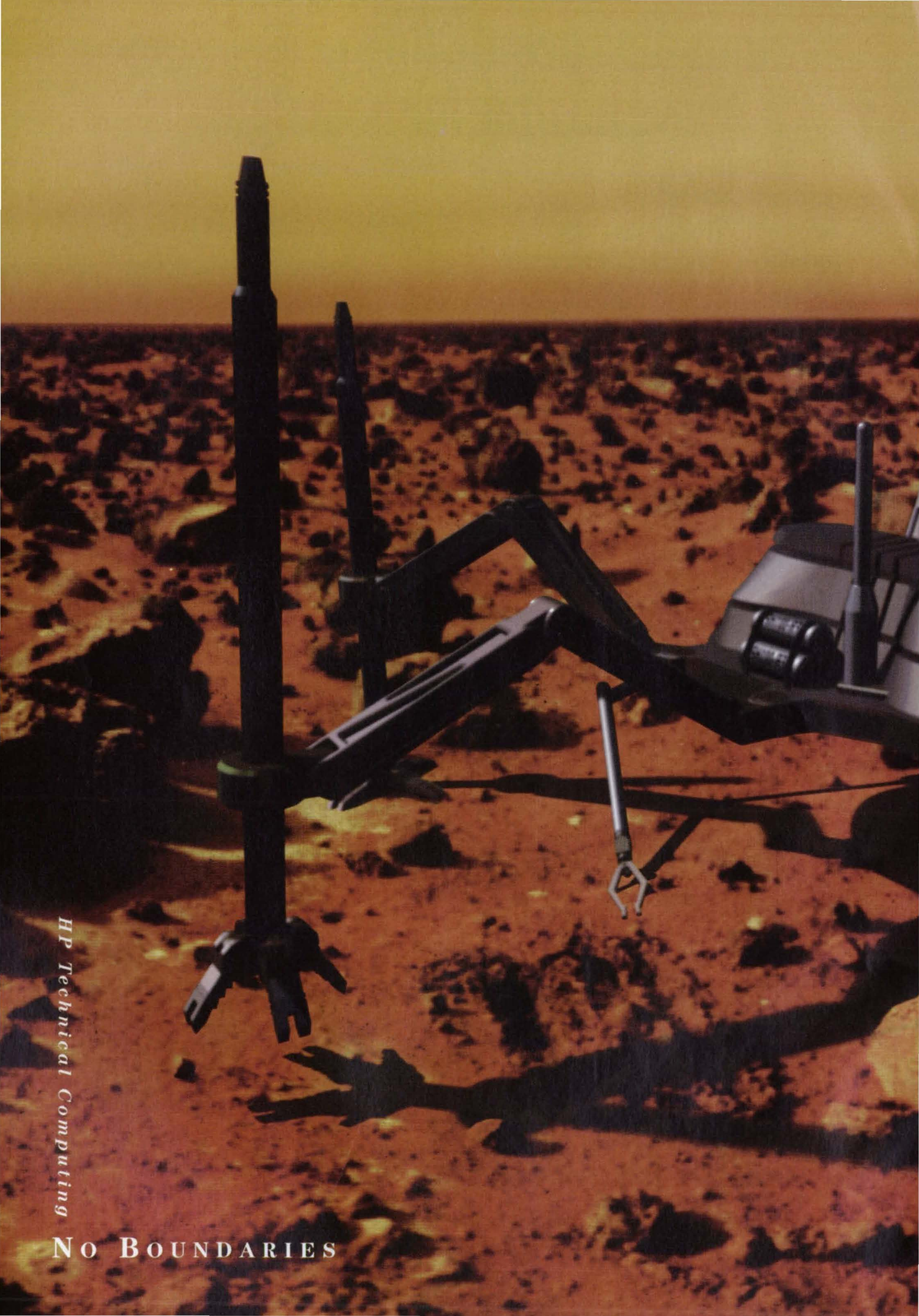
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NASA PATENTS

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

Controlling Flexible Robot Arms Using High Speed Dynamics Process

(U.S. Patent No. 5,546,508)

Inventors: Abhinandan Jain and Guillermo Rodriguez, Jet Propulsion Laboratory

Controlling robot manipulator arms is a familiar problem addressed in many publications. The present invention is a method and apparatus for controlling robot arms having flexible links using a high-speed recursive dynamics algorithm to solve for the acceleration of link deformation and hinge rotations from specified body forces applied to the links. The invention uses spatial operators to develop new spatially recursive dynamics algorithms for flexible multibody systems. In one embodiment, the controller operates by comparing the computed accelerations to desired manipulator motion to determine a motion discrepancy, and correcting the specified body forces so as to reduce the discrepancy.

For More Information Write In No. 771

Analysis of Supercritical-Extracted Chelated Metal Ions from Mixed Organic-Inorganic Samples

(U.S. Patent No. 5,561,066)

Inventor: Mahadeva P. Sinha, Goddard Space Flight Center

Mass spectrometry (MS) or gas chromatography-mass spectrometry (GC-MS) is widely used in the laboratory and the field for the analysis of the organic content of environmental samples. But it has not been used to detect and quantify metals or metal ions in these samples because of the problem of extracting and presenting them to the MS in vapor form. The new process adds an oxidizing agent to the sample to form metal ions, which are then converted to chelate complexes. These are brought into a vapor form by supercritical fluid extraction. Thus MS can be used in on-site analysis of environmental samples for both metal and organic content, enabling detection and quantification of metals in samples without extensive preparation or a separate instrument. The cost savings are said to be substantial.

For More Information Write In No. 772

Displaceable Spur Gear Torque Controlled Driver and Method

(U.S. Patent No.5,572,905)

Inventor: Joseph S. Cook Jr., Lyndon B. Johnson Space Center

When tightening fasteners, such as nuts, screws, or the like, it is often desirable to apply a selectively limited or controlled torque to one or more, since overtorquing can cause fastener failure and component damage. The improved apparatus's driver housing has two gear shafts with parallel axes of rotation, each with teeth mounted around the circumference. The second gear is carried by a support member that is displaceable in a lateral direction from the first shaft axis, and that can be biased into meshing engagement with the first to apply torque. Some of the teeth, however, are angled to produce a separating force in response to the engagement between the gears. Torque is transferred until the separating force overcomes the bias, separating the two gears and ending torque transfer to the fasteners.

For More Information Write In No. 773

Long Life Na/NiCl$_2$ Cells

(U.S. Patent No. 5,573,873)

Inventors: Ratnakumar V. Bugga, Subbarao Surampudi, and Gerald Halpert, Jet Propulsion Laboratory

A new class of sodium rechargeable batteries based on transition metal chlorides as positive electrodes has emerged in the last decade. Both Na/FeCl$_2$ and Na/NiCl$_2$ systems have demonstrated excellent performance in small and large cells and in batteries. But agglomeration of the electrode particles, causing premature cycle-life failure, is a problem with NiCl$_2$. Addition of sulfur alleviates this problem almost completely, but it is aggressive to the cell components, causing corrosion. But addition of a minor amount, such as 10 percent by weight, of a transition metal such as iron, cobalt, or manganese prevents agglomeration and maintains the electrode's morphology and its electrochemical area. The additives do not affect sintering. Addition of sulfur to the liquid catholyte is expected to further reduce agglomeration.

For More Information Write In No. 774

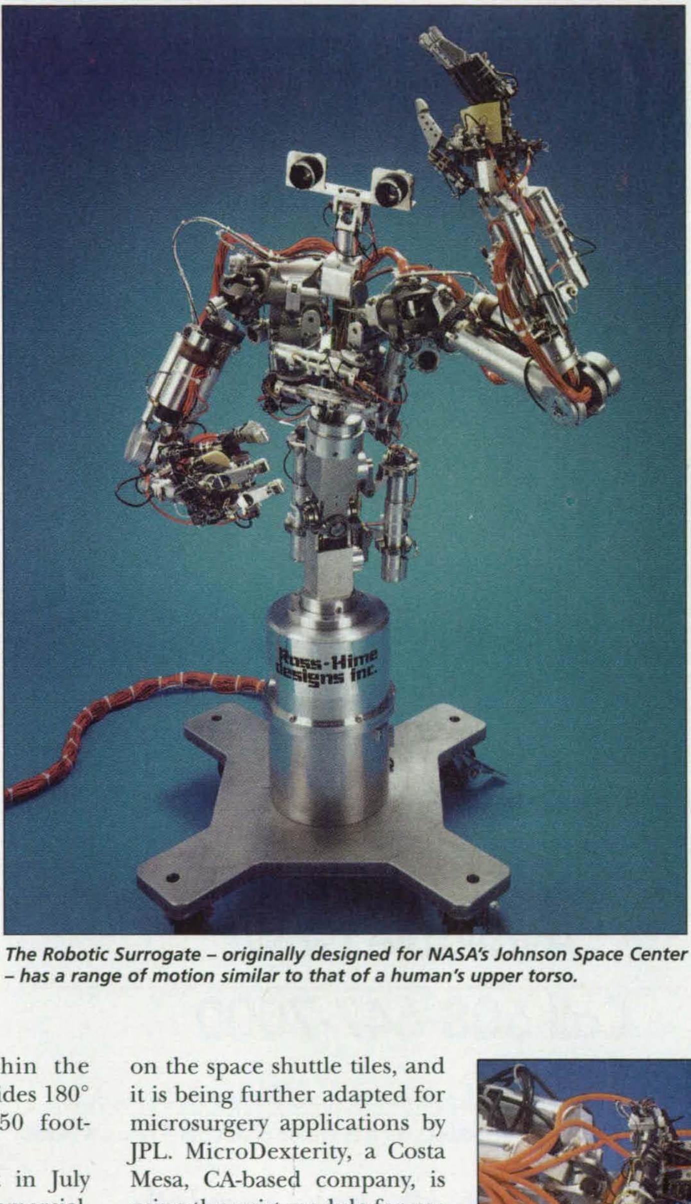
Mission Accomplished

The word "robot" often conjures up images of the human-like machines seen in science fiction films. But, in fact, real-world robots and robotics often are more remarkable in their capabilities than their fictitious counterparts. With funding through NASA's Small Business Innovation Research (SBIR) program, Ross-Hime Designs of Minneapolis, MN, has developed and commercialized a number of real-world robotic joints, as well as a humanoid robot that incorporates human motion and dexterity.

Incorporated in 1987 by Mark Rosheim, the company researches and develops new motion technology for applications in automation and robotics. Some of Ross-Hime Designs' major customers include Lockheed Martin, the Department of Defense, the Department of Energy, and NASA. In January 1987, the company received its first Phase I SBIR grant from NASA's Langley Research Center to design a computer-controlled, dexterous, compact telerobot wrist module for space station maintenance and space exploration. The result was the Omni-Wrist, the first mechanical wrist to solve the problem of singularity – the inability to make certain motions within the work envelope. The wrist provides 180° of motion, and forces to 250 foot-pounds.

Following a Phase II grant in July 1988, the Omni-Wrist was commercialized by Graco Robotics, which sold more than 100 of the modules for uses such as spray painting and sealant application. Ross-Hime Designs now markets the product exclusively.

The Omni-Wrist has been purchased by NASA's Jet Propulsion Laboratory (JPL) for its Hazbot robot project and by Carnegie Mellon University for its joint Shuttle Orbiter Tessalator project with NASA's Kennedy Space Center. Kennedy has used the Omni-Wrist to spray sealant on the space shuttle tiles, and it is being further adapted for microsurgery applications by JPL. MicroDexterity, a Costa Mesa, CA-based company, is using the wrist module for use in microsurgery and other medical applications.



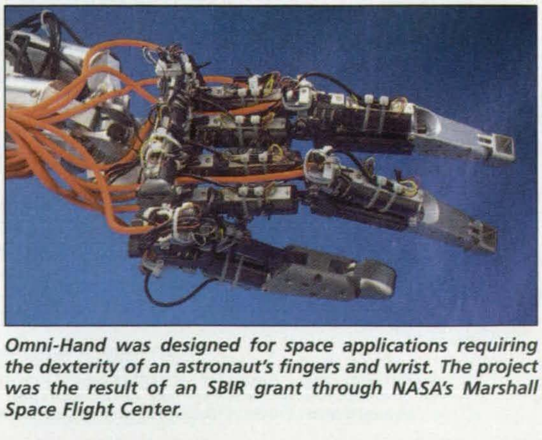
The Robotic Surrogate – originally designed for NASA's Johnson Space Center – has a range of motion similar to that of a human's upper torso.

NASA's Marshall Space Flight Center awarded Ross-Hime a Phase I SBIR grant in January 1988 and a Phase II grant in November 1989 for the design of a robotic hand. The Omni-Hand was designed for space robotic applications such as equipment maintenance and space exploration, which require a robotic device with dexterity equivalent to that of an astronaut's fingers and wrist. The hand module features interchangeable digits, as well as an opposable thumb that allows the hand to accommodate tools. It has its own integral wrist with pitch, yaw, and roll, and is powered by miniature electric linear actuators called Minnacs, which function like human muscles.

The Future is Now

Ross-Hime Designs took a big step into the future when it designed the Robotic Surrogate for NASA's Johnson Space Center (JSC) through Phase I and II SBIR grants awarded in December 1993 and January 1995, respectively. The anthrobot, which possesses the range of motion associated with the upper torso of the human body, was designed for space station maintenance, interplanetary exploration, and to construct astronaut base camps on Mars in anticipa-

(continued on page 20)



Omni-Hand was designed for space applications requiring the dexterity of an astronaut's fingers and wrist. The project was the result of an SBIR grant through NASA's Marshall Space Flight Center.

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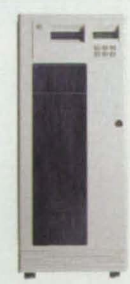

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tion of a manned mission. The "robotic carpenter" is a surrogate to human astronauts, eliminating the dangers of extra-vehicular space exploration.

The Robotic Surrogate is a 43-axis electrically powered humanoid robot that incorporates both the Omni-Wrist in its shoulder rotator cuff, and a second-generation Omni-Hand for its hands and wrists. The robot's human-like flexibility comes from operating shoulder blades, spine, and fingers. It is constructed primarily of aircraft-grade aluminum; the spine and shoulders are made of titanium and the shoulder joints are stainless steel.

A Robotic Surrogate recently was sold to the Korean Institute of Science and Technology (KIST) for use in research and development. The robot has potential commercial applications as a replacement for humans in hazardous environments such as nuclear and chemical facilities, munitions disposal areas, hazardous waste removal, under water, and other applications in which repetitious tasks require complex motion from a single robotic body.

For more information, contact Mark Rosheim, president, Ross-Hime Designs, 1313 5th Street SE, Minneapolis, MN 55414; Tel: 612-379-3808; Fax: 612-379-3875; E-mail: mrosheim@visi.com.

An SBIR grant awarded by NASA Langley in 1987 funded Ross-Hime Designs' Omni-Wrist, which was commercialized in 1988.

Commercialization Opportunities

Single-Camera Stereometric Laser Ranging System

This system needs no expensive high-speed computers. Measurement of distances to nearby objects in real time would be sufficiently accurate for many robotic applications.
(See page 24.)

Ultrasonic Instrument Produces Thickness-Independent Velocity Images

A new imaging subsystem incorporated into a conventional ultrasonic C-scan apparatus improves the inspection of materials for flaws and imperfections. Designed originally for the inspection of advanced ceramic materials, the unit could be used for nondestructive evaluation of other materials.
(See page 30.)

Magnetic-Bubble Annihilator for Use in VBL Memories

An improvement in a new class of high-density magnetic-storage devices features an enlarged electrically conductive loop. The enlarged loop increases tolerance to misalignment of the magnetic blade.
(See page 42.)

Variable-Buoyancy Balloons for Tracking Tropical Storms

Charged with helium and a phase-change fluid, this type of radiosonde dual balloon maintains approximately constant altitude as it is drawn into a storm. The balloon can monitor the storm at sea and over land much longer than conventional radiosonde balloons.
(See page 52.)

Toughened Carbon/Carbon Pistons

A three-dimensional carbon/carbon would be toughened with metal or plastic in its pores. The material would thus be better capable of withstanding the stresses in internal combustion engines than the present pistons with carbon fibers oriented in two dimensions.
(See page 58.)

High-Performance Silver-Recovery Apparatus

Developers of photographic and radiographic films may recover more than 99.9 percent of silver from wastes generated in film processing. The resulting effluent is deemed safe enough for sewage-treatment plants.
(See page 59.)

Piezoelectric Flexural-Traveling-Wave Pumps

These miniature pumps can be useful in such applications as injecting small controlled amounts of liquid medications and in sampling and vacuum pumping for miniature scientific instruments.
(See page 66.)

Single-Camera Stereometric Laser Ranging System

Distances could be measured and computed quickly, with relatively simple equipment.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed laser ranging system would provide measurements of distances to nearby objects in real time, with accuracy sufficient for many robotic, telerobotic, and teleoperation applications. In comparison with other ranging systems developed for the same purpose and based on various optical, radio, and acoustic measurement principles, this system would offer the advantage of relative simplicity of hardware and software. In particular, the data-processing aspects of this system would involve relatively simple algorithms that could be implemented with the requisite speed without having to resort to expensive high-speed computers.

Figure 1 illustrates the ranging system and ancillary equipment in a telerobotic scenario. The ranging system would include a low-power eye-safe laser (e.g., a 1-mW laser diode) mounted on a camera platform at a fixed baseline distance, *b*, to the side of a video camera. In the simplest example of alignment, the camera and the laser would be aimed along parallel lines. The video image would be projected to an operator through a helmet-mounted display system. The camera and laser would be positioned and aimed toward an object of interest by turning the camera platform under remote control, in imitation of movement of the operator's head as measured by position and orientation sensors in the helmet.

Ranging in this system would be based on stereometry (see Figure 2). That is, the distance to a point on the object of interest illuminated by the laser beam would be computed from a stereoscopic disparity. In this case, the stereoscopic disparity would be the distance x, on the focal plane of the video camera, between the central pixel (coinciding with the optical axis of the camera) and the image of the laser-illuminated spot on the object. Then from the basic geometric principle of stereometry, the distance, z, from the camera to the illuminated spot on the object would be approximated by $z = fb/x$, where f is the focal length of the camera.

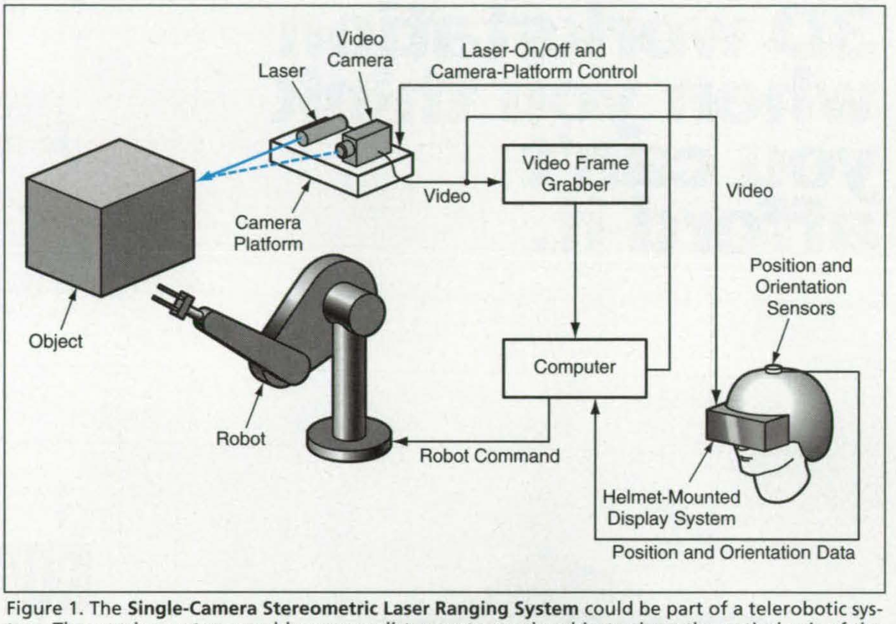

Figure 1. The **Single-Camera Stereometric Laser Ranging System** could be part of a telerobotic system. The ranging system would measure distances to nearby objects along the optical axis of the camera. The measurements would provide guidance for controlling the robot.

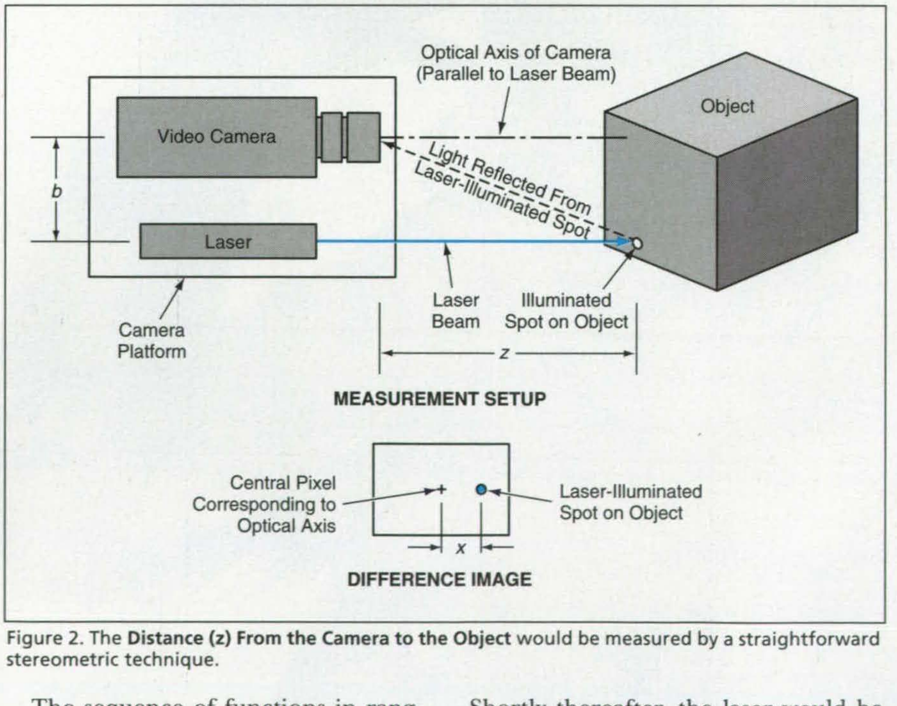

Figure 2. The **Distance (z) From the Camera to the Object** would be measured by a straightforward stereometric technique.

The sequence of functions in ranging would be as follows: First, a frame grabber would acquire an image of the object without laser illumination and send the image data to a computer. Shortly thereafter, the laser would be turned on and the frame grabber would acquire an image of the object, including the laser-illuminated spot and send the image data to the com-

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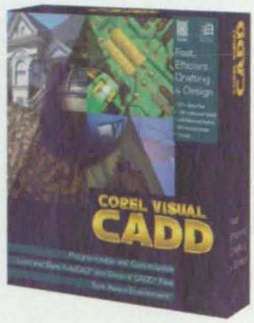

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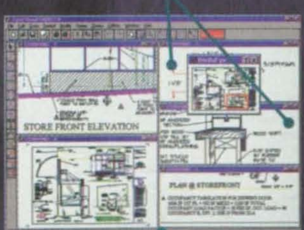

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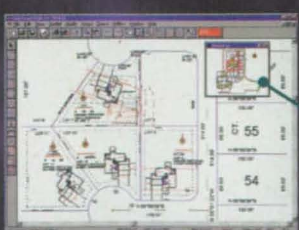

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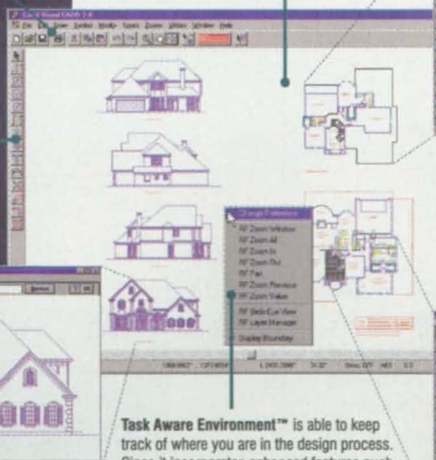

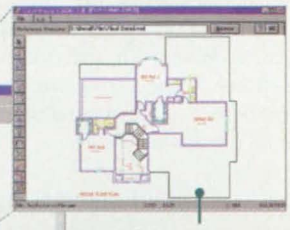

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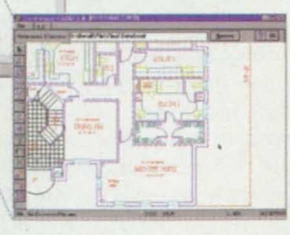

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puter. The computer would effectively subtract the first image from the second image to obtain a difference image that would contain only the laser-illuminated spot on the object. The computer would then calculate the centroid of the laser-illuminated spot. Then setting x equal to the distance between this centroid and the pixel on the optical axis (at the center of the image frame), the computer would calculate z from the equation shown above.

This work was done by Larry Li and Dennis L. Wells of **Johnson Space Center** *and Brian Cox of Lockheed Engineering and Sciences Co. For further information,* ***write in 56*** *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-22549.

Enhancing the Ultrasonic C-Scan of a Second Interface

A signal-processing algorithm corrects for the effect of the first interface.

Goddard Space Flight Center, Greenbelt, Maryland

Figure 1 illustrates schematically an ultrasonic pulse/echo inspection system that yields C-scan images of flaws in two interfaces at different depths in a laminated specimen. The system corrects for the effect of flaws in the first interface, which could otherwise mask or distort the image of flaws in the second interface.

The masking or distortion arises because a flaw in the first interface alters the probing ultrasonic signal on its way to the second interface. Thus, if a flaw in the second interface lies behind (that is, at the same x,y position as that of) a flaw in the first interface, then this second flaw is insonified by the altered probing ultrasonic signal, and the resulting ultrasonic image is altered accordingly.

The present system processes the ultrasonic signals to separate the ultrasonic echoes from the two interfaces and applies a correction algorithm, which is based on the following two equations derived from the fundamental equations of transmission and reflection of ultrasonic pulses:

$$A_I(x, y) = C_1 R_{12}(x, y) \textit{ and}$$

$$A_{II}(x, y) = C_2 R_{23}(x, y) - C_3 A_I^2(x, y) R_{23}(x, y);$$

where $A_I(x,y)$ and $A_{II}(x,y)$ denote the position-dependent amplitudes of the ultrasonic signals returned from the first and second interfaces, respectively; $R_{12}(x,y)$ and $R_{23}(x,y)$ denote the position-dependent ultrasonic reflection coefficients of the first and second interfaces, respectively; and C_1, C_2, and C_3 are constants. $A_I(x,y)$ and $A_{II}(x,y)$ are measured ultrasonic parameters. $R_{12}(x,y)$ and $R_{23}(x,y)$ are the interface properties that one seeks. C_1, C_2, and C_3 are derived from combined transmission coefficients, attenuation coefficients, thicknesses, and other material parameters.

The system gates the ultrasonic return signals by round-trip travel times to separate the returns from the first and second interfaces, then peak-detects the gated returns to measure the amplitudes $A_I(x,y)$ and $A_{II}(x,y)$. The correction algorithm then computes normalized versions of these amplitudes and, in the case of $A_{II}(x,y)$, applies a correction in the form of an approximation

$$A_{II}'(x, y) = A_I^2(x, y)\, A_{II}(x, y)$$

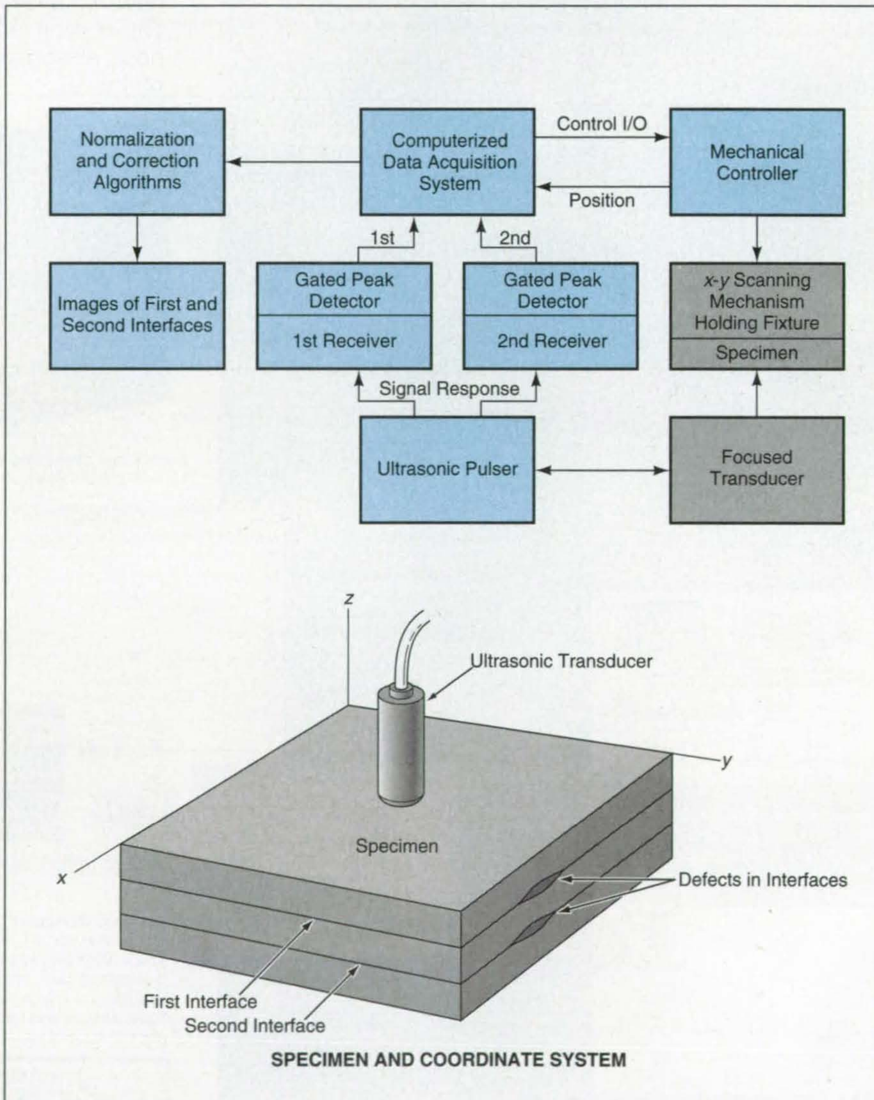


Figure 1. This **Ultrasonic Pulse/Echo System** produces a C-scan of a laminated specimen. When the specimen contains two interfaces, it produces independent C-scans of the first and second interfaces.

Thus, the output of the system is a normalized amplitude proportional to $R_{12}(x,y)$ and a normalized, corrected amplitude approximately proportional to $R_{23}(x,y)$.

In an experiment to demonstrate feasibility, the system was used to scan a specimen that contained two defects in the first interface and two defects in the second interface, positioned so that one of the defects in the first interface partly shadowed a defect in the second interface. As shown in Figure 2, processing in the system by use of the correction algorithm recovered the shadowed portion of the image of the second interface.

This work was done by E. James Chern of **Goddard Space Flight Center.** *For further information,* ***write in 37*** *on the TSP Request Card.*
GSC-13792

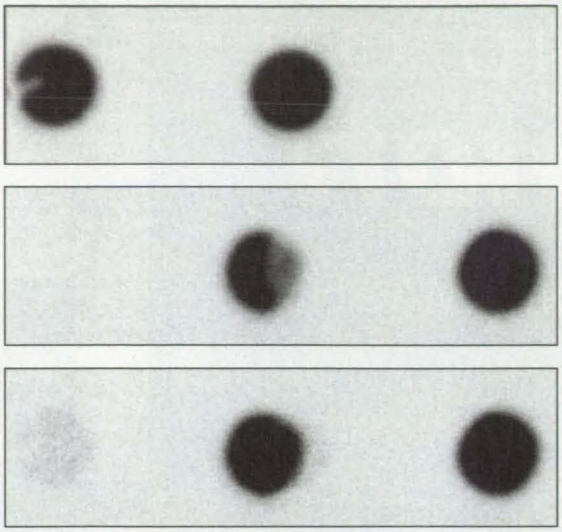


Figure 2. **Processing of the Raw Scan** from the second interface of a demonstration specimen illustrates the ability of the correction algorithm to filter out the effect of an overlying defect in the first interface.

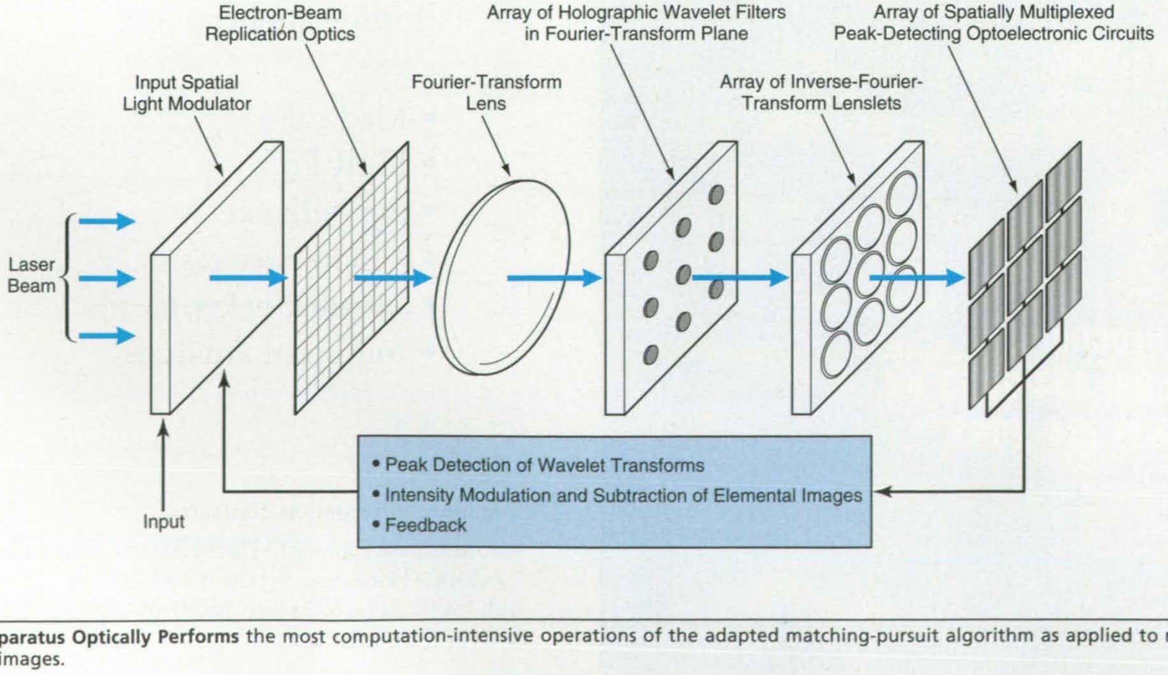
Optically Implementing an Algorithm for Representing Images

The matching-pursuit algorithm has been adapted to image-analysis applications.

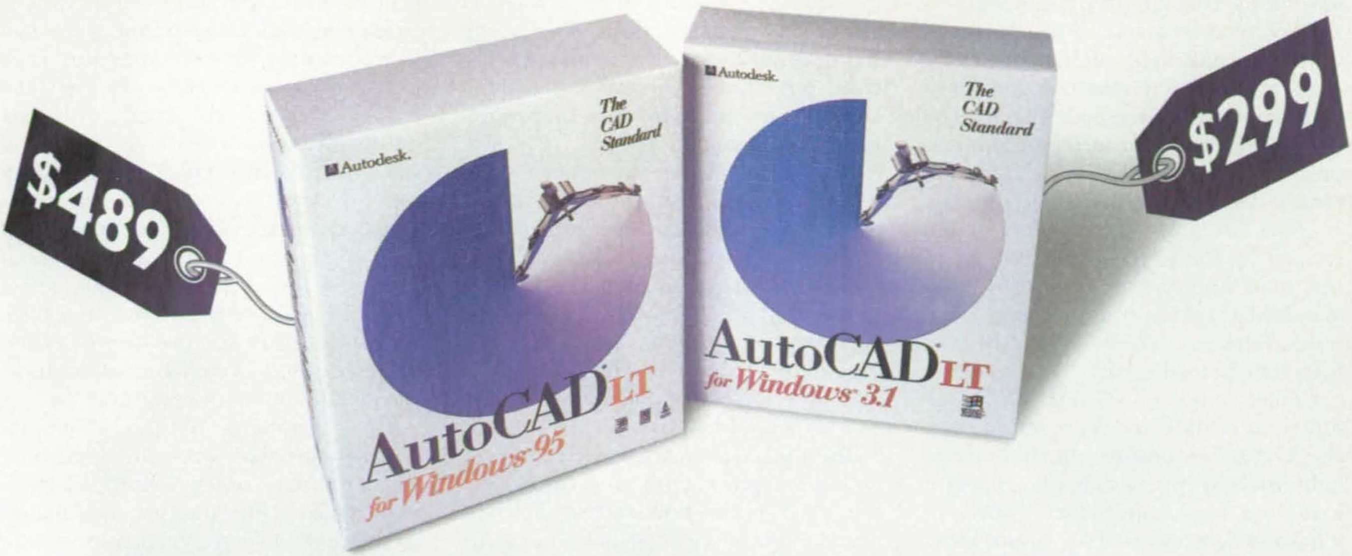
NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype optoelectronic apparatus has been developed to implement an improved scheme for the analysis and representation of images. The scheme is based on an adaptation of an algorithm, called the "matching-pursuit" algorithm, that was originally formulated for use in analyzing sound and other time-varying signals. A system that implements this scheme automatically and rapidly decomposes a two-dimensional image into a linear combination of elemental images from a dictionary of such images. Thus, the scheme offers potential utility for analysis of images and compression of image data. Moreover, the elemental images could be patterns that the system is required to recognize, so that the scheme offers potential utility for industrial and military applications that involve robotic vision and/or automatic recognition of targets.

The original version of the matching-pursuit algorithm expresses a sound or other signal as a linear combination (a finite series) of unit-norm elemental



This **Apparatus Optically Performs** the most computation-intensive operations of the adapted matching-pursuit algorithm as applied to representation of images.



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waveforms from a highly redundant dictionary of waveforms. The elemental waveforms and their coefficients in the series are chosen in decreasing order of correlation with the signal, where correlations are expressed in terms of inner-product integrals and each successive term in the series is applied to only the residue left after the approximation formed by the preceding terms. Thus, the matching-pursuit algorithm is a greedy algorithm, and each successive term in the series is less significant than is the one preceding it.

Unlike sound waveforms, which are functions of time and have zero means, image data are positive distributions of light intensity in two dimensions, and it is desired to classify them in terms of known images rather than known waveforms. These considerations must be taken into account in adapting the matching-pursuit algorithm to the image-representation problem. Accordingly, the elemental functions chosen for inclusion in the dictionary are two-dimensional brightness-distribution functions (that is, elemental images) that are sufficiently similar to targets that one seeks to recognize and sufficiently dissimilar to decoys or other extraneous objects that one seeks to ignore. Similarity and dissimilarity are quantified, for these purposes, in terms of correlations or inner-product integrals over the image area. The dictionary should include all elemental images of interest, including a representative selection of translated, rotated, magnified, and minified versions of the elemental images that could be encountered in practice.

The matching-pursuit algorithm as adapted to representation of an image requires iterative performance of three basic operations: (1) two-dimensional adaptive wavelet transforms that represent the elemental images; (2) peak detection for those transforms; and (3) subtraction, from the input image, of intensity-modulated versions of the elemental images. An optical or optoelectronic image-processing system like the prototype apparatus can perform all three operations in much less time than would be needed to perform the same operations on a digital electronic computer.

The prototype apparatus (see figure) includes a spatial light modulator, electron-beam replication optics, a Fourier-transform lens, an array of holographic wavelet filters, an array of inverse-Fourier-transform lenslets, and an array of interconnected integrated-circuit chips, each of which contains a two-dimensional array of photodetectors and associated peak-detection circuitry. In order to identify the wavelet that would produce the maximum wavelet-transform peak against the input image, it is necessary to conduct an exhaustive search.

First, all wavelet elements in the dictionary are arranged in a two-dimensional array of Fourier holograms that constitutes the array of holographic wavelet filters mentioned above. Multiple replicas of the input image — one for each filter — are formed by use of electron-beam optics. The Fourier transform of each replica is formed in the corresponding filter. A two-dimensional array of lenslets inverse-Fourier-transforms the outputs from the filters, producing the corresponding wavelet transforms on the corresponding photodetector/peak-detector circuits. The output of each such circuit yields data on the locations of all pixels with intensities above a threshold level. The outputs of all of these circuits are monitored simultaneously. The threshold level is increased until the brightest of the peaks found by the photodetectors is identified. This peak value and location of this peak and the identity of the corresponding wavelet are recorded for use in subsequent operations.

The brightness of the elemental image associated with the identified wavelet is then multiplied by this peak value (this is the intensity modulation mentioned above), recentered at the identified location, and subtracted from the input image. The remaining image (residue) is then fed back as the input image for the next iteration. The iterations continue until the energy in the residue falls to zero or exhibits a tendency to increase or oscillate with further iteration.

Some preliminary optical experiments have demonstrated that the system operates substantially as expected. In addition, the adapted matching-pursuit algorithm has been verified through computational simulation.

This work was done by Tien-Hsin Chao and Brian K. Lau of Caltech and William J. Miceli of the Office of Naval Research for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 27*** *on the TSP Request Card.*
NPO-19471

Ultrasonic Instrument Produces Thickness-Independent Velocity Images

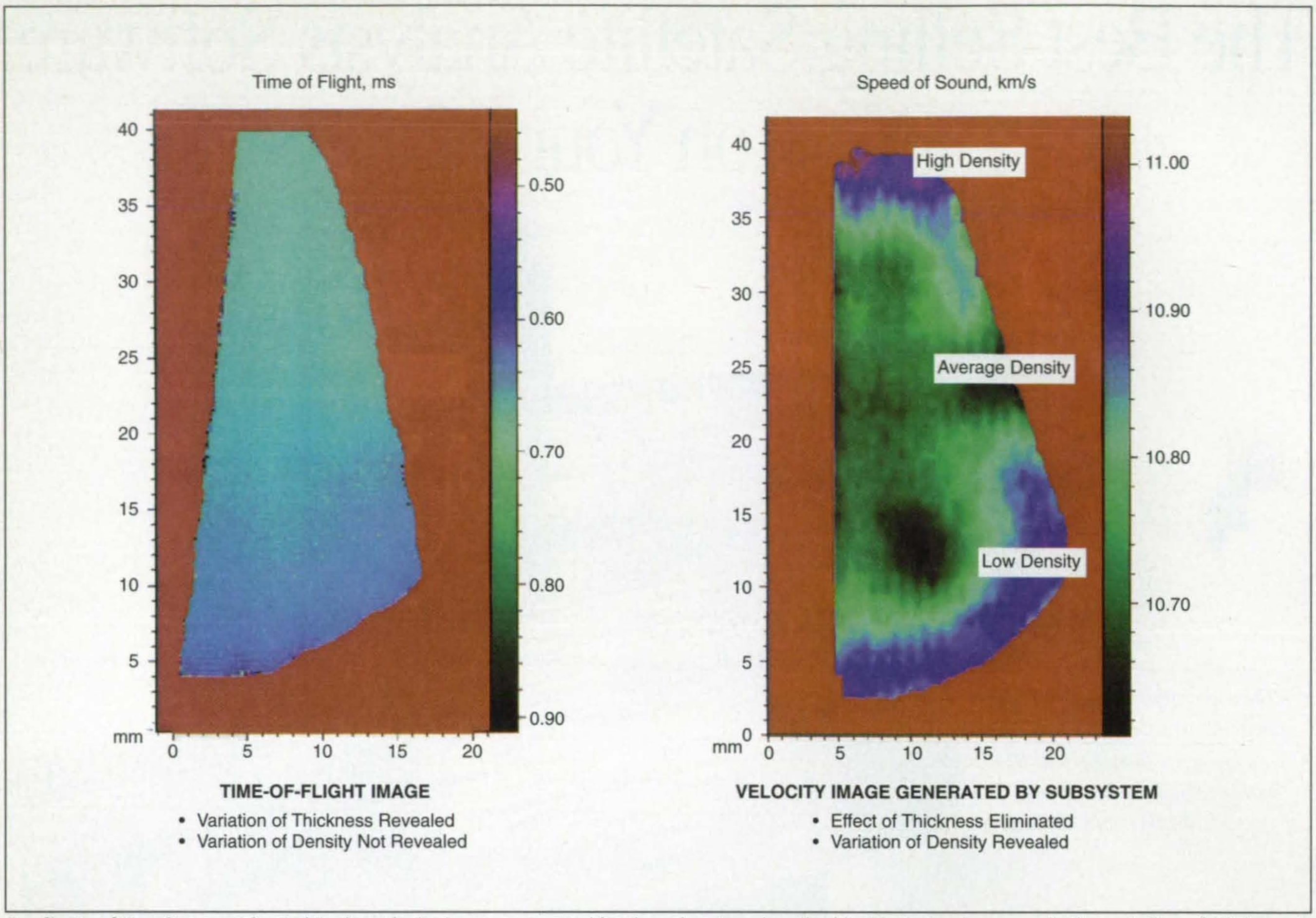
Thickness effects can be eliminated, yielding images indicative of properties of materials.

Lewis Research Center, Cleveland, Ohio

A weakness of conventional C-scan imaging regarding both peak amplitude and time-of-flight modes is that gray or color scale variations in images for back-surface reflections indicate part-thickness variations, as well as microstructural variations, unless the part is uniformly thick. A single transducer ultrasonic imaging method based on ultrasonic velocity measurement is described here that eliminates the effect of plate-thickness variation in the image, i.e., the method is thickness-independent. The method thus isolates ultrasonic variations due to material microstructure.

The present imaging subsystem is incorporated into a conventional ultrasonic C-scan apparatus with a single ultrasonic transducer and a computer with conventional ultrasonic-signal-processing software plus special software to implement the subsystem computations. The apparatus is set up for pulse/echo measurements of the velocity of sound in a tank of water. The transducer is mounted in the water on a scanning mechanism above the specimen. Below the specimen is a plate for reflecting ultrasound. At each scan position, the ultrasonic echoes from the surfaces of the specimen and the plate are analyzed to determine the speed of sound in the specimen material.

The subsystem is expected to find use in numerous applications in which there is a need for nondestructive detection of flaws in structural parts and nondestructive evaluation of spa-



Gradients of Density are indicated in the velocity image generated by the subsystem described in the text, whereas only the variation of thickness is depicted in the time-of-flight image.

tially varying properties of materials. In the case of advanced ceramic materials undergoing development in the aerospace and automotive industries, gradients of density, porosity and chemical composition are properties that are of particular interest and that affect the speed of sound. The data generated by the ultrasonic apparatus equipped with this subsystem quantify such gradients about 10 times better than do the data generated by the same apparatus operating in the traditional peak-echo-amplitude or relative-echo-time (time-of-flight) mode.

The figure illustrates the superior capability of this subsystem for revealing gradients of density in a specimen of a ceramic material that is under consideration to replace metal parts in automobiles. The specimen is 0.3 mm thicker at the top of the figure than at the bottom, and varies smoothly from top to bottom. The specimen contains distinct regions of low (95 percent of theoretical), average (98 percent of theoretical), and high (100 percent of theoretical) density. The image in the left part of the figure was generated in an ultrasonic C-scan in a conventional time-of-flight mode; this image indicates the variation in thickness from top to bottom, but gives no indication of the variation in density. The image in the right part of the figure, generated by scanning the specimen while using the present subsystem, clearly reveals the variation in density, without the effect of thickness.

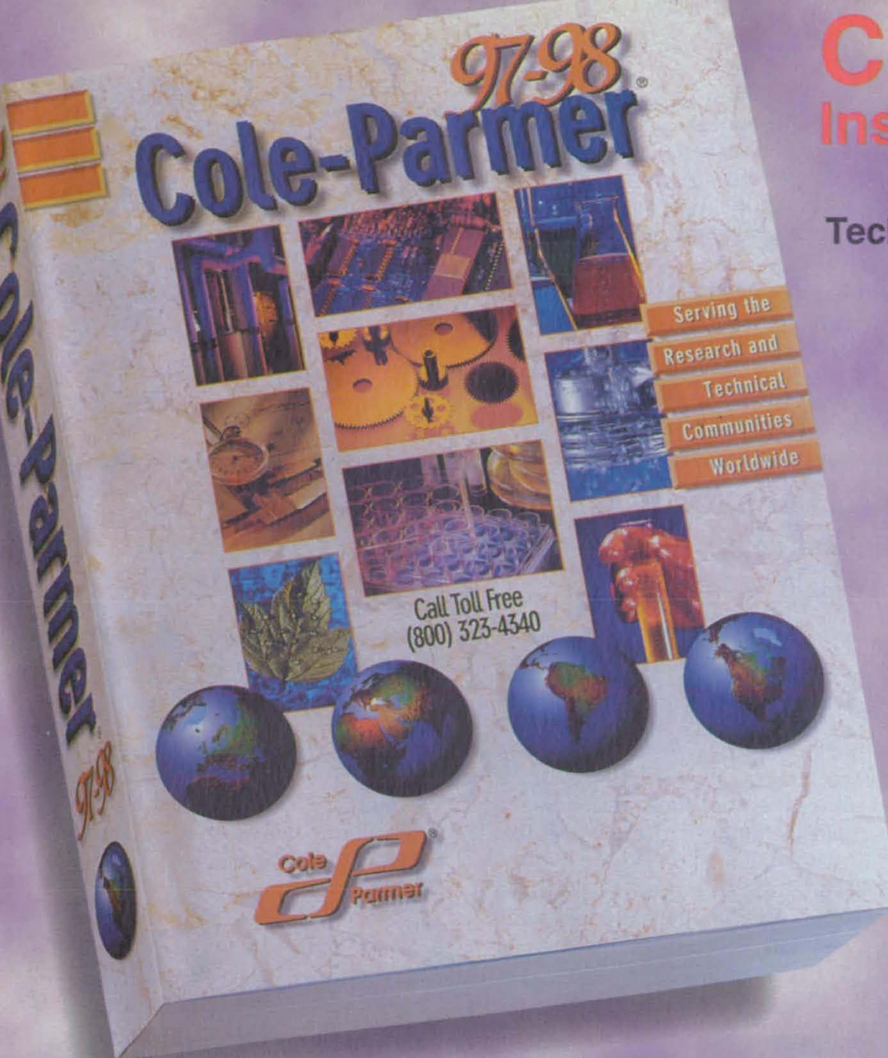
This work was done by Don J. Roth of **Lewis Research Center,** *Mike F. Whalen and J. Lynne Hendricks of Sonix, Inc., and John H. Hemann and James R. Bodis of Cleveland State University. For further information,* ***write in 64*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: James Martz, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16257.

Software for Operating on Image Data

NASA's Jet Propulsion Laboratory, Pasadena, California

The Imageclass computer software simplifies the development of image-processing applications by providing a uniform programmer's interface via an object-oriented class library. Written in the C++ programming language, Imageclass is designed to provide a high-level interface to image objects so that application programmers can efficiently implement complex image-processing operations without worrying about the low-level details. Most available image-processing libraries focus on computer graphics applications and are limited to a set of commercial industry file formats. Imageclass is oriented toward the scientific uses of images. Therefore, it is designed to provide a uniform interface for images that use science data types and science data formats such as CIPE, VICAR, and FITS.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The library consists of a genus of image subclasses, each of which handles a different pixel type, such as char, int, float, and the like. For each image subclass, member functions are provided for the essential image operations, such as creation, reading/writing to/from a file display through a spawned process, and element access. In addition a wealth of other basic operations, mathematical filters, statistical analysis, data type conversion, flipping, transposition, zooming, insertion, and subsetting are provided. The file I/O (input/output) interface supports reading from and writing to image files of several popular file formats used in the NASA community, including CIPE, FITS, VICAR, and raw data format. Imageclass can easily be extended to accommodate other file formats. With the Imageclass library, image-processing applications can be developed in a faster, cheaper, and better manner.

This work was done by Ansel Teng, Hillel S. Rom, Richard J. Weidner and Meemong Lee of Caltech for NASA's **Jet Propulsion Laboratory.** *For further information,* ***write in 51*** *on the TSP Request Card.*
NPO-19888

Apparatus for Advanced Ultrasonic C-Scan Imaging

C-scan plots indicate both amplitude and depth.

Goddard Space Flight Center, Greenbelt, Maryland

Figure 1 schematically illustrates a computer-controlled ultrasonic C-scan instrumentation system that incorporates recent advances in hardware and software for better characterization of specimens. In some respects, this system operates like a typical ultrasonic C-scan apparatus of older design. The innovative aspects of this system lie in the specific combination of signal- and data-processing functions to obtain plots containing two types of data that characterize defects in specimens.

Like some other systems, this system includes an ultrasonic transducer that is scanned along in a horizontal *(x,y)* plane parallel to the top surface of a nominally flat plate specimen, which is typically laminated. As in other systems, the ultrasonic transducer is connected to an electronic pulser/receiver, a dual timing gate, a peak detector, and a universal timer. At each position *x,y* along the scan, the computer estimates the depth of any defect or other feature that reflects ultrasound, using the known or assumed speed of sound and the measured round-trip travel time (also called "time of flight," or "TOF," for short) of the ultrasonic signal between the top surface of the specimen and the defect. The peak detector operates with a time gate chosen so that its output indicates the amplitude of the signal reflected from the defect or other feature at *x,y*.

Some older ultrasonic C-scan systems generate similar data on depth and amplitude as functions of *x* and *y*, but they lack

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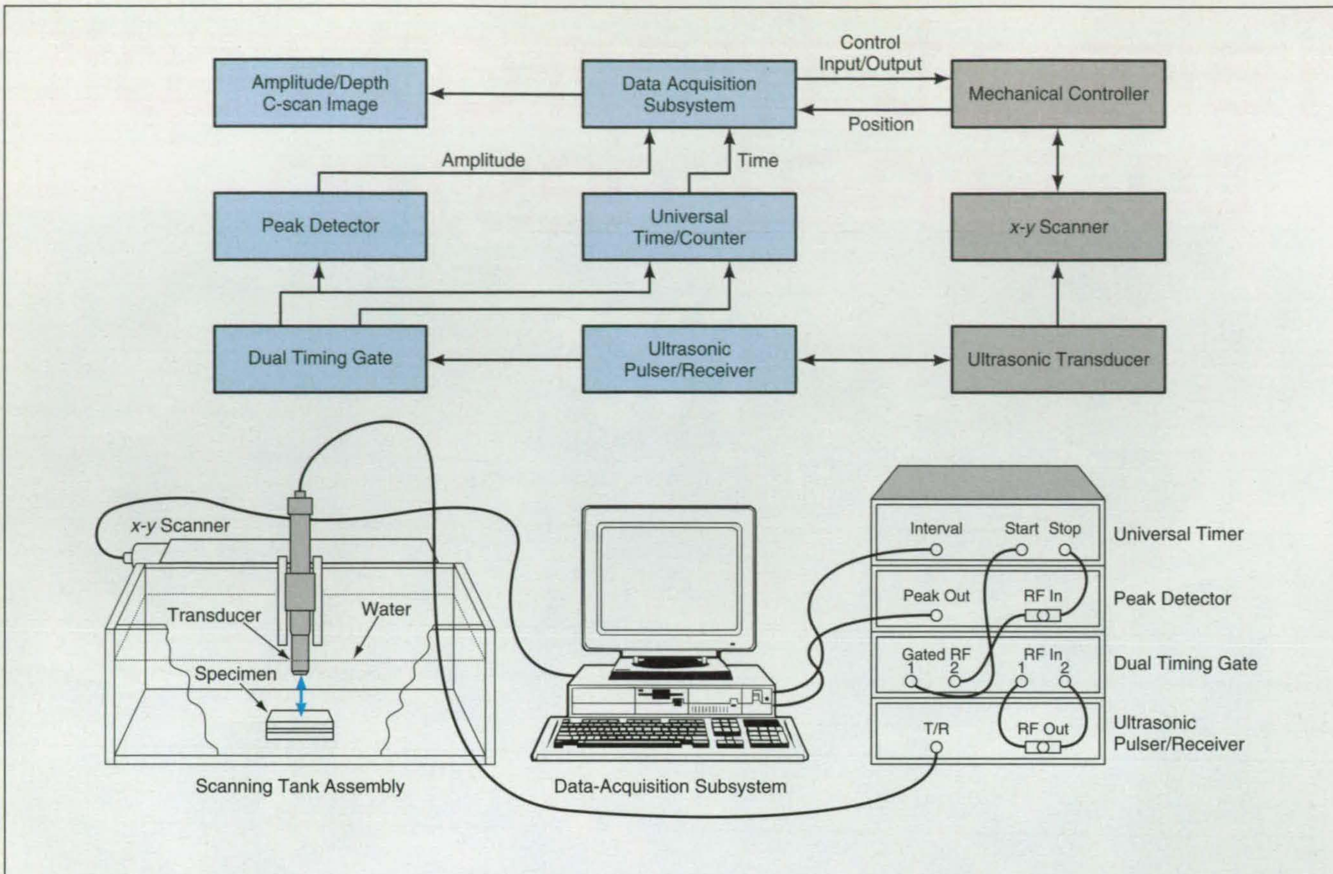


Figure 1. This **Instrumentation System** performs an ultrasonic C-scan of a plate specimen.

the means to correlate the depth and amplitude data automatically and are limited to presenting depth and amplitude data on separate plots. The software of the present system includes a program that processes the x,y scanning-position data and the associated depth and amplitude data into a single three-dimensional-appearing plot that shows both depth and amplitude as functions of x and y. Figure 2 shows an example of such a plot, wherein the vertical (z) axis represents depth, and a gray scale indicates amplitude. Alternatively, false color could be used to indicate amplitude.

This work was done by Engmin James Chern and David Warren Butler of **Goddard Space Flight Center.** *For further information,* ***write in 53*** *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-13524.

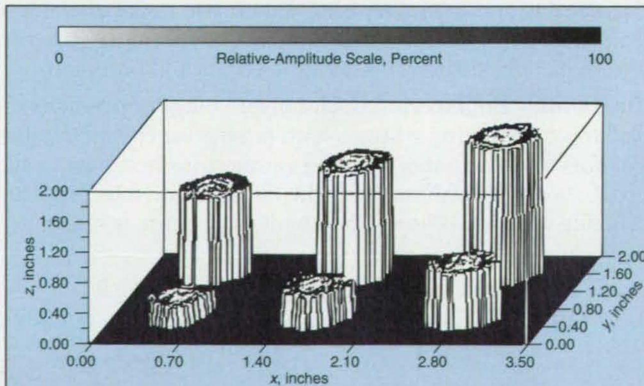


Figure 2. This **Plot Presents Ultrasonic C-Scan Data** from a specimen that contained six disk-shaped defects at various depths with features to reflect ultrasound with differing amplitudes.

Video & Imaging

The SuperView 2000 **multi-video windowing system** from RGB Spectrum, Alameda, CA, adds multiple live video images to any computer display of 2K x 2K resolution. It displays from two to ten video signals on one screen; each window can be positioned, scaled, overlaid with computer graphics, and overlapped with other video windows. Video input signals may be NTSC, PAL, or S-Video, and the display screen may be any monitor up to 2048 x 2048 pixel resolution.

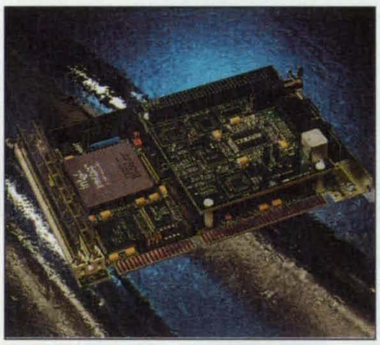
The system is an external standalone peripheral that can be used with any computer system. It supports software control to manipulate the windows, adjust video parameters, and control graphics overlays via the RS-232 port.

For More Information Write In No. 746

FLIR Systems, Portland, OR, has introduced the Tracer™ **thermal imaging system** to record and analyze long thermal event sequences at real-time frame rates to 60 Hz on a Windows™-compatible PC. Designed for R&D, process control, and other applications requiring thermal activity monitoring over time, the system consists of a Prism DS thermal imaging camera, a Pentium® PC, a digital video recording system, and Windows-based analysis software.

The system can record 5+ minutes of thermal activity at a 60-Hz frame rate with 12-bit pixels, capturing 9.3 Gb of data per second. The system can measure temperature of objects from -10°C to 2000°C with an accuracy of ±2 percent or 2°C. It stores the captured digital thermal data without using data compression, ensuring the integrity of the data captured.

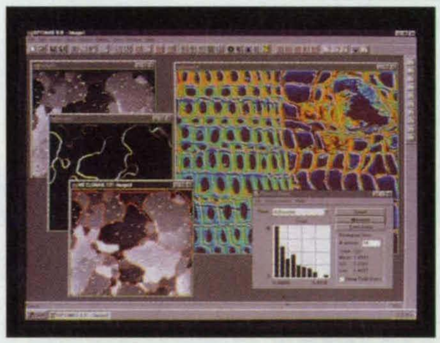
For More Information Write In No. 740



Teknor Industrial Computers, Montreal, Quebec, Canada, has introduced the VIPer Vision TEK-380 **video interface module**, which produces real-time video for LCDs and analog CRT screens while occupying no bandwidth at the system bus level. The board can be embedded into a variety of industrial environments.

It has inputs for up to six composite or three S-Video signals; NTSC, PAL, and SECAM operation; CCIR or square pixel digitizing; and a variety of digital video features for color control, sizing and positioning, cropping, and image file storage. The unit comes with one BNC connector for composite video, one 4-pin mini-DIN for S Video input, and one 14-pin header for multiple inputs. Single-unit cost is $395.

For More Information Write In No. 745



OPTIMAS 6.1 **image analysis software** from Optimas Corp., Bothell, WA, is a Windows-based interface that provides image analysis functions and is compatible with industry standards and components. Operating with Windows NT and Windows 95, it supports 32-bit NT hardware drivers for a range of new PCI-bus frame grabbers, as well as older 16-bit image capture devices.

The OPTIMAS Wizard feature guides users through interactive examples of image acquisition and enhancement, feature identification, measurement extraction, and macro automation.

For More Information Write In No. 741

Nikon, Melville, NY, has introduced the Veritas™ VM-500 **video measuring system**, which allows measurement of extremely large parts with an increased stage size. The system consists of a Nikon measuring microscope with computer-controlled zoom of 10:1; a 20" x 21" x 6" stage; an integral CCD camera; measuring software, which provides real-time video display, graphical part view, CNC stage motion with field-of view measuring capability; a digital read-out; and a video monitor.

The system offers DC servo motor control for positioning of the stage, which moves at 200 mm per second. The illumination system features up to six channels of computer-controlled fiber-optic illumination, allowing dark objects to be measured with vertical, contour, and/or oblique illumination.

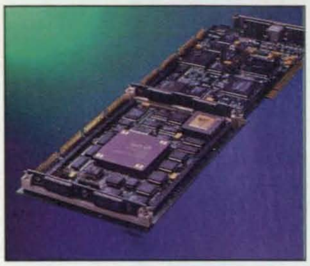
For More Information Write In No. 743

The Encore™ **digital video camera** from Olympus America, Industrial Products Group, Melville, NY, records action that takes place too quickly to be captured by the human eye or by standard video systems. It digitally stores the recorded images and plays them back in variable-speed slow motion. Designed for motion analysis of high-speed machinery and equipment, the system can troubleshoot and prevent or predict maintenance.

The cameras are available with recording rates of 250, 500, 1,000, and 2,000 frames per second, in full-color or black-and-white display. They feature high frame storage capacities and are constructed with a urethane outer shell that resists scratches.

For More Information Write In No. 748

Video & Imaging



Coreco, St. Laurent, Quebec, Canada, offers the Oculus-F/64™-PCI **image acquisition and processing boards** for implementing high-speed, high-resolution, computationally intensive image processing algorithms. The series consists of four dedicated processors: the TMS320C40 DSP, a programmable processor that performs multiple operations per clock cycle; a system controller to accelerate imaging and graphics applications; and a histogram processor and the IP-Engine, which combine for real-time arithmetic operations in industrial inspection and quantitative image analysis applications.

The F/64-PCI offers frame-grabbing from any source and is compatible with camera types such as single- and dual-tap line scan and area scan, and high-frame rate and high-resolution digital cameras. It features a 40-MHz acquisition, 250 MOPS, and an internal 80 Mb/second communications bus to transfer images between dedicated on-board processors.

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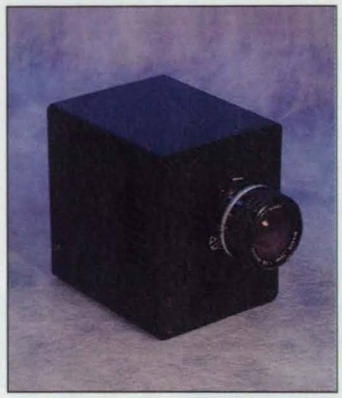

The Cryocam Series II slow-scan **chilled CCD camera** from Micro Luminetics, Los Angeles, CA, was designed for low-light imaging in scientific applications. It supports large-format scientific CCDs with resolutions to 2048 x 2048 pixels and features low noise circuitry for high sensitivity. An 8-bit mode provides focusing at 400,000 pixels/second. Readout rates to 200,000 pixels/second at 12 or 16 bits are provided.

The camera includes a built-in shutter, quartz window, variable offset and multiple gain settings prior to the digitizer, CCD temperature control, sub-windowing, antiblooming, on-chip binning, and external syncs. Camera-control and image processing software is included.

For More Information Write In No. 749

Xerox Engineering Systems, Rochester, NY, has announced the 8830 A- to E-size digital **engineering printer**, which provides mid-volume printing in engineering, technical, or CAD environments. It can be connected to virtually any PC or network and prints from a variety of software, including AutoCAD, Pro/Engineer, and most Windows-based applications. Users can construct jobs from one or more files, set print options, and print data files directly from desktop computers using the system's Documentation Submission Tool. The print queue can be viewed from the desktop using a Printer Manager Tool, which also can be used for remote access to the printer. The system provides printing speeds up to 3" per second, 400 dpi resolution, single-pixel reproduction, a 33-step half-toned gray scale, and the ability to produce multiple prints and sets of engineering documents.

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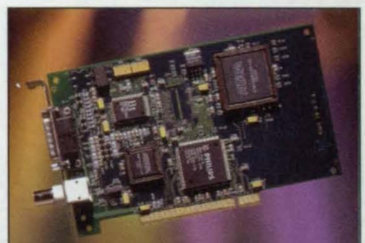
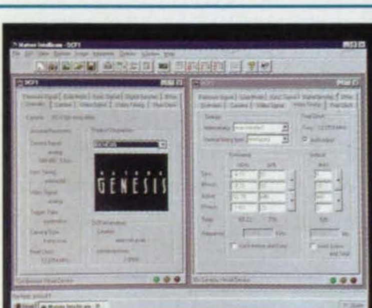


The DT3153 MACH color **PCI frame grabber** from Data Translation, Marlboro, MA, features integrated digital I/O and genlocking functionality. It has horizontal, vertical, and pixel outputs, enabling genlocking of multiple cameras from a single source, allowing users to switch instantly between cameras without loss of vertical sync. The PCI Bus Master board can transfer images in real time to system memory without intervention from the CPU.

The board uses Microsoft's DirectDraw standard to display non-destructive overlays on live video, allowing users to place graphic images on top of live video without affecting image throughput. Up to three NTSC/PAL composite inputs or one Y/C (S-Video) input and two NTSC/PAL inputs can be connected. Decoded color data can be saved in 32-bit RGB format or in 16-bit YUV format.

For More Information Write In No. 747



Matrox Imaging Products Group, Dorval, Quebec, Canada, has introduced the Intellicam 2.0 32-bit **camera interface software** for Windows NT and 95. The program comes with pre-built digitizer configuration format files for many popular cameras, describing the video signal's characteristics. The file communicates the video specs to the digitizer and initializes the hardware. Users can fine-tune parameters such as video timing, pixel clock, bit depth, and synchronization to match a specific camera.

Images can be grabbed and stored in a TIFF file format without writing code. A built-in command line interpreter feature allows a user to experiment with MIL/MIL-Lite commands without recompiling each time a change is made.

For More Information Write In No. 751

Silicon Mountain Design, Colorado Springs, CO, has announced the SMD-1M60X and SMD-4M15X **digital cameras** for use in X-ray imaging applications in the medical and industrial fields. They offer 12-bit dynamic range and on-chip charge binning to increase optical sensitivity in low-light imaging conditions. Remotely controlled 2 x 2, 4 x 4, and 8 x 8 binning capabilities provide on-chip gain enhancement of up to 64:1 without the need for external image intensifier tubes.

The 1M60X features 1024 x 1024 resolution at 60 FPS; the 4M15X features 2048 x 2048 resolution at 15 FPS. Both models utilize CCD sensors designed for high-frame-rate, low-noise operation.

For More Information Write In No. 744

Electronic Components and Circuits

Magnetic-Bubble Annihilator for Use in VBL Memories

Enlarged loop increases tolerance to misalignment of the magnetic bubble.

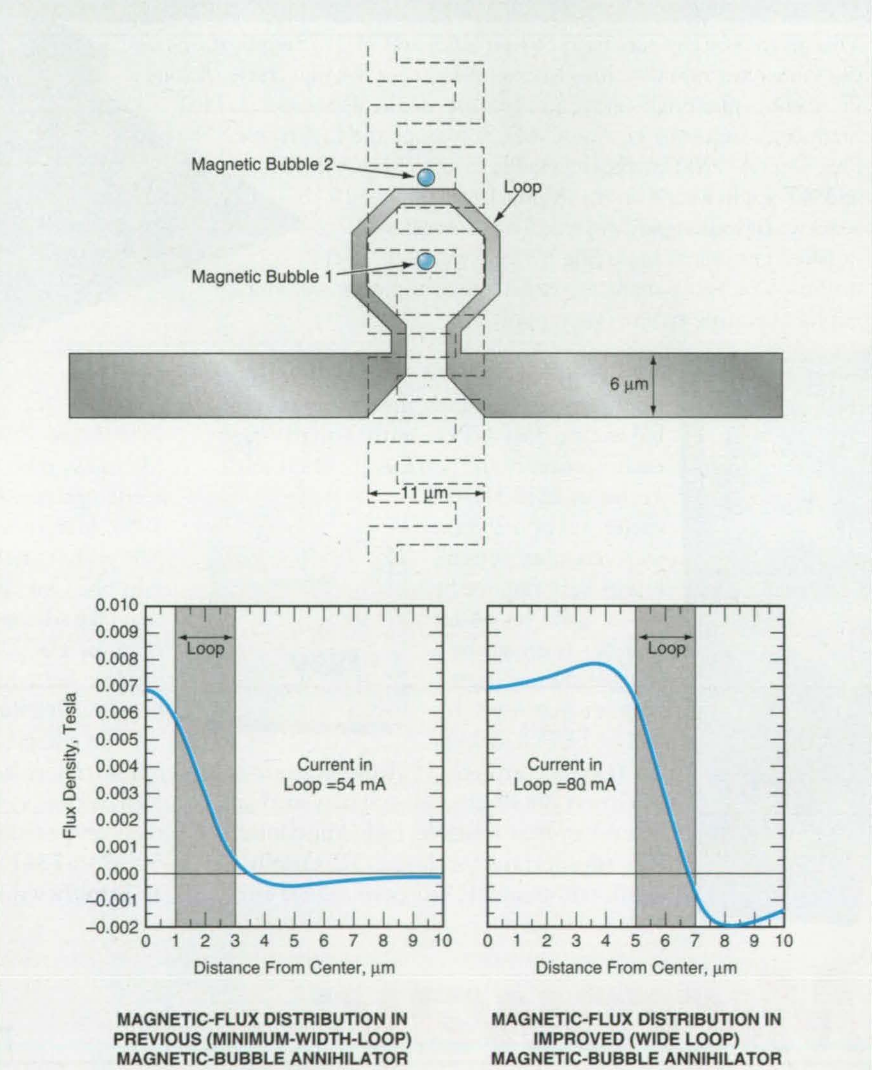
NASA's Jet Propulsion Laboratory, Pasadena, California

Vertical-Bloch-Line (VBL) memories are a new class of high-density magnetic-storage devices in which the information is represented by magnetic structures (VBLs) in the domain walls, rather than by the domains themselves as in magnetic-bubble memories. Writing and reading of VBLs in long stripe domains is achieved by interaction of the stripe heads with bubbles of input/output (I/O) lines. Because the VBLs are propagated along the stripe walls by an external field, the bubbles must be propagated by local fields, e.g., created by meandering current loops. Although this "current access" mode had long been proposed for bubble memories, details for bubble nucleation and annihilation by current loops had not been worked out. This article describes a substantial improvement of an earlier bubble annihilator for current access technology.

An improved design for a magnetic bubble annihilator in a magnetic memory device features an enlargement (relative to a previous design) of an electrically conductive loop. This enlargement increases the electrical current needed to annihilate a magnetic bubble, but also increases tolerance to misalignment of the bubble and increases tolerance to variation in the amplitude and duration of the annihilating current pulse.

In general, a magnetic memory device of the type in question (see figure) includes a magnetic garnet film with its "easy" direction of magnetization perpendicular to the surface. A magnetic bubble is a round cylindrical domain, wherein the direction of magnetization is opposite the direction of magnetization in the surrounding area of the garnet film. Magnetic bubbles are confined within a bubble track, which is a groove in the garnet film. A metal-film loop connected to metal-film strip conductors is laid across the bubble track for use in annihilating bubbles; this is the loop mentioned above. The device also includes a meandering strip of metal film laid along the track; this strip is part of a structure that propagates magnetic bubbles along the track.

A loop of the previous design was made with an opening of minimum width in the hope of generating a strong local magnetic field that would reverse the magnetization of a bubble. The magnetic flux density produced by the pulse of current in the loop was maximum at the center of the loop. The current needed to annihilate a perfectly or nearly perfectly centered magnetic bubble was estimated to be about 44 mA. However, it was observed that when a bubble was not well centered in the loop, either the bubble was pushed away from the loop instead of annihilated, or else it was necessary to use a very large and very short current pulse to achieve annihilation.



The **Loop in the Improved Magnetic Bubble Annihilator** is 5 times as wide as it was in the prior version; the resulting distribution of magnetic flux density is more favorable to retention of a magnetic bubble in the loop.

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In a loop of improved design with the wider opening, the magnetic flux density reaches a maximum at a distance of a few microns from the center, with a shallow local minimum at the center. This shallow local minimum in the magnetic field helps to hold the magnetic bubble in the loop when the average magnetic field is raised by increasing the current. This design is consistent with state-of-the-art track widths of 4 to 5 µm, bubble diameters of 2 to 3 µm, and bubble misalignments of the order of 1 µm. As long as the magnetic bubble lies entirely within the loop, it can be annihilated by a current of about 80 mA. The optimum size of the loop is determined in conjunction with the requirement that the next bubble in line not be pushed away by the magnetic field outside the loop.

This work was done by Udo Lieneweg, George N. Patterson, and David Opalsky of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, **write in 80** on the TSP Request Card. NPO-19716*

Charge Amplifier/Discriminator With Wide Dynamic Range

Output includes two logarithmic bar graphs.

NASA's Jet Propulsion Laboratory, Pasadena, California

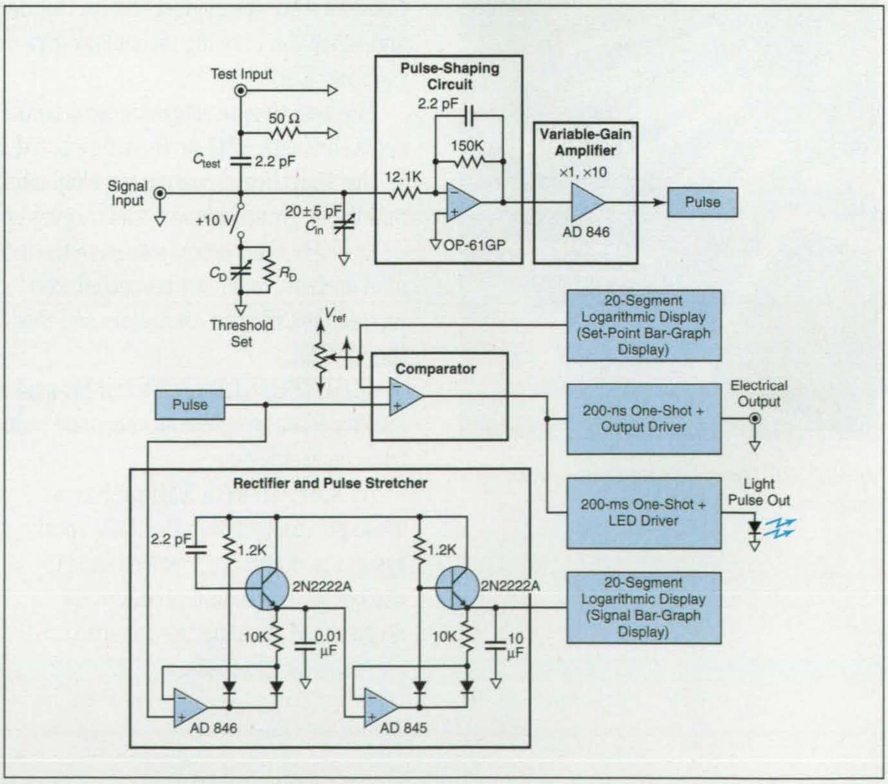
The figure shows the major functional blocks and some of the circuitry of a charge amplifier/discriminator that accepts, as input, the output of any of a variety of electron, photon, and ion detectors operating in the pulse-counting mode at rates up to 500 kHz. This instrument generates a 20-segment logarithmic-bar-graph display of the threshold level and of each input pulse that exceeds a threshold charge-detection level. Calibrated charge-detection thresholds can be adjusted within the range of 8.8×10^{-15} to 3.2×10^{-10} Coulombs, (5.5×10^{4} to 2×10^{9} electrons); this amounts to a dynamic range of about 91 dB.

Each pulse of charge arriving at the input terminal is stored in the total input capacitance, $C_{total} = C_{test} + C_{in} +$ (when switched in) C_D. The durations of the pulses are much shorter than the characteristic times of the input circuitry and the following pulse-shaping circuitry, so that a given pulse can be regarded as an impulse of infinitesimal duration and total charge q; thus, the voltage across the total input capacitance immediately after the arrival of the pulse is $v_{in} = q/C_{total}$. For calibration (instead of discriminating unknown input charge q), pulses of calibrated charge $Q_{cal} = C_{test}V_{peak}$ are obtained from the negative transitions of a square wave of peak-to-peak voltage V_{peak} applied to the test input terminal.

The input voltage is fed to a pulse-shaping amplifier which produces a semisinusoidal (positive half) output voltage pulse proportional to the input charge, with full width at half maximum (FWHM) of 1 µs. The switch labeled "÷10" can be closed to connect C_D to increase the input capacitance by a factor of 10, thus dividing the input voltage and extending the dynamic range of the instrument by this factor. To maintain the FWHM of 1 µs, shunt resistor R_D is switched in along with C_D. The pulse-shaping circuit is followed by an amplifier stage that can be set to a gain of either 1 or 10, thus enabling further extension of the dynamic range.

The novelty of the design lies in a high-speed, half-wave, peak-detector circuit (denoted "rectifier and pulse stretcher" in the figure) configured in two stages with time constants of 100 µs and 100 ms, respectively. The first stage must drive a 0.01-µF output capacitor to at least 10 V in 500 ns, requiring a maximum current of 200 mA. A pass transistor is added to supply this current. Biasing the transistor to class A with the various diodes improves the small-signal response by decreasing the dead band to approximately the bias voltage (which is of the order of 28 mV per stage (56 mV total) and depends on temperature. Both stages are underdamped such that their small-signal responses include overshoots of approximately 20 mV. The overshoot voltage can be subtracted out, reducing the remaining offset error with input signal to 36 mV. Any real signal exceeding this limit is accurately displayed at the output. Inasmuch as an analog output signal is also available, an oscilloscope can be used to monitor signals at levels less than 36 mV, if necessary. The bar-graph output display is most accurate for inputs in the frequency range of 3 kHz to 200 kHz.

This work was done by Christopher J. Wrigley, Geoffrey K. James, and Brian O. Franklin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, **write in 61** on the TSP Request Card. NPO-19597*



This **Charge Amplifier/Discriminator** features a logarithmic-bar-graph output display and a charge threshold that can be adjusted within a dynamic range of about 91 dB.

Ultra-Low-Resistance Metal Contacts on InP

Resistivity can be as low as 10^{-8} $\Omega\cdot cm^2$.

Lewis Research Center, Cleveland, Ohio

Metal contacts on InP semiconductor devices can be made to exhibit electrical resistivities close to the theoretical minimum value — of the order of 10^{-8} $\Omega\cdot cm^2$. Heretofore, the lowest contact resistivities were of the order of 10^{-7} $\Omega\cdot cm^2$; these were achieved by use of Ni and other metals and alloys as the contact materials. The present ultra-low-resistance contacts are formed by first depositing Au on the InP surfaces, then depositing Ni on the Au, then sintering. During sintering, Ni diffuses through the Au into the InP, but the Au retards the diffusion of In from the InP into the contacts. As a result, after sintering, the concentration of In at the interface between the semiconductor and the metal is greater than it is when Au is not used; the net effort of the higher concentration of In and the diffusion of nickel into the subcontact bulk material is to reduce the interfacial barrier height and thus the resistivity.

This work was done by Victor G. Weizer and Navid S. Fatemi of Sverdrup Technology, Inc., for **Lewis Research 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 NASA Lewis Research Center, Commercial Technology Office, Attn: James Martz, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-15816.

Sinterless Formation of Contacts on Indium Phosphide: Part 2

A different intermediate contact material can be used.

Lewis Research Center, Cleveland, Ohio

An alternative intermediate contact material can be used in the technique, described in "Sinterless Formation of Contacts on Indium Phosphide," *NASA Tech Briefs*, Vol. 19, No. 10 (October, 1995) page 45, for sinterless formation of low-resistivity ($\approx 10^{-6}$ $\Omega\cdot cm^2$) electrical contacts on InP semiconductor devices without damaging the devices. The alternative material is Ni_3P. A layer of this material is deposited, between the InP and the metal contact layer, to the same thickness (40 Å) as that of the AgP_2 intermediate contact layer described in the prior noted article.

This work was done by Victor G. Weizer and Navid S. Fatemi of Sverdrup Technology Corp. for **Lewis Research Center**. *For further information,* ***write in 60*** *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: James Martz, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-15815.

Radio Beacon Indicates Direction to Receiver

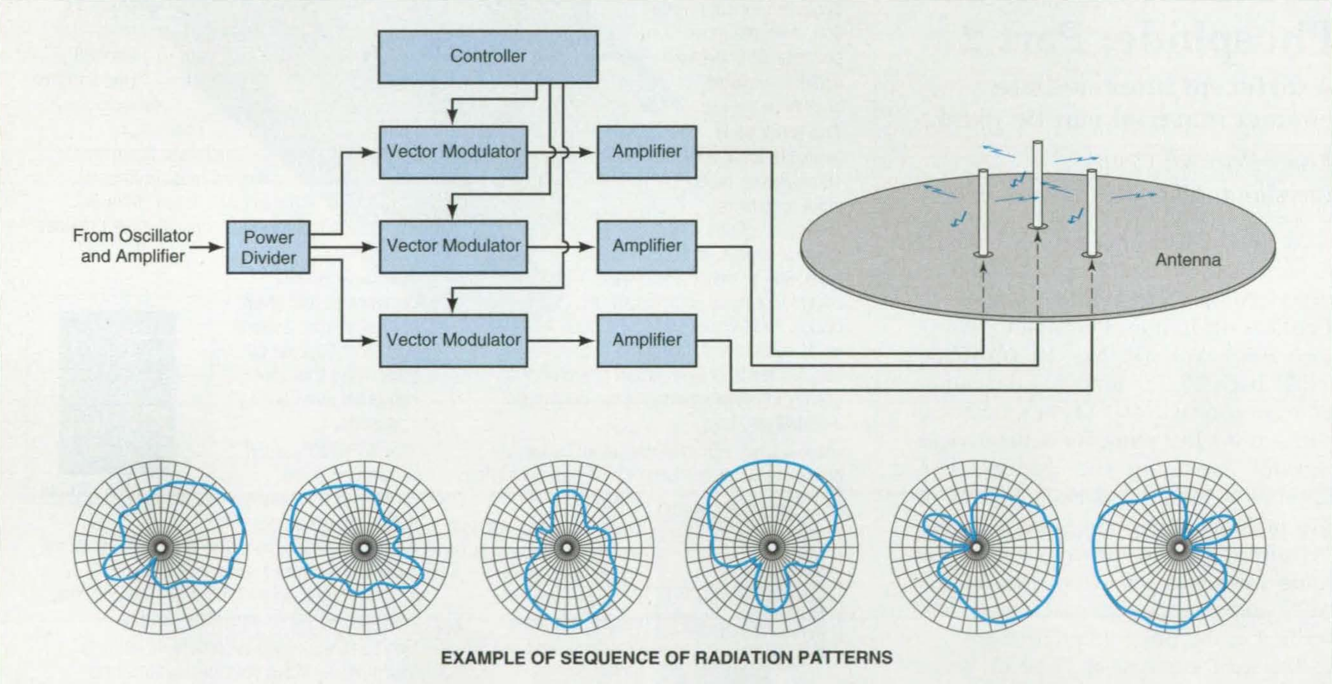
The receiver need not be equipped with a directional antenna.

Marshall Space Flight Center, Alabama

A radio-beacon system provides information on the direction of a receiver relative to a transmitter, without need to equip the receiver with a directional antenna. The major advantage of this system is that by eliminating the need for a directional antenna, it also eliminates the need for antenna-steering mechanisms and circuitry, which can be expensive. In a typical application, the transmitter and receiver would be mounted in two different vehicles, and the operator of the receiving vehicle would use the directional information along with other information to prevent a collision with the transmitting vehicle.

The basic idea is to transmit a radio signal with amplitude that varies with time and direction according to prescribed waveforms that the receiver can recognize. The directional information is encoded in a repeating sequence of direction-dependent amplitude steps, which are generated in the following way: The amplified continuous-wave signal from an oscillator is fed through vector modulators to vertically oriented antenna elements mounted over a horizontal ground plane (see figure). Modulation waveforms that produce amplitude and phase modulation are applied to each vector modulator; these waveforms are designed to provide the required amplitude steps and the required variation in the antenna radiation pattern with time, the net result being that the amplitude steps of the signal radiated in a given direction differ from the amplitude steps of the signal radiated in a different direction.

The sequence can comprise any number of different amplitude steps and radiation patterns; the optimum number depends on the design of the antenna and the required performance of the system. The receiver includes a digital processor and a memory that contains digital representations of the prescribed waveforms that correspond to a set of directions. In the processor, a digital representation of the amplitude-vs.-time waveform of the received signal is compared with each prescribed waveform. The direction from the transmitter to the receiver is then assumed to be the direction associated with whichever prescribed waveform most closely matches the received waveform. It should also be possible to modulate the transmitted signal to convey information on the heading or orientation of the transmitting vehicle; in that case, the absolute direction from the transmitter to the receiver would also be known.



A **Phased-Array Antenna** is excited through vector modulators to radiate a signal with stepped amplitude and a radiation pattern (in the horizontal plane) that varies with time. The prototype system contains three antenna elements, but other numbers of elements could be used.

This work was done by James W. Harper of Science Applications International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 57*** *on the TSP Request Card.*
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Powering a Lightweight Airplane With Phased Microwave Beams

A radio beacon aboard the airplane would transmit signals for aiming and phasing.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figures 1 and 2 illustrate aspects of a proposed system for microwave beaming of power from multiple phased microwave antennas at ground stations to a lightweight airplane flying in the vicinity. The system would operate independently of any other telemetry links between the airplane and ground, would contain a minimal number of components, and could be expanded by adding ground stations.

All of the ground stations would transmit high-power microwave uplink signals at the same carrier frequency, at controlled phases with respect to each other. One power signal would not be modulated, while each of the others would be phase-modulated at a unique frequency. A rectenna on the airplane would convert several uplink signals to dc to power the plane. The amplitude of the resulting dc will contain a ripple component at each of the unique uplink modulation frequencies, which is proportional to the phase error of the signal with that modulation frequency. The airplane would carry a low-power microwave downlink transmitter operating at a higher carrier frequency. The downlink signal would serve as a beacon for aiming the ground-station antennas. (Optionally, some antennas could be aimed in preparation, without turning on their high-power transmitters until needed or until the airplane was close enough.)

The downlink signal would also be modulated with the amplitude ripples from the rectenna. These ripples contain sufficient information to serve as feedback for adjusting the phases of the uplink signals at the ground stations so that the uplink signals would be made to arrive at the rectenna in phase with each other to maximize the power delivered to the rectenna.

The ground station transmitting the unmodulated uplink signal would be denoted the master; the other ground stations would be denoted slaves, and the phases of their uplink signals would be adjusted relative to that of the master, as described below. The rectenna would receive a composite of master and slave signals. A sample of the modulation in the composite signal would be extracted via low-pass filter 2 and used to modulate the downlink signal. The modulated downlink signal would thus contain information on the relative phase of each slave transmitter.

The uplink carrier frequency would be provided to each slave station through a common radio-frequency distribution subsystem. In each slave station, the distributed common carrier signal would be phase-modulated at its unique frequency, then passed to a high-power amplifier via a phase shifter, which would adjust the phase in response to the feedback phase-control signal. The high-power output signal would be bounced off a dichroic reflector, which would reflect at the uplink

PARAMETRIC TECHNOLOGY CORPORATION

In today's competitive environment many companies are at the point where they must upgrade to a more advanced design system or risk being left behind. To meet the business challenges of producing increasingly sophisticated products, faster and more affordably than ever before, companies worldwide are turning to Pro/ENGINEER® Solutions to dramatically improve their product development process and gain a competitive advantage. In the past, however, the high cost of purchasing and supporting UNIX-based workstations had driven smaller companies to settle for low-end design software and hardware solutions.

Enhancing the Product Development Process with Windows NT

With the rapid evolution of operating systems and improved hardware price-performance, Windows NT has developed into a robust, feature-rich operating system that is excellent for advanced applications, such as Pro/ENGINEER.

With the maturing of Windows NT® and continual performance improvements to PCs, a new computing platform has evolved that is able to run applications that were once dependent on the features provided only by UNIX workstations. By equipping the PCs with Windows NT and a high-end design system, users benefit from the advanced product development functionality currently available, without giving up the affordability and ease of use of the PC environment.

digital

PARAMETRIC TECHNOLOGY CORPORATION

Windows NT – The Solution

Windows NT was designed to be a high-performance, portable, scalable operating system, much like the original design specifications for UNIX. However, as a more modern system, it benefits from 20 years of advancements in operating system design and can today be offered at a much lower cost to the consumer. In short, with Windows NT, engineers can now take advantage of advanced product development software, such as Pro/ENGINEER, without giving up the familiar world of the PC.

Furthermore, an increasing number of companies are recognizing the financial and time-saving benefits of purchasing a system that can be used for both mechanical design and personal productivity applications. Many companies are purchasing PCs running Windows NT to extend the effectiveness of their work, while reducing the number of operating systems that need to be administered.

Digital Hardware – A Superior Choice

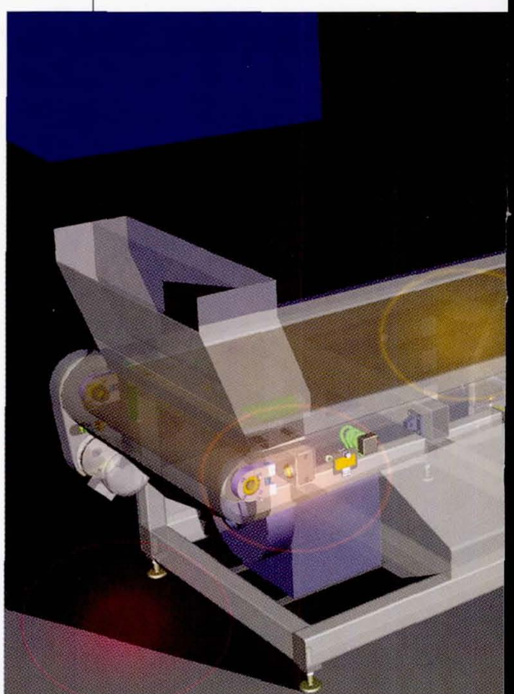
Digital Equipment Corporation was the first UNIX-based hardware manufacturer to recognize the impact that Windows NT would have on the computer industry and, specifically, the technical markets of mechanical design and manufacturing. With Windows NT as the catalyst for change, Digital has successfully reconciled its workstation business model with the PC computing paradigm that has swept the computer industry, by supplying aggressively-priced Windows NT-based PCs to customers who have hungered for a powerful, yet cost-effective, computing solution.

The combination of Windows NT on Digital's Alpha workstations has created a new platform offering the power of a high-end workstation with the affordability and familiarity of a PC. This platform is well suited for Pro/ENGINEER Solutions and allows companies to use their financial resources to automate additional engineers, instead of supporting costly system administration and multiple – often redundant – types of hardware.

The Power of Pro/ENGINEER Solutions

Pro/ENGINEER on a Windows NT-based workstation provides all the functionality and benefits that UNIX-based companies have been using so effectively to develop better products, faster and more affordably. Benefits that Pro/ENGINEER has always delivered, including faster modeling, enhanced collaboration, reduced cycle time and development costs, better communication with suppliers and customers, and greater accuracy throughout the entire product development process are now available in the PC environment.

There have always been many good reasons to upgrade – now, with Pro/ENGINEER running under Windows NT, there are no more reasons not to.



Manufacturer Has Fewer Surprises with Pro/ENGINEER

SRC VISION of Medford, Oregon, makes complex sorting systems that use machine vision technology to spot defective products and foreign materials on a high-speed processing line and remove them from the product stream. These machines, which transport the product at a rate of 500 to 1,000 feet per minute along a conveyor belt, compare optical images of items passing by with operator-entered standards stored in the system's computer. Defective items are quickly identified and removed from the good-product stream by a closely controlled air jet. Industries that use SRC VISION machines include food processing, plastics recycling, tobacco and wood.

Designing these machines is an exercise in large assembly modeling and management. The machines, which are the size of a small room and weigh about three tons, may contain between 2,000 and 6,000 mechanical parts. When SRC VISION was using conventional 2D CAD, designers had to manually perform clearance checks and interference checks prior to assembly. When it came time to assemble a newly designed machine, there were fit problems that necessitated engineering change orders, scrapped parts, and rework.

Three years ago, SRC VISION invested in software to optimize the product development process, installing Pro/ENGINEER Solutions from PTC and leaving 2D CAD behind. Now there are few surprises during assembly because fit and clearance can be thoroughly checked with the software. Assembly drawings are more accurate and "the ECO load has gone way down," says Tom Watkins, SRC VISION's director of mechanical engineering. "Because of Pro/ENGINEER we now have 80% to 90% fewer ECOs then we had when we used 2D CAD."

Another benefit of Pro/ENGINEER is the ability to send part models to vendors and get parts within hours–without producing drawings. "We've eliminated 8 out of 10 part drawings by sending Pro/ENGINEER models electronically," Watkins says. "And in the case of laser cutting, we're getting accuracies of less than 0.001 inch."

With accuracy up, ECOs down, and electronic communication with vendors, SRC VISION has experienced a significant reduction in cycle time. It has also experienced its best year ever. "In 1996, we put two new machines into production and both were company records," Watkins says. "We could never have gotten them done so quickly the old way."

Although UNIX workstations were the original Pro/ENGINEER platform, SRC VISION later added a Digital Alpha computer. "Over the next 18 months, our intention is to phase out all the UNIX boxes and replace them with the fastest Digital workstations available," Watkins says.

The reasons for this are mainly economic, due in part to the affordability of the Digital computers as well as their ability to run Windows NT. According to Watkins, having Windows NT as the operating system will spare SRC VISION the cost of maintenance and support contracts. It will also spare them the need for two computers per designer.

"When we're using a UNIX box for product development, we really need two computers on the desk because you also need a PC for applications like e-mail, Microsoft Office, and other specialized applications," Watkins says. "We'll need only one computer when we can put everything on a Digital Alpha computer running Windows NT."

SRC Vision

Medford

Oregon

Custom Mold & Design

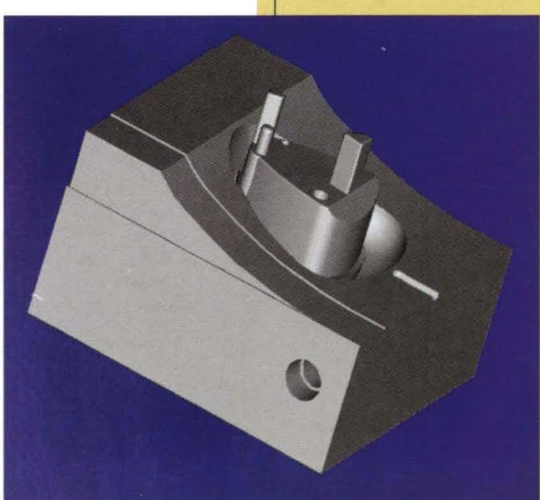
New Hope

Minnesota

Leveraging Pro/ENGINEER Solutions in the Windows NT Environment

Custom Mold & Design, a builder of custom molds for medical, computer, and automotive applications changed its mold design process to take advantage of the benefits that Pro/ENGINEER provides. Bob Hullander, design manager, estimates that the company's customer base has increased by 60% in the past three years, primarily because they are a user of Pro/ENGINEER, a requirement of many of their customers.

By applying Pro/ENGINEER to the entire mold design process, rather than just using it for estimating, Custom Mold & Design has experienced additional benefits, such as a reduction in cycle time. And rather than running the software only under UNIX, Custom Mold & Design also uses three Windows NT-based computers from Digital Equipment Corp. as Pro/ENGINEER design stations. "We wanted Windows NT for the ease of file management and system administration," explains Hullander. "UNIX can be really cryptic, but Windows NT is almost a natural."



As an example, he tells of the first time they tried to connect a Digital Alpha workstation to the company network. "It was relatively easy," he says. "We just clicked on different items until we got it connected. In UNIX, we would have been typing in cryptic commands that are really confusing, unless you have a strong UNIX background." Hullander added that with Windows NT as the operating system, "There isn't much time involved in teaching people how to maintain their computers. And most people have at least a basic understanding of Windows applications."

For Hullander, the Digital Alpha workstation provides a competitive advantage for a number of reasons. "We chose Digital's system because of their innovative technology – they were running Windows NT before anyone else. Another critical factor – one that all CAD users can identify with – is speed. We wanted to invest in state-of-the-art technology and after doing some research we found that Digital's Alpha processor was one of the fastest processors on the market," Hullander commented.

By combining the speed of the Digital Alpha workstations and the visualization and accuracy of Pro/ENGINEER Solutions, Custom Mold was able to reduce the time to design a mold by 30 percent. "Today we turn a mold around in eight weeks," concluded Hullander. "Using our previous software and hardware systems, that would have been impossible. And with business more than doubled over last year, the winning combination of Pro/ENGINEER Solutions and Digital NT machines clearly delivers a true competitive advantage."

carrier and thereby direct this signal along the uplink path.

The dichroic reflector would be transparent at the downlink carrier frequency, and would thus allow the simultaneously received downlink signal to pass through the dichroic reflector into a monopulse receiving feed. Error and sum signals would be generated, filtered, and used to point the antenna to higher accuracy. In addition, a sample of the sum signal would be demodulated in a phase-locked loop, and the unique frequency of the modulation component from this particular slave would be separated from those of the other slaves; the modulation from this slave would be extracted from the composite modulation by use of a band-pass filter. The conditioned output of the phase-locked loop would serve as a control signal for adjusting the phase shifter.

This work was done by Bruce L. Conroy and Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 24 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
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Refer to NPO-19647, volume and number of this NASA Tech Briefs *issue, and the page number.*

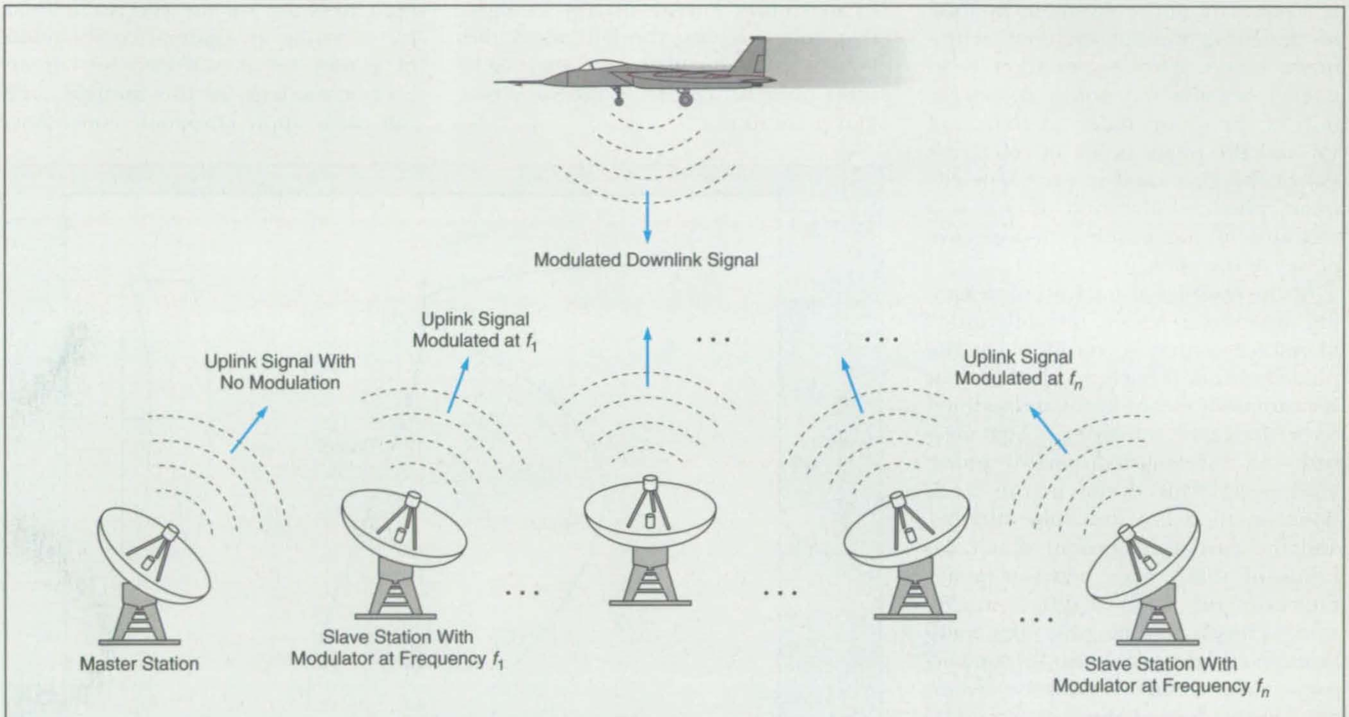


Figure 1. The **Downlink Transmitter in the Airplane** would provide phase information for adjusting the relative phases of the uplink transmitters, plus a beacon signal for monopulse tracking.

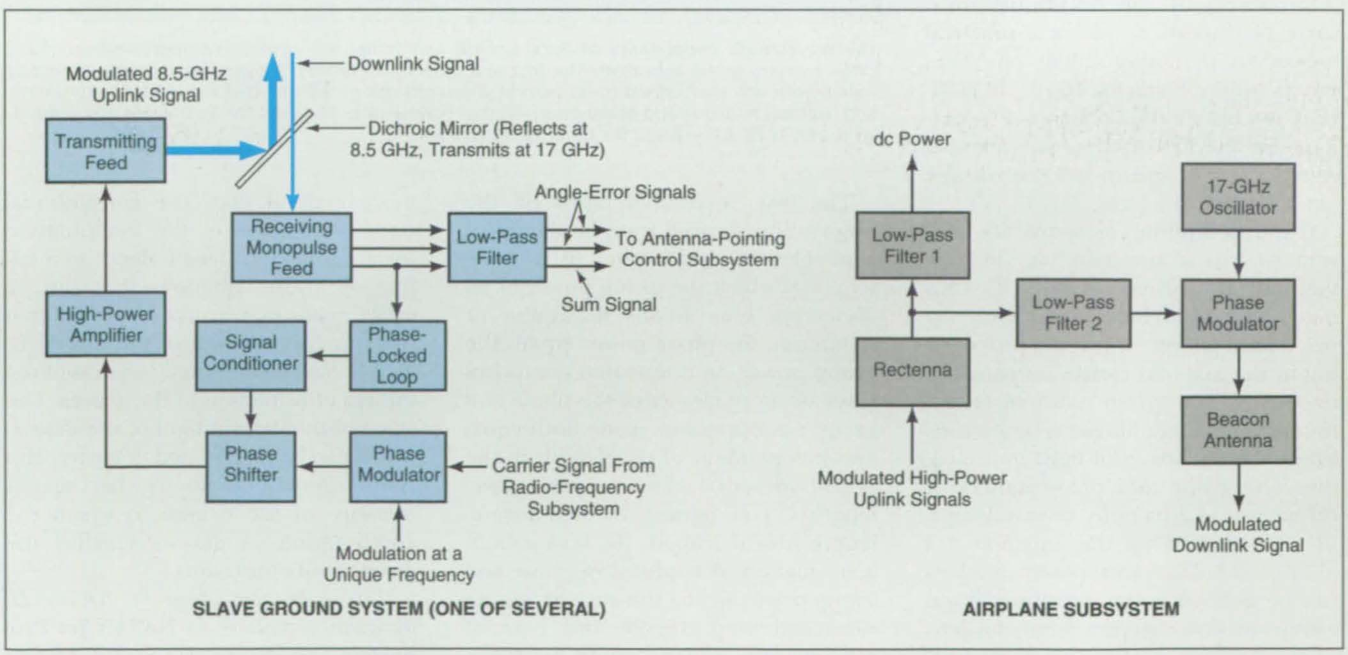


Figure 2. **Airplane and Ground-Station Subsystems** would cooperate as parts of an aiming and phase-controlling system to maximize the uplink power delivered to the rectenna.

The γ–μ Method of Designing Achromatic Lenses

Both group and phase indices of refraction are taken into account.

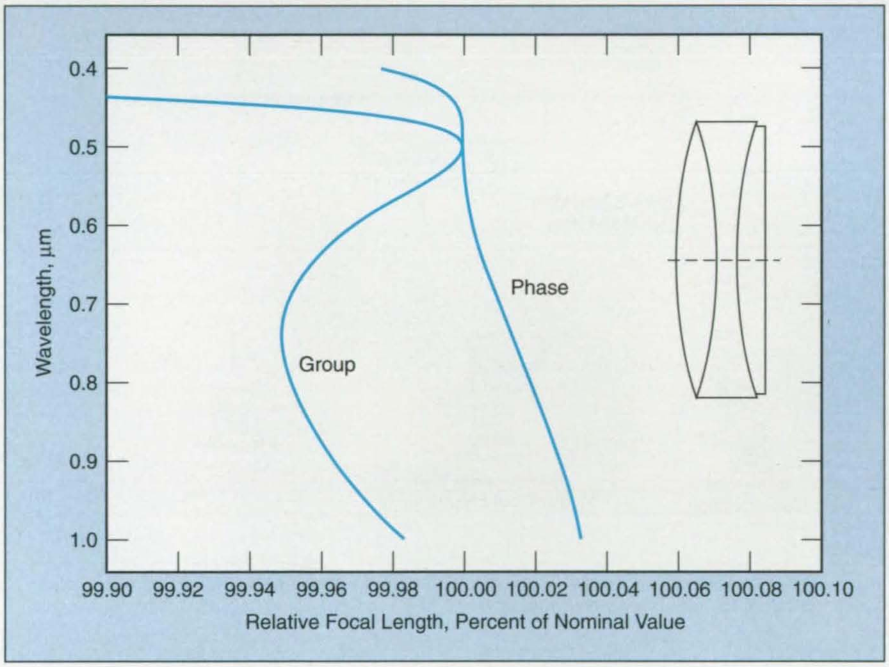
NASA's Jet Propulsion Laboratory, Pasadena, California

The γ–μ (gamma minus mu) method is a powerful and convenient method of designing multiple-element achromatic lenses. The γ–μ method is so named because it involves consideration of the group index of refraction (γ) and the phase index of refraction (μ) of the glass used in each lens element, plus consideration of γ–μ as a measure of the wavelength-dispersive power of the glass.

In the traditional method of designing achromatic lenses, the only index of refraction that is considered is the phase index of refraction, which is what is customarily meant by the unmodified term "index of refraction." The measures of wavelength-dispersive power ("dispersion" for short) in the traditional method are the Abbe number and the partial dispersion, which are ratios of differences between phase indices of refraction at different arbitrarily chosen wavelengths. The traditional method is algebraically cumbersome and unduly restrictive when applied to a lens of three or more elements. Unlike the traditional method, the γ–μ method does not involve the arbitrariness of the traditional measures of dispersion and is a practical means for designing a lens of N elements (where N can exceed 3). In addition, the γ–μ method elucidates — perhaps for the first time — the physical significance of group velocity in the performance of a lens.

Some definitions of terms are prerequisite to a summary of the γ–μ method: The group velocity (v_g) in a material is the velocity at which a signal, a wave packet, or photon propagating in the material carries information or energy. The group index of refraction of the material is given by $\gamma = c/v_g$, where c is the speed of light in a vacuum. The group and phase indices of refraction, as functions of wavelength (λ), are related via the equation $\gamma = \mu - \lambda(d\mu/d\lambda)$. The phase power of a lens can be defined as the curvature of the wavefront that emerges from the lens when the lens is illuminated steadily from a distant point source of light. The group power of a lens can be defined as the curvature of the surface of maximum energy density of light that emerges from the lens when the lens is illuminated by an extremely short pulse of light from the same distant point source.

An important byproduct of the development of the γ–μ method is a method for choosing an optimal combination of glasses for the N elements of an achromatic lens. In this method, one can easily apply chromatic constraints more general than the conventional ones. Furthermore, the computation for an N-element lens reduces to a system of linear equations that can be solved easily by a matrix formalism that involves computation of the inverse of an $N \times N$ matrix defined in terms of the indices of refraction of the glasses. The value of the determinant of the matrix, which can be interpreted in terms of an N-dimensional geometry, becomes a measure of the degree to which the combination of glasses satisfies the given set of constraints.



The **Wavelength Dependence of Focal Length** was computed in thin-lens approximation for a three-element group achromat. The first and second derivatives of phase power with respect to wavelength are constrained to be zero at a wavelength of 0.5 µm, making the lens achromatic and confocal in group and phase power at that wavelength. The inset shows the lens as a cemented triplet at *f*/7.8 corrected for spherical aberration.

The γ–μ method is based on the observation, derived from fundamental principles of optics, that at a wavelength at which the group power of an N-element lens attains maximum or minimum, the phase power equals the group power. In a lens that comprises three or more elements, the phase and group powers can be made both equal and independent of wavelength in the neighborhood(s) of one or more wavelength(s) (see figure). In such a wavelength neighborhood, the lens is both achromatic and confocal in phase and group power, giving this type of lens an unprecedented degree and type of achromatism, called "group achromatism." A lens of this type is denoted a group achromat.

This work was done by Arthur H. Vaughan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 98 on the TSP Request Card.*
NPO-19702

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Variable-Buoyancy Balloons for Tracking Tropical Storms

Evaporation and condensation of a secondary buoyancy fluid helps maintain approximately constant altitude.

NASA's Jet Propulsion Laboratory, Pasadena, California

Radiosonde-balloon systems for tracking tropical storms at approximately constant altitudes over both land and sea are undergoing development. Customarily, a radiosonde balloon, which is attached to a floating ocean buoy, is launched into a tropical storm and is quickly drawn into the eye of the storm, even if released hundreds of miles away. The buoy and balloon, however, are destroyed when the storm eye passes over land. It would be highly desirable for a balloon system to track the eye and maximum hurricane winds over both land and sea from some altitude(s) in the troposphere.

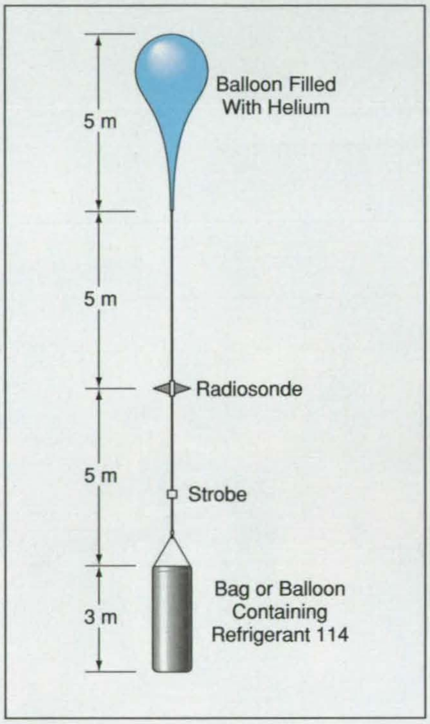


Figure 1. A **Dual-Balloon System** carries a radiosonde and strobe.

A balloon system of the type undergoing development contains a primary buoyancy fluid and a secondary buoyancy fluid. The buoyancy fluids are contained in separate balloons (see Figure 1). The primary buoyancy fluid is typically helium, while the secondary buoyancy fluid is a phase-change fluid [(for example, butane, ethyl chloride, or refrigerant 114 (dichlorotetrafluoroethane)]. The type and amount of secondary buoyancy fluid is chosen so that under the prevailing conditions of temperature and pressure, this fluid condenses above the desired altitude and evaporates below the desired altitude, causing the balloon to bob around the desired altitude.

The feasibility of this bobbing altitude concept was demonstrated in clear weather in an experiment with a two-balloon system like that of Figure 1. The system was released over California and went through several cycles of bobbing about an altitude of about seven kilometers (see Figure 2). In an actual hurricane, the balloon is likely to repeatedly travel to the eye, be drawn up to high

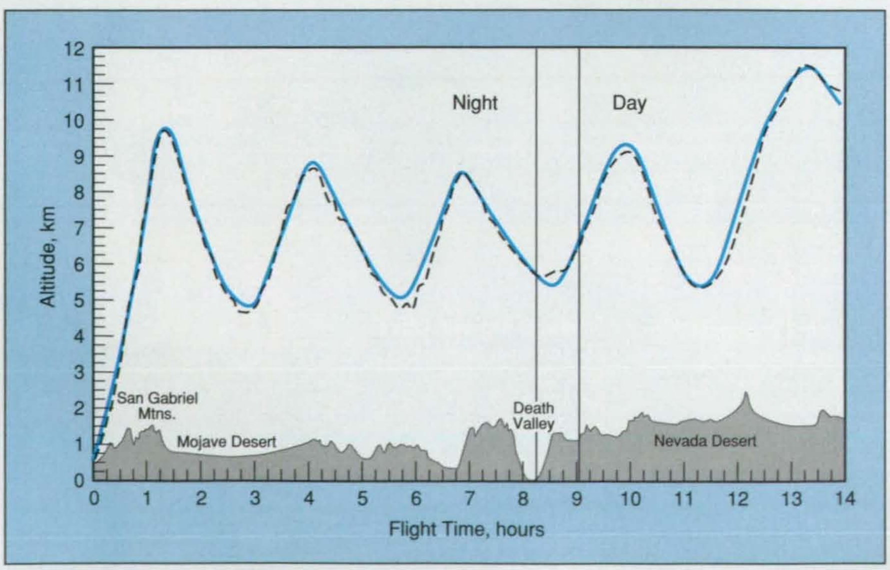


Figure 2. The **Altitude of a Balloon System** like that of Figure 1 was tracked until radio contact was lost over the Nevada Desert.

altitude and be forced outward and downward, and then travel to the eye, thus continuously measuring the hurricane wind-distribution patterns.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 55 on the TSP Request Card.*
NPO-19709

Evaluating Effects of Weather on Optical Communications

A mathematical model incorporates statistics from observations of visibility through the atmosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

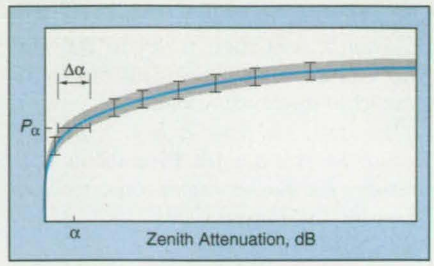
A method of evaluating the effects of weather on optical communication links from spacecraft to ground involves the use of an empirical mathematical model for attenuation of signals in the atmosphere. The method is related to an older method of evaluating a radio-communication link, wherein one takes account of gains and losses in estimating the amount of signal power needed to ensure some baseline level of performance, and the link is designed with greater power; the extra power is called "link margin" and can be incorporated into the design as a precaution against uncertainty in design assumptions and/or to enhance performance.

A basic assumption of the present method is that local weather at each ground receiving station severely affects reception of signals and, therefore, a satellite-to-ground optical-communication system will include multiple ground stations in a diversity reception scheme. In this case, diversity entails locating stations far enough apart (e.g., hundreds of kilometers) that they can be considered to be exposed to different weather conditions. In designing such a system and analyzing its performance, the availability of each station must be defined, and it is necessary to quantify the link margin needed to accommodate link uncertainties accurately. In the older method of calculating link margin, one does not take atmospheric attenuation into account, with the result that a system designed by that method can end up over- or underdesigned.

In the present method, one does not

use the power-based measure of link margin of the older method; instead, one uses a different metric, called the "expected data volume" (EDV), which takes account of both availability and uncertainties in atmospheric attenuation. As a prerequisite to a description of how this is done, it is necessary to define the terms "available," "unavailable," and "availability" as used in this special context. A ground station is said to be available or unavailable at given instant if, at that instant, the atmospheric attenuation there is less than or greater than α, respectively. "Availability" is defined as the nominal probability P_α that the atmospheric attenuation will be less than or equal to a specified amount α (see figure). The figure contains a representative plot of P_α versus α; the plot includes a nominal curve within a band that represents the uncertainty $\Delta\alpha$ in atmospheric attenuation.

One can construct a mathematical model of P_α and $\Delta\alpha$ as functions of α from statistical data on cloudiness. Such data are being gathered by three diverse (in the sense defined above) observatories (two in California, one in Arizona) that monitor the intensities of light received from known stars of known brightness.



A Cumulative Probability Distribution of α for a typical ground receiving station would look like this plot. The α represented on this plot is zenith attenuation. When analyzing an optical communication link with reception from an off-zenith direction, the path length is greater and thus the value of α must be increased. For design, the α for the largest expected zenith angle should be used.

Consider a set of N stations capable of viewing the spacecraft source of the optical signal under cloud-free conditions ("candidate stations," for short). The probability $P_N(m)$ that m of those stations are available is given by

$$P_N(m)=B(N,m)P_\alpha^m(1-P_\alpha)^{N-m}$$

where $B(N,m)$ denotes the binomial coefficient [the number of combinations of N things taken m at a time; that is, $N!/m!(N-m)!$]. The probability P_N that at least one of the stations is available is given by

$$P_N=\sum_{m=1}^{N} P_N(m)=1-(1-P_\alpha)^{N-m}$$

This is the "joint availability" of the network of ground stations to receive a downlink signal if everything is constant. In practice, the number of candidate stations changes with rotation of the Earth and motion of the source. Suppose that total downlink time is T, which is divided into K disjoint segments $t_1, t_2, \ldots t_K$, such that during each segment t_i there are N_i candidate stations. Suppose also that when at least one station is available, it is possible to reliably receive data transmitted from the source at a rate R. Then the expected data volume is defined as the volume of data expected to be received during T and is given by

$$EDV=R\sum_{i=1}^{K} t_i P_{N_i}$$

This is the metric for determining the capability of the link. The EDV and the underlying methodology are proposed for use when making comparisons between proposed radio-frequency and optical communication links.

This work was done by James R. Lesh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write* ***in 6*** *on the TSP Request Card.*
NPO-19774

Kinematic Positioning With GPS Pseudorange and Carrier Phase

Accuracy would be 2 to 3 times that of positioning with pseudorange alone.

NASA's Jet Propulsion Laboratory, Pasadena, California

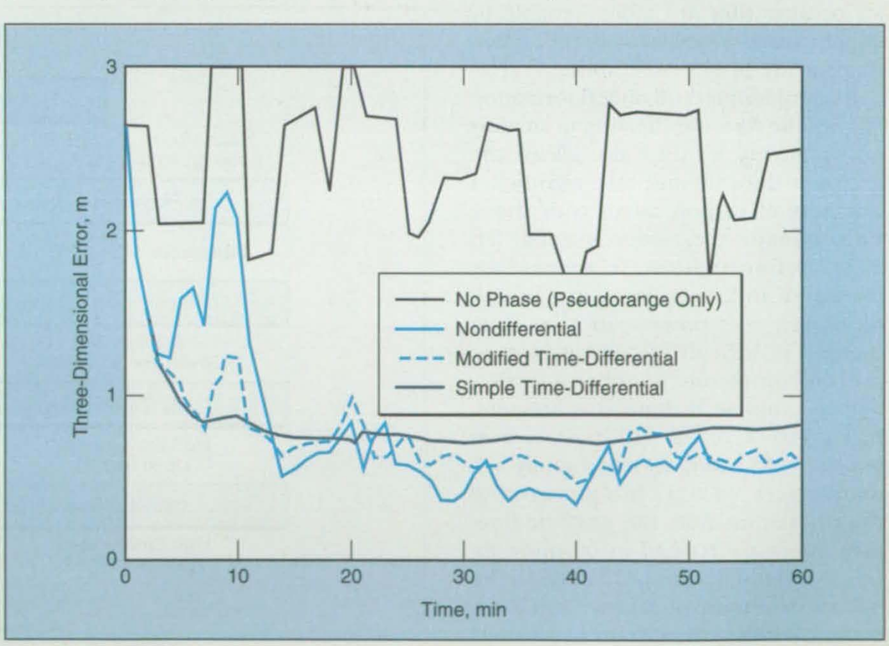
Three techniques have been proposed to increase the accuracy of real-time kinematic positioning via the Global Positioning System (GPS). These techniques involve the processing of simultaneous GPS pseudorange and carrier-phase measurements to estimate position with accuracy greater than that achievable by use of pseudorange alone. The techniques are computationally efficient and thus suitable for implementation in compact navigational electronic equipment that could be carried aboard airplanes, land vehicles, boats, and Earth-orbiting satellites.

GPS pseudorange measurements provide absolute but crude positioning information, while carrier-phase measurements provide precise information on changes in position; thus, one can determine position with greater accuracy from a combination of pseudorange and carrier-phase data. The "catch" in using carrier-phase data is that each continuous pass of carrier phase measurements is accompanied by an unknown phase bias, so that it is necessary to remove or estimate this bias in processing the data for accurate real-time positioning. The three proposed techniques provide various means to account for phase biases and to use pseudorange and carrier-phase data for kinematic positioning.

For all three techniques, an on-board GPS receiver must be capable of producing pseudorange and carrier phase measurements from multiple GPS satellites. The pseudorange measurements at a single epoch are used to obtain crude estimates of three-dimensional position and time. These estimates are then used as the nominal values for calculation of partial derivatives of measurements with respect to position and time, and are combined with the carrier-phase measurements in the subsequent precise estimation. Pseudorange measurements are valuable in speeding up the convergence of the phase-bias estimates, and thus the position and time estimates. On the other hand, carrier-phase measurements provide ties between successive time points, thus enhancing positioning accuracy.

The three techniques are called "nondifferential," "simple time differential," and "modified time differential." In the nondifferential technique, the estimation process is carried out in a square-root information filter formulation. The estimated parameters include the four-dimensional current state (position and time) and carrier-phase biases. All these are treated as white-noise parameters; the four-dimensional state is to be reset (i.e., white-noise updated) at every epoch, whereas each of the phase biases is to be reset only when its continuity ceases.

In the simple time-differential technique, phase biases are eliminated by taking differences between phase measurements at consecutive sampling times, and the current four-dimensional state is estimated by use of a recursive formula that incorporates the preceding estimate and the current pseudorange and differenced carrier-phase measurements. In the modified time differential technique, carrier-phase biases are removed in such a way as to recover the absolute-position information embedded in the carrier phase; this involves, among other things, simultaneously estimating the four-dimensional state for both the current and the immediately preceding sampling times.



Three-Dimensional Position Error would be reduced by processing carrier phase data along with pseudorange data, using any of the three proposed techniques.

Without information from ground GPS observations, on-board kinematic positioning is limited by dithering of GPS clock signals pursuant to a policy called "Selective Availability," (SA) in which the precision available to unauthorized users is limited by introducing pseudorandom errors that can be corrected by use of codes available to authorized users. Pseudorange and carrier-phase measurements are equally corrupted by these effects, which are typically tens of meters in magnitude. The SA effects can be removed if, at any epoch, each GPS satellite observed by the user is also observed by a ground station and the information retransmitted to the user for differencing.

The figure is a plot of selected results from a numerical simulation that was conducted to assess the positioning accuracies achievable with the proposed techniques. The simulation was carried out for a GPS user aboard a satellite in orbit around the Earth at an altitude of 700 km. The results of the simulation show that when wide-area differential GPS data for reducing SA clock errors and GPS ephemeris errors are available and the proposed techniques are used, it should be possible to estimate position to within a three-dimensional root-sum-square (rss) accuracy between 0.5 and 0.8 m; this level of accuracy is between 2 and 3 times that achievable with pseudorange measurements alone.

This work was done by Sien-Chong Wu and Thomas P. Yunck of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 78 on the TSP Request Card.*

NPO-19575

Modification of Carbon Fibers for Higher Young's Modulus

The Young's modulus of carbon fibers is increased after a cycle of fluorination-defluorination treatment.

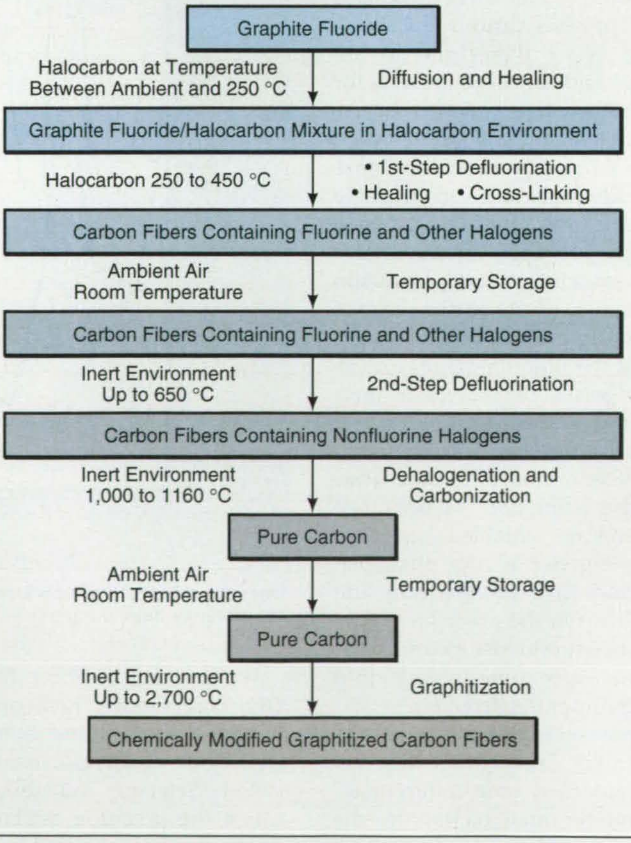
Lewis Research Center, Cleveland, Ohio

Processes for the defluorination of graphite fluoride fibers have been developed as means of producing new, chemically modified carbon-fiber materials. The starting materials and process conditions for defluorination can be chosen so that the resulting modified carbon fibers take on properties that are desired in specific applications. The chemically modified carbon materials have interplanar spacings in the range of 3.35 to 3.45 Å. Some of the modified carbon-fiber products exhibit very high moduli of elasticity, which heretofore have been achievable only with extreme difficulty. Other of these products, generally denoted as "activated graphite," can be used to make stronger metal-matrix/carbon-fiber composite materials because they are more wettable by metal matrix materials than are carbon fibers made by older methods.

In an older method of defluorination of graphite fluoride (heating in an inert environment), fluorine atoms leave the graphite fluoride and take significant numbers of carbon atoms with them. Consequently, the carbon material left after defluorination is extensively damaged and, therefore, not useful. Moreover, the process in the older method is difficult to control because the defluorination is either (a) slow and incomplete if done at a temperature < 400 °C or else (b) likely to turn explosive if heating is done rapidly at a temperature > 400 °C. In a precursor to the present method, the graphite fluoride fibers are treated in bromine vapor at a temperature of 350 °C. Defluorination in this case is faster and more complete than when done in an inert environment, but the material is still damaged significantly.

The present method involves the use of halocarbon compounds to heal some of the damage as defluorination proceeds. The figure schematically illustrates a typical process according to this method. First, the graphite fluoride fibers, obtained by fluorination of carbon fibers, are exposed to a suitable halocarbon gas (e.g., CCl_4, $CHBr_3$, $Br_2CHCHBr_2$, or $BrCH_2CH{=}CHCH_2Br$) at a temperature between ambient and 250 °C to let the halocarbon molecules diffuse into the graphite fluoride molecular structure in preparation for the defluorination-and-healing process. Then, while maintaining the same halocarbon atmosphere, the fibers are heated to a temperature between 250 and 450 °C for an interval between 2 and 10 h; this heating effects the first-step defluorination, in which the majority of fluorine atoms are detached from the carbon atoms in CF_x and quickly removed from the proximity of graphite fluoride by reacting to the halocarbons. Simultaneously with the defluorination, the halocarbons go, variously, to the sites vacated by the fluorine atoms and to sites that contain damage and defects. Thus, the halocarbon molecules not only enhance the rate of defluorination, but also prevent and heal the damage. Depending on the length of the halocarbon molecules, these molecules may produce crosslinks of the molecular structure in the carbon material and thereby produce a new carbon material; namely, graphite with its adjacent carbon layers crosslinked.

The halocarbon molecules should be small so that they can enter the molecular structure of the graphite fluoride. All of the fluorocarbon compounds mentioned above have molecules that are small enough; they can prevent and



This **Multistage Process** yields graphitelike carbon fibers with physical and chemical properties that are useful in selected applications.

heal the damage during the first-step defluorination. However, with respect to effectiveness as a cross-linking agent, the ability of CCl_4 is weak or nonexistent, the abilities of $CHBr_3$ and $Br_2CHCHBr_2$ are moderate, and that of $BrCH_2CH{=}CHCH_2Br$ is strong.

After the first-step defluorination, the carbon material still contains some fluorine (up to 11 percent of the weight of the carbon) plus other halogens (up to 31 percent) from the halocarbons. Therefore, after removing this carbon material from the halocarbon environment to ambient air for temporary storage, the material is subjected to second-step defluorination, in which it is heated in an inert environment (e.g., a nitrogen atmosphere) to a temperature of 600 °C to remove most or all of the remaining fluorine and some of the other halogens. The fibers are further heated in an inert environment to a temperature between 1,000 and 1,160 °C to remove most or all of the remaining halogen atoms.

After a second interval of temporary storage in ambient air, the fibers are heated in an inert environment (argon atmosphere) to a temperature of as much as 2,700 °C to increase the degree of graphitization and thereby increase the modulus of elasticity and thermal conductivity of the fibers. The properties of the carbon fibers thus produced depend on the temperatures and other particulars of the various stages of the process, including the final heating stage. In particular, according to the process described in the figure, when the graphite fluoride reactant was made from pitch-based carbon fibers having modulus of elasticity of 105 Msi and $BrCH_2CH{=}CHCH_2Br$ was chosen during the first-step defluorination, the final carbon fiber product was found to have modulus of elasticity value much higher than 120 Msi. Such an increase in modulus of elasticity is believed to be due to the cross-linking between the adjacent graphite layers.

This work was done by Ching-cheh Hung of **Lewis Research Center**. *For further information,* ***write in 22*** *on the TSP Request Card.*

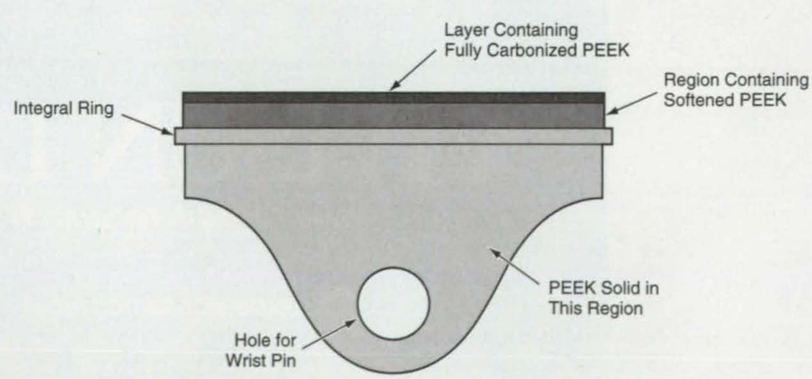
Inquiries concerning rights for the commercial use of this invention should be ad-dressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-15847.

Toughened Carbon/Carbon Pistons

Three-dimensional carbon/carbon would be toughened with metal or plastic in its pores.

NASA's Jet Propulsion Laboratory, Pasadena, California

Carbon/carbon pistons of a proposed type would be tougher than those that have been tested thus far and would thus be capable of withstanding the high temperatures and high impacts of use in internal-combustion engines. The state-of-the-art carbon/carbon pistons that the proposed pis-



In a **Proposed Carbon/Carbon Piston** made of partly densified three-dimensional carbon/carbon filled with PEEK as a toughening agent, the PEEK would become carbonized at the combustion-chamber surface during operation, would be softened in the cooler layer below this surface, and would be solid (providing maximum reinforcement) in the highly stressed region around the wrist-pin hole.

tons would replace tend to fail prematurely in use because they are brittle.

The state-of-the-art carbon/carbon pistons are made with carbon fibers oriented predominantly in two dimensions. However, three-dimensional carbon/carbon composite materials would be used in the proposed pistons. Fabrication of a piston would begin with weaving a preform to near net shape, using carbon fibers oriented in three orthogonal directions. The preform would then be partly densified into carbon/carbon by use of a highly graphitizable matrix precursor like petroleum or synthetic pitch, leaving a porosity of about 15 percent.

By use of resin-transfer molding, the pores would be filled with a metal or a thermoplastic like poly(ether ether ketone) (PEEK), which would serve as a toughening agent. The part would then be machined to net shape.

During operation, in the case of PEEK, a layer of PEEK would become carbonized at the combustion chamber surface of the piston (the top surface in the figure). Immediately below that surface, the PEEK would be soft, so that the carbon/carbon composite in that region would bear all of the load. The regions farther below would be cooler, and would be coolest (at the temperature of the engine oil) in the vicinity of the wrist pin. The PEEK would be solid in these lower regions, providing the greatest support where stresses would be the greatest.

This work was done by D. Kyle Brown of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 36 on the TSP Request Card. NPO-19592.*

High-Performance Silver-Recovery Apparatus

John F. Kennedy Space Center, Florida

An apparatus at Kennedy Space Center recovers silver from liquid waste produced during the development of photographic and radiographic film. In comparison with previously available silver-recovery equipment, this apparatus recovers a greater proportion of silver from the waste stream. In this apparatus, dissolved silver is removed from the waste stream by exchanging silver ions for iron ions in sacrificial cartridges in treatment cells, while particulate silver is removed by filtering. The system includes several treatment cells in series; a "lead" (farthest upstream) cell followed by a "lag" cell followed by a tailing or "polishing" stage that comprises a dual cell plus a single cell. When the concentration of silver in the lead-cell cartridge reaches the maximum allowable, this cartridge is removed to harvest the silver, the cartridge from the lag cell is moved to the lead position, and a fresh cartridge is placed in the lag cell. The apparatus treats as much as 15 gallons (≈166 liters) of waste per day, recovering more than 99.9 percent of the silver. The concentration of silver in the effluent is no more than 5 parts per million — low enough to permit the effluent to be sent to a sewage-treatment plant.

This work was done by Edsel W. Fickey, Daniel J. Tierney, and Clarence E. Gillenwater of EG&G Florida, Inc., for **Kennedy Space Center**. *For further information,* ***write in 67*** *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-11846.

Computer Programs

Computing Characteristics of Dual-Reflector Antennas

The DUALREF computer program accurately predicts radiation characteristics of microwave antennas. Such antenna radiation characteristics as beam width, gain, aperture efficiency, side-lobe level, and cross polarization are used in analyzing and designing advanced antenna systems. While the single offset paraboloid has been the configuration used most extensively for satellite multiple-beam antennas, the trend toward large apertures and toward requirements for minimum degradation of scanned beams over the field of view (18° wide for full coverage of the Earth from geostationary orbit) may lead to impractically long focal lengths and large feed arrays. On the other hand, dual-reflector antennas offer packaging advantages and more degrees of design freedom to improve beam scanning and cross-polarization properties. Reflector antennas are widely used in communication satellite systems because they provide high gain at low cost. The Cassegrain and Gregorian antennas are the most commonly used dual-reflector antennas. DUALREF can calculate the secondary patterns and directivities of these antennas and of any similar generalized dual-reflector antenna system.

DUALREF uses the physical-optics-current methodology for describing the induced currents on the sub- and main reflectors. The resulting induced currents on the main reflector satisfy Maxwell's equations, so they are integrated to obtain the antenna far-zone electric fields. The output of the program describes such antenna radiation characteristics as beam width, gain, aperture efficiency, side-lobe level, and cross polarization. This program has been verified with other physical-optics programs and with measured antenna patterns, and the comparison shows good agreement in far-field side-lobe reproduction and directivity.

DUALREF is written in Microsoft Fortran PowerStation for IBM PC-compatible computers running Windows 3.1, Windows 95, or Windows NT. Microsoft Fortran PowerStation for Windows and a plotting program (e.g., MATLAB or Mathcad 5.0 Plus) are required. DUALREF has been successfully implemented on an IBM PC-compatible 486DX/33 computer running Windows 95. The standard distribution medium for DUALREF is one 3.5-in. (8.89-cm), 1.44MB, MS-DOS-format diskette. The contents of the diskette have been compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE v2.04g, is included. DUALREF was released to COSMIC in 1995.

This program was written by Roberto J. Acosta of **Lewis Research Center.** *For further information, **write in 72** on the TSP Request Card.*
LEW-16226

Software for the Airborne Emission Spectrometer

Special-purpose software has been developed to support both in-flight and ground processing of data from the Airborne Emission Spectrometer (AES), a Fourier-transform spectrometer for studying tropospheric chemistry from a variety of airborne platforms. The AES support software includes components in three categories; decommutation, cataloging, and utilities. The decommutation software transforms the spectrometer readout data from instrument format to a format suitable for calibration and further processing; it is used for both routine processing and for testing the instrument. The cataloging software generates catalog and data-quality information stored in a relational database. The utilities were developed as needed to perform specific functions, including copying data onto and from magnetic tape, "smart" downloading of data, geolocation, extraction of specified subsets of data, and averaging. The decommutation and cataloging software were designed concurrently with the AES hardware. Overlapping functional requirements in the support software were identified early in the design effort, enabling the reuse of many software components: Overall, the AES support software comprises 326 modules, of which only 171 are unique.

This program was written by Steven Larson of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 16** on the TSP Request Card.*
NPO-19917

Software Manages Recorded Data Structures

The Spacecraft Data Recorder (SDR) computer program enables flight software in a spacecraft (or similar software in a terrestrial application) to manage data structures (e.g., link lists and tables) recorded in a persistent medium such as a magnetic disk or a solid-state recorder based on nonvolatile random-access memory. The SDR software also prevents corruption of persistent data by errors in application programs or by rebooting of computers. The data structures are treated as objects in the C programming language. The software supports the use of an abstract data-recording device, which is also denoted "SDR." The SDR abstraction insulates the application software from the specific characteristics of the real data-storage device and, as much as possible, from traditional data-storage and -retrieval chores. The underlying principle is that an SDR provides standardized support for user data organization at object granularity and direct access to persistent user data objects, rather than supporting user data organization only at "file" granularity and requiring the user to implement access to data objects accreted within those files.

This program was written by Scott Burleigh and Alan Schlutsmeyer of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 15** on the TSP Request Card.*
NPO-19905

Software for Analyzing Vibrations of Levitated Liquid Drops

The STV-Data Analyze computer program extracts frequencies and damping parameters from raw data acquired in laboratory observations of vibrations of electrostatically levitated liquid drops. The frequencies and damping parameters of these vibrations are used to calculate the surface tensions and viscosities of the drops. The program reads a raw data file in a format used in the laboratory observations, high-pass filters the data, provides for selection of the relevant portion of the data, then performs a nonlinear least-squares fit of the filtered, selected data to the product of (1) a decaying exponential and

(2) a sine wave, the frequency of which changes linearly with time. The parameters reported as a result of this fit are the exponential-decay time constant, the initial frequency, the coefficient of change of frequency with time, and the approximate standard deviations of the foregoing quantities. Optionally, the program writes the filtered, selected data to an ASCII file for further processing. The program is optimized for the specific raw-data format and the specific fitting function. The program was written as a Virtual Instrument in version 3.0.1 of the LabVIEW software system, and can be executed only within that system. Also needed for execution is a Macintosh (or equivalent) computer with a 68040 (or better) processor and at least 16MB of random-access memory (RAM), or else a Power Macintosh (or equivalent) computer with at least 24 MB of RAM.

This program was written by Erik Spjut and Won-Kyu Rhim of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 96** on the TSP Request Card.*
NPO-20000

Software for Exciting Vibrations of Levitated Liquid Drops

The Excite to Disk computer program governs the generation of a sinusoidal voltage of specified frequency, amplitude, and duration for exciting the vibrations described in the preceding article. Following the excitation, this program records the vibrational response, time-stamps the response data, and writes the resulting data to a hard disk in a binary format that occupies less disk space than does an ASCII format: these are the raw data mentioned in the preceding article. Also recorded on the disk are ancillary data on experimental conditions and notes written by the experimenter. The program also high-pass-filters the data, displays the filtered data as a function of time, computes a fast Fourier transform (FFT) of the filtered data under the assumption that the data represent an exponentially decaying sinusoid, displays a power spectrum based on the FFT, and estimates the values of exponential-decay time constant and the frequency from the FFT and from the period between zero crossings. Like the program described in the preceding article, this program was written as a Virtual Instrument in version 3.0.1 of the LabVIEW software system, and can be executed only within that system on either a Macintosh (or equivalent) computer with a 68040 (or better) processor and at least 16MB of random-access memory (RAM) or else a Power Macintosh (or equivalent) computer with at least 24 MB of RAM. Also needed for execution is version 4.7.0f3 of the NI-DAQ software.

This program was written by Erik Spjut and Won-Kyu Rhim of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 97** on the TSP Request Card.*
NPO-20001

Automated Monitoring With Learned Envelope Functions

The Envelope Learning and Monitoring via Error Relaxation (ELMER) computer program automates the monitoring of time series of data from multiple sensors in a complex engineering system. The basic idea in automated monitoring is to trigger an alarm when the signal from any given sensor goes beyond allowable upper and lower limits; the problem is how to specify these limits. ELMER is designed to avoid the disadvantages of both (1) traditional monitoring with fixed limits, which tends to be too imprecise (to miss alarms) and (2) monitoring based on dynamical simulation of the system, which tends to be too expensive and too precise (to generate false alarms). Starting from traditional high and low limits, ELMER uses computational models of recurrent neural networks to "learn" global functional approximations for the upper and lower limits. For each sensor, these evolving limits are embodied in a pair of functions of time, collectively denoted an "envelope." As learning progresses with time, the limits become tighter; thus, in effect, ELMER makes a gradual transition from a mode of operation that resembles traditional fixed-limit monitoring toward a mode that looks more like a compromise between fixed-limit and simulation-based monitoring. The point of compromise — the balance between false alarms and the ability to detect malfunctions — is controlled parametrically. A graphical user interface enabler presents data from multiple time series on multiple time scales, as determined by the user. ELMER has been implemented on Sun Sparc computers running Solaris 2.X and could probably be ported to other UNIX systems running C++ and Java. Large color monitors and at least 32MB of random-access memory are recommended for the graphical user interface.

This program was written by Dennis DeCoste of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, **write in 18** on the TSP Request Card.*

Mechanics

Characterizing Worst-Case Flutter Margins From Flight Data

A robust stability theory enables computation of flutter margins consistent with variations in flight data.

Dryden Flight Research Center, Edwards, California

A mathematical-modeling method for characterization of the flutter stability margins of an airplane has been formulated within the conceptual framework of a robust stability theory. The method was developed in a recent program to improve flight flutter testing on the F/A-18 Systems Research Aircraft (SRA) shown in Figure 1.

Some definitions of terms are prerequisite to an explanation of this development. "Flight envelope" denotes a range of velocities and altitudes within which it is considered to be safe and possible to operate an airplane. "Flutter stability margin" signifies a margin, defined with respect to a flight envelope, for avoiding flutter.

The development was prompted by the following considerations: Because of the danger posed by relying on inaccurate estimation of aeroelastic-stability properties, expansion of the flight envelope is costly and time-consuming. Mathematical models for preflight prediction and in-flight estimation must be accurate enough to represent the true stability margins.

In this method, the mathematical model of the airplane as an aeroelastic system comprises a nominal plant model generated as a structural model coupled with a linear state-space representation of unsteady aerodynamic forces, with associated uncertainty operators to represent modeling errors. The uncertainty operators admit variations in modal frequencies and damping parameters, nonlinearities, unmodeled dynamics. The robust stability margin is represented by a structured singular value called "μ."

Flight data are easily incorporated into the stability analysis in this method. Uncertainty operators are derived by modal validation to ensure that the dynamics observed in the data are represented in a robust mathematical model. The stability-margin parameter μ is robust to the measured variations associated with the uncertainty operators. In this sense, worst-case flutter margins are computed with respect to the flight data.

The worst-case flutter margins are computed for the F/A-18 SRA by use of aeroelastic-response data generated during operation of a wing-tip excitation apparatus, which includes a rotating aerodynamic vane on each wing tip to produce a modal vibration-excitation force. The frequency of rotation can be varied to obtain sine-sweep-response data. Symmetric and antisymmetric modes can be excited separately by use of in- or out-of-phase excitation, respectively, at the wing tips.

computed by both methods are similar, but the robust margins indicate that the flutter margins may lie closer to the flight envelope when modeling errors are taken into account.

This method offers significant advantages over traditional flutter-estimation methods. Analytical methods — for example, the one implemented by the *p-k* algorithm — rely on theoretical models to approximate the dynamics of aircraft without utilizing flight data. In-flight-estimation methods — for example, modal tracking — depend on noisy data and often produce unreliable stability estimates. The μ-analysis approach utilizes a well-developed theo-

Figure 1. The **F/A-18 Systems Research Aircraft** has been used in research on flutter margins.

Flight data from 260 maneuvers throughout the flight envelope are used to generate uncertainty operators for a linear mathematical model with 28 structural vibrational modes. Figure 2 illustrates nominal and robust flutter margins computed with μ, along with flutter margins of a traditional type called "*p-k*," for symmetric and antisymmetric modes. The nominal margins as

retical model and realistic flight data to obtain accurate estimates of the stability properties of an aircraft.

This method may significantly decrease the cost and danger associated with flight testing for expansion of the flight envelope. A modal damping parameter of the type used heretofore for flutter estimation is merely a stability indicator (as distinguished from a stability predictor) and is truly informative only at a point of instability. On the other hand, μ is a stability predictor and can be updated throughout a flight test by revising the uncertainty operators on the basis of current measurement data and computing a new stability margin.

This work was done by Martin Brenner and Rick Lind of **Dryden Flight Research Center**. *For further information, write in 65 on the TSP Request Card.*
DRC-97-03

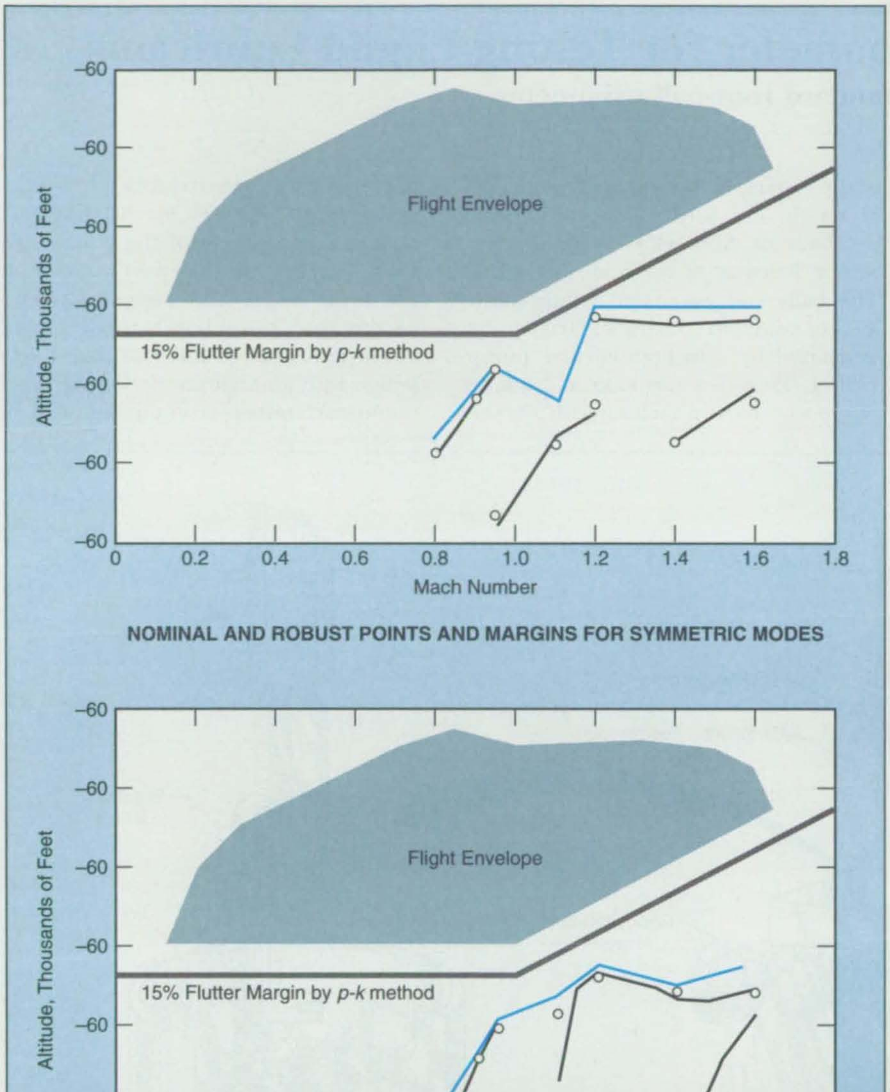


Figure 2. **Flutter Margins** were computed for symmetric and antisymmetric flutter modes by the μ-analysis method and by the traditional *p-k* method.

Vacuum Four-Ball Tribometer for Testing Liquid Lubricants

This is a modified version of a standard four-ball tribometer.

Lewis Research Center, Cleveland, Ohio

Figure 1 shows a four-ball vacuum tribometer for evaluating the performances of oils and greases as lubricants at room temperature. Tests can be conducted in air or nitrogen at atmospheric pressure, or in a vacuum.

The configuration of the balls is essentially the same as that of the four-ball tribometer of standard D-2783-88 of the American Society for Testing and Materials. The balls are precision bearing balls of AISI 440C stainless steel with a diameter of 0.375 in. (9.5 mm). The balls and associated components are contained in a chamber that can be evacuated by a turbomolecular pump (140 L/s) and a mechanical backing pump to achieve a vacuum with a residual pressure approximately in the range of 10^{-4} to 10^{-6} Pa. All vacuum-chamber flanges are of the knife-edge type and they are sealed by contact of the knife edges and copper gaskets, except for the chamber, which is equipped with a quick-access door sealed with an elastomeric O-ring. The vacuum chamber is equipped with a

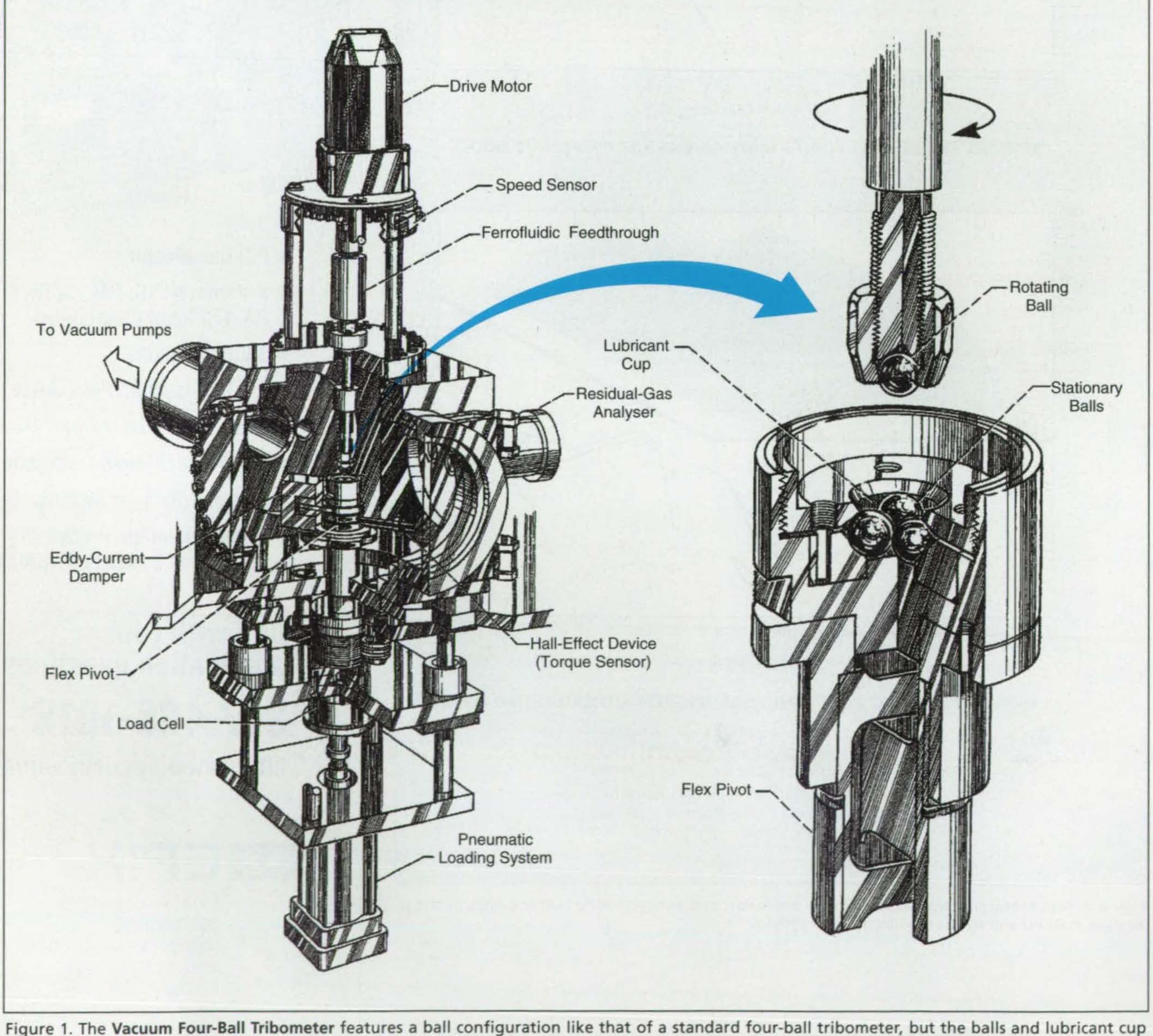


Figure 1. The **Vacuum Four-Ball Tribometer** features a ball configuration like that of a standard four-ball tribometer, but the balls and lubricant cup are mounted in a chamber that can be evacuated.

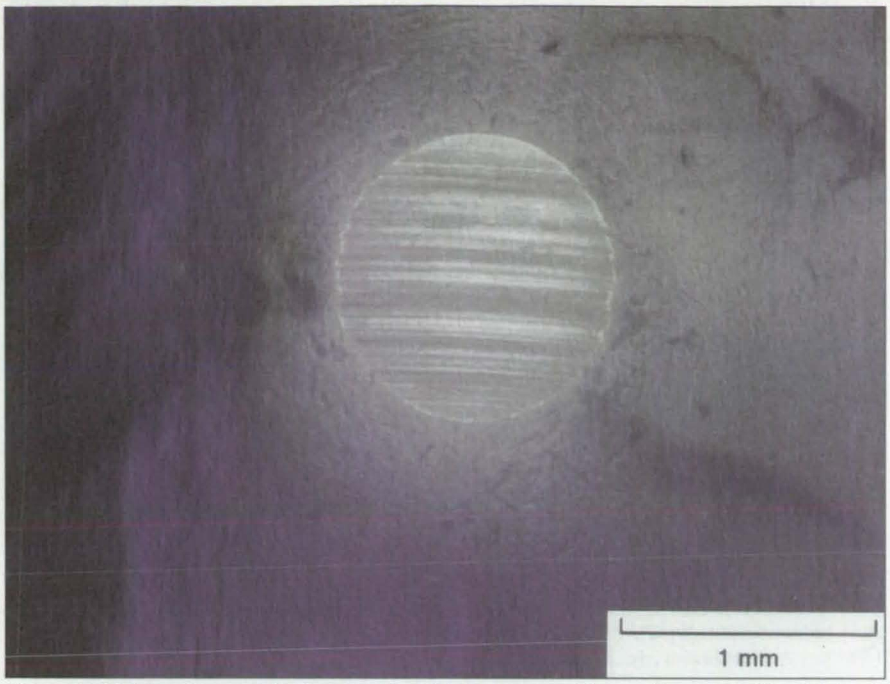


Figure 2. This **Wear Scar on a Ball** was produced in a vacuum with a perfluoropolyether lubricant at a load of 600 N, a speed of 100 r/min, and a sliding distance of 366 m.

hot-filament ionization gauge for measuring pressure, plus a mass spectrometer for use as a residual-gas analyzer. Frictional torque is measured during the test, and wear patterns on the balls can be examined afterward.

The rotating upper ball is mounted on a spindle that is connected to an external motor drive via a ferrofluidic rotary feedthrough. The lower three balls are held stationary in a ball holder (lubricant cup) mounted on a stage, which can be moved vertically to press the lower three balls against the upper ball. In preparation for a test, the balls are immersed in and/or covered with the lubricant to be tested. During a test, the lower three balls are pressed upward against the upper ball with a controlled force, and the lower balls remain stationary while the upper ball is made to rotate around its vertical axis and thus to rub against the lower balls. The speed of rotation can be set at a value between 10 and 500 r/min.

The vertical force and motion are generated outside the vacuum system by a pneumatic cylinder and transmitted to the stage via a linear-motion feedthrough sealed with a welded metallic bellows. A load cell outside the vacuum chamber measures the vertical force. The force can be set at a level between 50 and 1,032 N (11 to 232 lb).

The stage is connected to the linear-motion feedthrough via a "flex pivot," which is essentially a spring that is stiff against axial thrust, but allows some twist around the axis of the shaft. The angular deflection of the stage during a test is proportional to the frictional torque between the upper ball and the lower balls, characterized by a torsional spring stiffness of 48.6 N·m/radian (710 ft·lb/radian). Thus, the angular deflection is sensed by use of Hall-effect devices and a magnet to obtain a measure of the frictional torque. An eddy-current damper suppresses torsional oscillations that could distort the frictional-torque measurements; this damper includes a yoke and magnets affixed to the nonrotating end of the flex pivot and a copper plate that is affixed to the rotating end and that intrudes into the magnetic field.

Wear is determined by removing the cup from the chamber and measuring the diameters of wear scars (see Figure 2) on the three stationary balls by use of a microscope. A stage on the microscope is designed so that the diameters of the wear scars can be measured without removing the balls from the cup. If necessary, the experiment can then be resumed, using the same set of balls.

This work was done by William R. Jones, Jr., Ben Ebihara, and Stephen V. Pepper of **Lewis Research Center**; *Ralph Jansen of Ohio Aerospace Institute; Masabumi Masuko of the Tokyo Institute of Technology; and Larry S. Helmick of Cedarville College. For further information,* ***write in 44*** *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-16194.

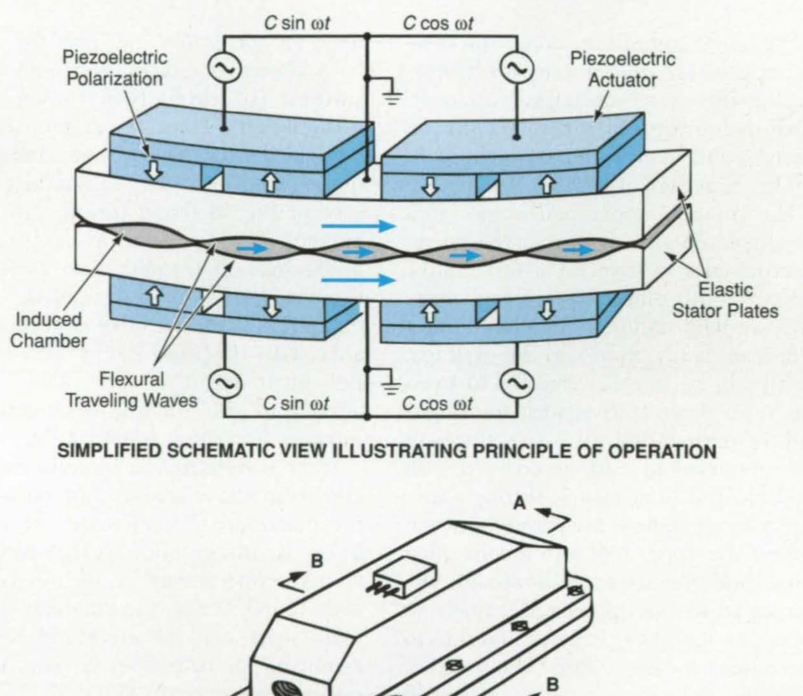
Piezoelectric Flexural-Traveling-Wave Pumps

Advantages would include small size, low power, and no sliding parts.

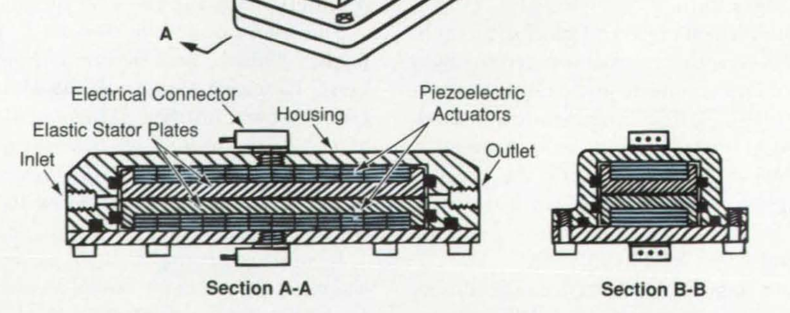
NASA's Jet Propulsion Laboratory, Pasadena, California

In miniature pumps of a proposed type, fluids and gases would be conveyed in a nearly frictionless manner in multiple shallow chambers formed by piezoelectrically actuated flexural traveling waves. These pumps could be useful in such applications as (1) injecting controlled small amounts of liquid medications and (2) sampling and vacuum pumping for miniature scientific instruments.

A basic piezoelectric flexural-traveling-wave pump, shown in the upper part of the figure, would include one or two stator plates with normally flat surfaces pressed together on the inside and with piezoelectric actuators attached on the outside. The flow path would be along the common contact surface of the plates. In the absence of piezoelectric actuation, the faying surfaces of the plates would remain flat and coincident with the common contact surface, so that there would be no gap between the plates and thus no flow. In other words, shutoff would occur automatically in the absence of piezoelectric actuation, and there would thus be no need for shutoff valves.



SIMPLIFIED SCHEMATIC VIEW ILLUSTRATING PRINCIPLE OF OPERATION



A PRACTICAL DESIGN WITH STACKED PIEZOELECTRIC ACTUATORS

Synchronized Flexural Traveling Waves on the stator plates would form chambers that would convey fluid, effecting a pumping action reminiscent of peristalsis.

When suitably polarized and phased sinusoidal voltages are applied to the piezoelectric actuators, traveling flexural waves would be excited on the faying surfaces of the stator plates. The waves on both plates would be synchronized; this would cause the formation of shallow chambers sealed by contact between the stator plates at the crests of the waves. These chambers would capture small volumes of fluid and carry them along as the waves propagated along the plates from one end to the other. It would be desirable to drive the piezoelectric actuators at the frequency of resonance of the desired flexural-wave mode; doing so would maximize the wave amplitude, thus maximizing the depth of the wave-induced chambers and, in turn, maximize the volumetric pumping rate.

It would also be desirable to optimize the configuration of the piezoelectric actuators to maximize the wave amplitude. A practical design, illustrated in the lower part of the figure, would involve stacked piezoelectric actuators. In a typical case, chamber depths up to about 10 µm could be achieved. The pumping rate could be enhanced significantly by further optimization of design, including the choice of driving frequency (typically between 10 and 80 kHz) in conjunction with the other parameters.

In addition to eliminating the need for valves, these pumps would offer the following advantages over other miniature pumps that are scaled-down versions of larger conventional pumps:

- Compactness;
- Low mass;
- Low power consumption;
- No sliding parts, with resultant low wear and high reliability;
- Simplicity of construction;
- Quiet operation.

This work was done by Yoseph Bar-Cohen, Benjamin Joffe, and Shyh-Shiuh Lih of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, write in 85 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-19737, volume and number of this NASA Tech Briefs *issue, and the page number.*

Simpler Combustion Chamber, Nozzle, and Fabrication Process

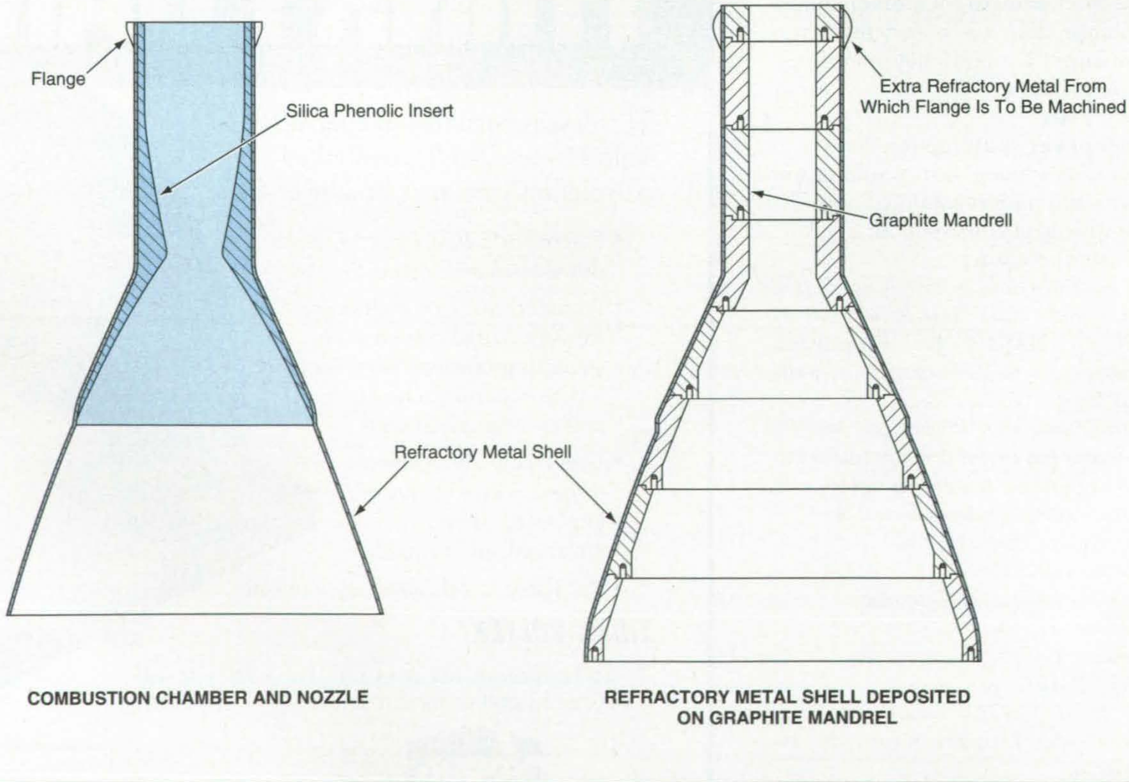
An ablative insert would protect against excessive temperatures.

Marshall Space Flight Center, Alabama

A simplified design for the combustion chamber and nozzle of a rocket engine has been proposed to reduce the time and cost of fabrication. A conventional combustion-chamber/nozzle assembly of the type to be replaced operates with active cooling; for this purpose, it must contain integral cooling passages fed by manifolds. The fabrication of such a complex object in one integral piece involves processing of numerous piece parts through numerous steps of machining, plating, welding, and brazing, leading to long fabrication time and high cost. The proposed combustion-chamber/nozzle assembly would not be actively cooled, so that there would be no need for cooling passages, and fabrication would be simplified and accelerated accordingly.

The proposed combustion chamber and nozzle (see figure) would include a shell of refractory metal (e.g., a niobium-based alloy). An integral flange would be formed at the upper end of the shell. To provide some thermal protection and a barrier against oxidation, the inner surface of the shell would be coated with aluminum oxide or other suitable material. In the combustion-chamber region, the shell would be further lined with an ablative silica phenolic insert. During operation, resins would boil off from the phenolic, leaving behind a char layer that would, along with an remaining phenolic, protect the refractory-metal shell against overheating. The thickness of the insert would be chosen so that the char would not penetrate too deeply during the design operating life. Inasmuch as the operating temperature would decrease toward the exit (lower) end of the nozzle, the thickness of the insert would be made to taper down to the point where the coated refractory metal could survive without further protection.

The shell would be fabricated by vacuum plasma spraying (VPS) on a graphite mandrel. Optionally one could first apply the aluminum oxide or other thermal/oxidation-barrier layer to the mandrel by either a traditional coating technique or VPS. If this option were selected, then VPS would be started — initially with the thermal/oxidation-barrier material, then making a gradual transition to the refractory alloy, then continuing with the alloy to obtain the required thick-



The **Combustion Chamber and Nozzle** would be made in only two pieces: a refractory metal shell with a silica phenolic insert bonded inside.

ness. The other option would be to deposit only the alloy by VPS, then coat the inner surface of the shell with a silicide after completion of deposition and removal of the shell from the mandrel. The alloy would be deposited to extra thickness at the upper end; the thickened upper end would then be machined to make the flange. Because of a large difference between the coefficients of thermal expansion of graphite and the refractory alloy, the shell could be easily removed from the mandrel once it had cooled from the VPS temperature.

The ablative insert would be made from silica phenolic tape wrapped on a steel mandrel, which would be configured to obtain approximately the contour of the interior of the combustion chamber. While still on the mandrel, the wrapped tape would be cured, then machined to make an insert to match precisely the contour of the combustion chamber. The insert would then be removed from the mandrel and bonded into the combustion chamber.

This work was done by Charles S. Cornelius and W. Neill Myers of **Marshall Space Flight Center**. *For further information, write in 58 on the TSP Request Card. MFS-31148*

VPS Fabrication of Ceramic/Metal Furnace Cartridges

Ceramic and metal contents are graded to obtain desired properties.

Marshall Space Flight Center, Alabama

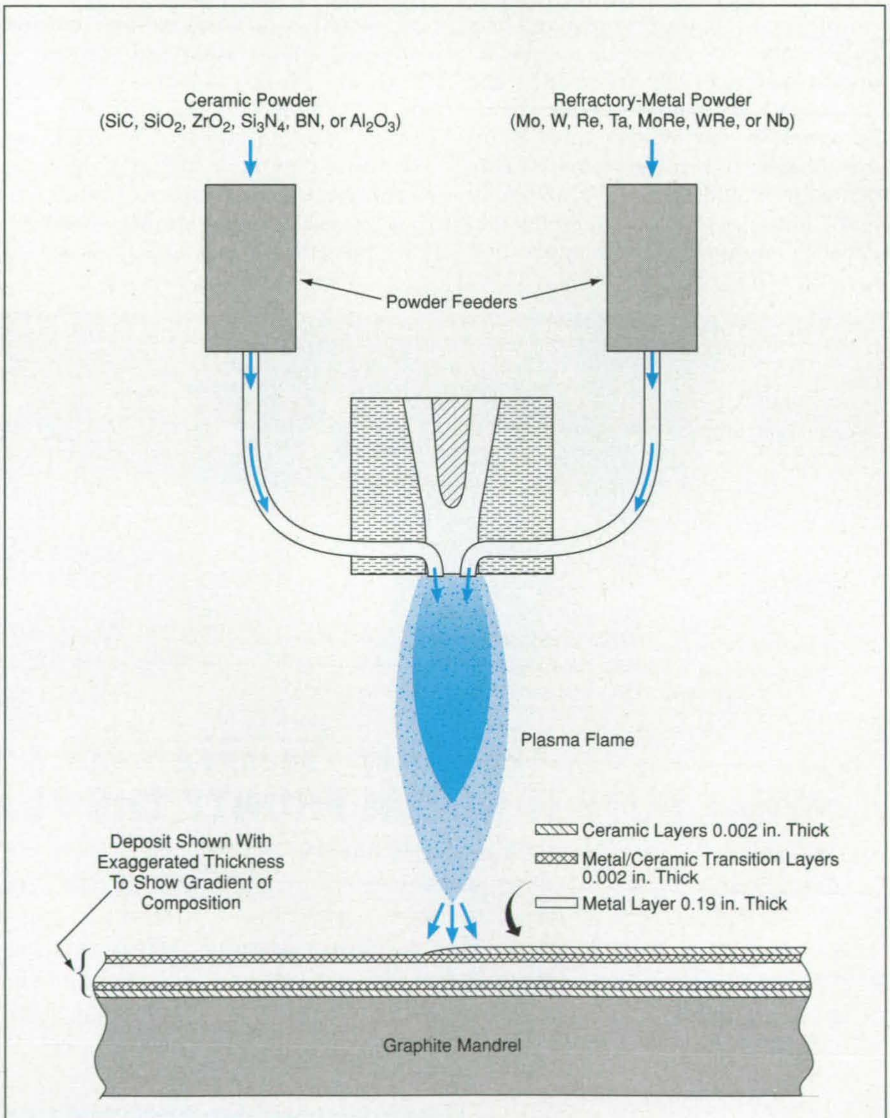
A vacuum plasma spray (VPS) process has been developed for making thin-walled ceramic/refractory metal composite furnace cartridges. These cartridges are used to contain and heat quartz ampoules that contain semiconductor materials for processing. The cartridges are required to resist chemical attack by the molten semiconductors in order to provide secondary containment should the quartz ampoules leak. The use of ceramic/refractory metal composites for this application makes it possible to utilize the corrosion resistance of the ceramics and the ductility and toughness of the metals, yielding robust cartridges that can withstand high temperatures and the stresses of fabrication and service.

In this process, a furnace cartridge is formed by VPS on a net-size-and-shape graphite mandrel, to which the deposited ceramic/metal composite material does not adhere. Upon cooling to ambient temperature after VPS, the mandrel shrinks at a greater rate than the deposited material due to its higher thermal coefficient of expansion, so that the deposit becomes the desired free-standing tube and can be slipped off the mandrel. Mandrels of this type were described in "Removable Mandrels for Vacuum-Plasma-Spray Forming" (MFS-30005), *NASA Tech Briefs*, Vol. 19, No. 5 (May 1995), page 82.

In this VPS process (see figure), refractory-metal and ceramic powders are injected into a gun that generates a plasma flame by ionization of gases in a dc arc. The plasma flame melts the powders and accelerates the molten materials, depositing them on the mandrel. The process includes the use of a controlled-powder-feeding technique that enables the formation of a deposit with a gradient of ceramic/metal composition to obtain a desired combination of thermal, mechanical, and chemical properties. For example, one experimental tube comprised an inner layer of ceramic, followed by a transition layer of half metal/half ceramic, followed by a layer of metal, followed by another metal/ceramic transition layer, followed by an outer ceramic layer.

The process also involves robotic manipulation of the VPS gun and the graphite mandrel; this makes it possible to complete the deposition of an entire furnace cartridge tube in one operation. Typically, as the VPS gun and mandrel are manipulated, the VPS gun is kept aimed perpendicularly to the surface of the mandrel to obtain the greatest density of deposition. Before deposition, the mandrel is preheated by operating the gun without the powder feed. Before and during deposition, the loss of heat from the mandrel is minimized by use of metal reflectors to reflect thermal radiation back into the mandrel.

This work was done by Phillip D. Krotz, Douglas M. Todd, William M. Davis, Timothy N. McKechnie, Christopher A. Power, William H. Woodford, and Yoon K. Liaw of Rockwell International Corporation and Richard R. Holmes, Frank R. Zimmerman, and Richard M. Poorman for **Marshall Space Flight Center**. *For further information,* ***write in 26*** *on the TSP Request Card. MFS-29998*



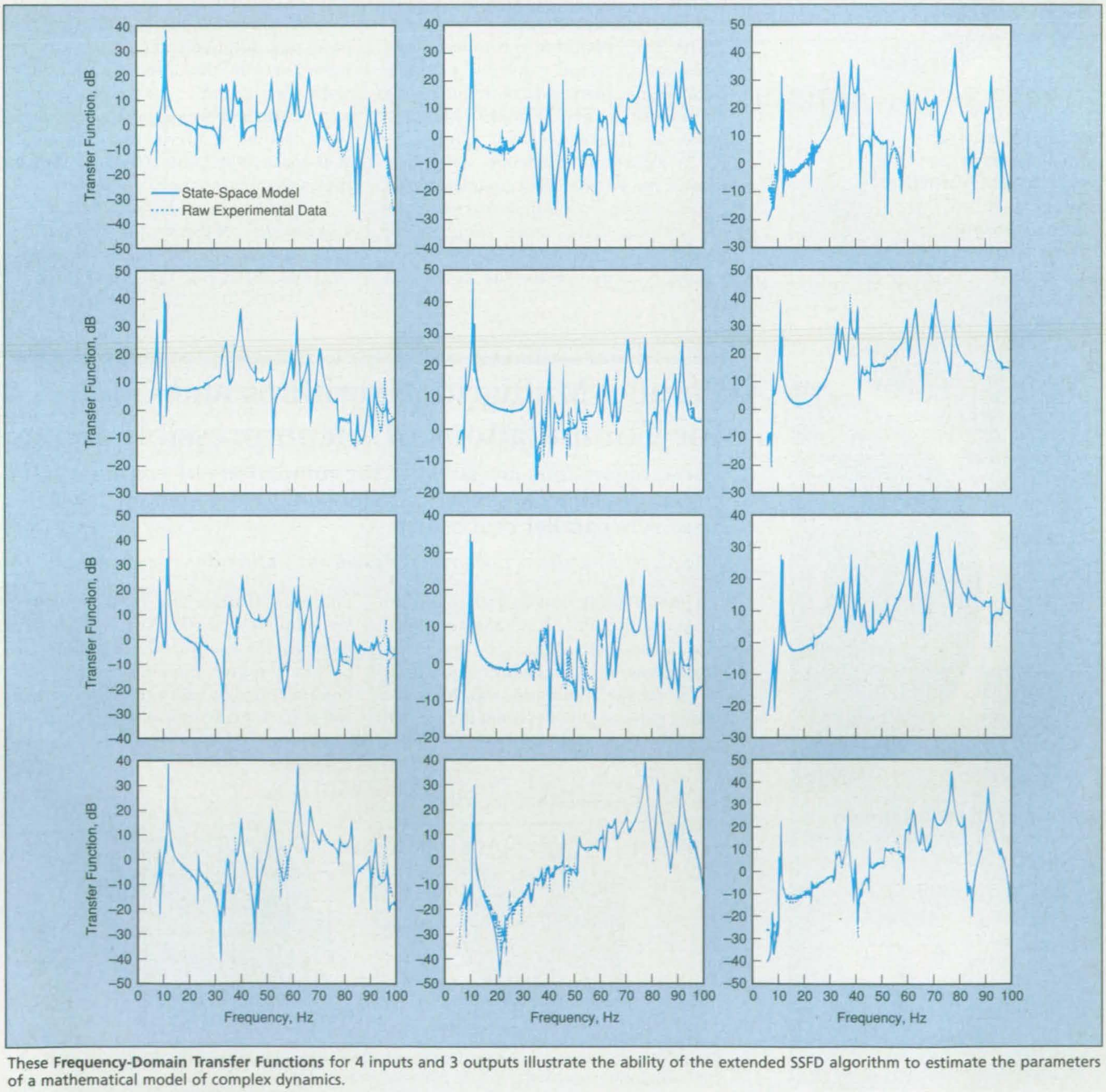
Ceramic and Refractory-Metal Powders are injected into the plasma flame in variable proportions to deposit a graded-composition ceramic/metal composite on the mandrel.

Multivariable State-Space Identification in Various Operators

Operators can include z, δ, and s.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm for estimating the parameters of state-space mathematical models of systems with complex dynamics, multiple inputs, and multiple outputs has been developed. For example, the system to be modeled may be a complex, flexible structure instrumented with actuators and sensors; the data needed for modeling are obtained by exciting the structure at each of several different actuator locations (multiple inputs) and measuring the responses at several sensor locations (multiple outputs). The present algorithm is an extended version of the State Space from Frequency Data (SSFD) algorithm, which was developed for use in modeling such systems. The present algorithm provides for modeling in any operator of interest and is particularly suitable for the shift operator (the variable z of the z-transform), the delta



These **Frequency-Domain Transfer Functions** for 4 inputs and 3 outputs illustrate the ability of the extended SSFD algorithm to estimate the parameters of a mathematical model of complex dynamics.

operator [$\delta \equiv (z-1)/T$], (where T is the sampling period) or the Laplace-transform complex-frequency operator (s).

State-space models are needed for designing control systems for dynamic systems; e.g., control systems to suppress vibrations in structures. It has been found that realization algorithms based on Markov parameters can help solve this state-space system-identification problem. In the past, these algorithms were developed primarily in the time domain. However, in many applications, the available data are in the frequency domain so that one must compute the Markov parameters from frequency-domain data. At this point, windowing distortions are often introduced. For example, an inverse discrete Fourier transform of the frequency data provides an estimate of the Markov parameter sequence distorted by time-aliasing effects.

The SSFD algorithm is comprised of a sequence of steps involving complex curve fitting, sparse-matrix singular-value decomposition, and balanced realization based on Hankel singular values. The SSFD algorithm estimates state-space models for systems with complex (high-order) dynamics, multiple inputs, multiple outputs, and large numbers of unknown parameters, and is not subject to windowing distortions. The basic idea is to generate Markov parameters indirectly from a transfer function that has been curve-fitted to frequency-domain data.

An important aspect of the SSFD algorithm is its use of overparameterization. It has been proven that the extra dynamics introduced by overparameterizing in the shift operator are stable, while the extra dynamics introduced by overparameterizing in the Laplace-transform complex-frequency and delta operators are generically unstable. This leads to modifications of the Laplace and delta operators to ensure stability under overparameterization.

The extended version of the SSFD algorithm has been verified by use of data from 4-input/3-output vibration experiments on the JPL Advanced Reconfigurable Control Testbed — a towerlike flexible-truss structure with vibration sensors and actuators. The algorithm performed complex curve fitting on the input and output data and estimated 780 parameters in the fitted transfer functions (see figure). Markov parameters were estimated from the transfer functions, leading to a reduced multivariable state-space model with 100 states accurate over a frequency range of 100 Hz.

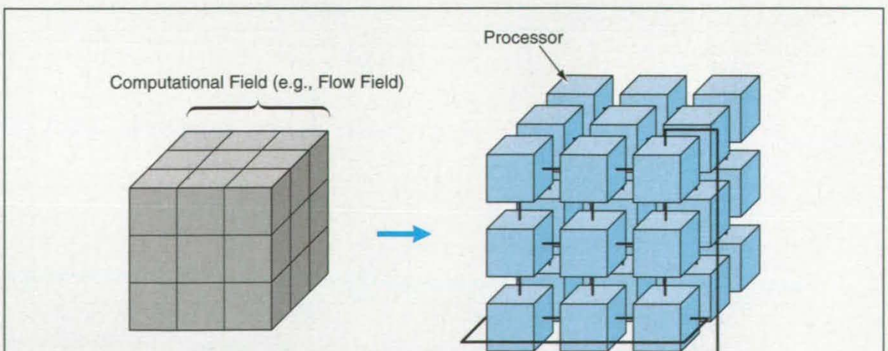
This work was done by David S. Bayard of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 31*** *on the TSP Request Card. NPO-19168*

Parallel Multigrid Algorithms and Code for Computations of Incompressible Flows

These algorithms are suitable for simulations of complex incompressible flows; the parallel code scales well on massively parallel processors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A parallel numerical algorithm for solving incompressible Navier-Stokes equations on two-dimensional (2D) and three-dimensional (3D) finite-difference grids and a parallel multigrid algorithm for solving general elliptic partial differential equations (PDEs) have been developed, implemented, and tested. Numerical experiments show that the algorithms are physically robust, numerically stable, and computationally efficient. The parallel solver package developed is highly modu-



The **3D Global Computational Grid** (left) is partitioned into a set of rectangular subgrids. Each subgrid is assigned to a processor in a 3D processor array (right).

lar; it can either be used as a stand-alone flow solver or be used as a template that can be modified or extended to solving a variety of physics and engineering flow problems; the elliptic kernel in the solver package can be used to solve elliptic equations on vertex-centered, cell-centered, and staggered grids.

The numerical Navier-Stokes algorithm used here is a second-order projection method applied to a staggered grid. Projection method is a type of operator-splitting method in which one solves the differential equations of the pressure and the velocity fields separately in an iterative procedure. At each time step, the momentum equations are solved first for an intermediate velocity field without the knowledge of the correct pressure field, and therefore no incompressibility condition is enforced. The intermediate velocity field is then corrected in a "projection" step in which one solves a pressure equation with properly derived boundary conditions and then uses the computed pressure to produce a divergence-free velocity field. The computation kernel used for computing intermediate velocity and pressure fields is a parallel multigrid solver based on "V-cycle" and "full-V-cycle" schemes. Multigrid schemes are a class of highly efficient iterative algorithms in which a set of hierarchical fine and coarse computational grids is used to compute a solution on the finest computational grid, a detailed description of which lies beyond the scope of this article. Briefly, V-cycle scheme performs solution relaxation, residual restriction, and solution correction in a recursive fashion on fine and coarse grids, while full-V-cycle scheme is a generalization to the V-cycle scheme with a higher convergence rate. These multigrid schemes are optimal in solving elliptic problems in that the numerical solution can be obtained in a time proportional to the number of unknowns on the finest computational grid.

The overall approach for the parallel implementation is a domain-decomposition strategy in which the computational (finest) grid is partitioned into multiple rectangular subgrids, each subgrid and its derived coarse grids being assigned to a processor in a logically rectangular processor array (see figure). Values at grid points lying on "partition boundary layers" (the thicknesses of which are usually dictated by the specific numerical schemes used) are exchanged among neighboring processors in the form of "messages" to ensure a correct implementation of the corresponding sequential numerical algorithms on the global computational grid. To deal with coarse grid processing in multigrid schemes, a set of (logically) hierarchical coarse processor arrays are constructed in a preprocessing step of the code.

The 2D and 3D parallel solver codes can readily be scaled to a large number of processors on the Intel Paragon and Cray T3D parallel processors for problems with moderate granularity. Several message-passing protocols (MPI, PVM, and Intel NX) have been coded into the solver package to make the code portable to systems that support one or more of these protocols for interprocessor communications. The flow solver was tested for both numeral and parallel performances on a few model problems. Numerical experiments include a driven-cavity flow at Reynolds numbers of 5,000, 10^5, and 10^6, and a doubly-periodic inviscid-shear flow. Parallel performances were measured, on a JPL 256-node Cray T3D system and a Caltech 512-node Intel Paragon system, in terms of speed-up in which the code was run on a different number of processors for a fixed global grid size, and scaling in which the code was run on a different number of processors for a fixed local subgrid size in each processor.

This work was done by John Z. Lou of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 81*** *on the TSP Request Card. NPO-19593*

Life Sciences

Advanced Semicontainerless Crystallization of Proteins

Crystals are formed suspended in liquids.

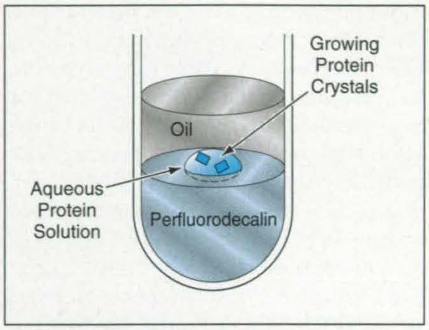
Marshall Space Flight Center, Alabama

Advanced methods for the semicontainerless growth of protein crystals are undergoing development. Each method involves dynamic manipulation, to various degrees, of one or more of the many parameters and conditions that affect the rates of growth, the quantities, and the types and degrees of imperfection of the crystals. These parameters and conditions include geometry, temperature, humidity, salinity, pH, concentrations of proteins in solutions, and concentrations of such other substances as solvents and precipitating agents.

"Semicontainerless," as used here, signifies that the crystals are not formed in contact with solid supports; instead, the crystals are made to grow suspended in liquids. The basic idea is to isolate each growing crystal from the adverse effects that would otherwise be exerted on its crystalline structure by a solid surface and by other, differently oriented growing crystals that would form on that surface. Of course, a liquid suspension environment can also affect a growing crystalline structure adversely, but the development of semicontainerless growth is motivated by the expectation that in many if not most cases, one could obtain crystals that are larger and more nearly perfect than are those grown by older techniques on solid supports.

One older method for semicontainerless growth of protein crystals is the hanging-drop method, which has been described previously in *NASA Tech Briefs*. More recently, four advanced methods have been investigated. These methods involve (1) stacking of layers of immiscible fluids, (2) gels under oil, (3) emulsions, and (4) lattices of bubbles.

In the layer-stacking method, one uses three or more immiscible fluids of different mass densities. In the simplest version of this method, a drop of an aqueous solution that contains the protein to be crystallized is placed on top of a denser liquid (e.g., perfluorodecalin), and an oil or other less dense liquid is placed on top (see figure). Together, the bottom and top layers suspend the protein solution in isolation from solid supports, and the top layer retards evaporation from the protein solution, as is necessary to ensure crystal growth at the optimum rate.



The **Layer-Stacking Method** is one of four advanced methods of semicontainerless growth of protein crystals. The crystals precipitate from the protein solution as water evaporates, driving the solution to supersaturation. The oil layer retards evaporation to a required low rate.

In the gel-under-oil method, the protein solution is contained within a gel, which is covered with an oil to retard evaporation. Growth takes place in the gel, which is used to prevent both undesired buoyant mixing (convection) of the protein solution and undesired sedimentation of crystals through the solution.

The present emulsion method differs from an older emulsion method that involved crystallization of protein in isolated drops, followed by coalescence of the growing crystals. In the present emulsion method, the protein solution is the continuous phase, and growth takes place as though in a loose gel; the discontinuous emulsified phases cushion growing crystals against sedimentation and suppress convection.

In the bubble-lattice method, bubbles are formed by blowing air through a protein solution, then the bubbles are formed into a nearly two-dimensional lattice between two microscope slides. Crystals grow on the faces of the bubbles as evaporation into the interiors of the bubbles drives the faces of the bubbles toward supersaturation, while capillarity supplies the growing crystals with more protein.

This work was done by David A. Noever of **Marshall Space Flight Center.** *For further information,* ***write in 28*** *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-31046.

Ring Method for Crystallization of Proteins

Rings provide additional control over crystallization conditions.

Marshall Space Flight Center, Alabama

The ring method of crystallization of proteins involves the use of wire rings to shape drops of protein solutions and/or position those drops with respect to adjacent and surrounding liquids. The ring method can serve as an alternative to the methods described in the preceding article "Advanced Semicontainerless Crystallization of Proteins" (MFS-31046). Rings can be added to protein-crystal-growth apparatuses along with position sensors, position actuators, and position-control circuitry to provide additional degrees of freedom for control of crystallization conditions and thereby afford additional opportunities to optimize crystallization processes to obtain larger, higher-quality protein crystals for use in biomedical and pharmaceutical research.

Four versions of the ring method have been tested thus far in experiments on growing crystals of hen egg-white lysozyme. In the first version, a drop of protein solution rests on an appropriately sized single ring in air, so that water can evaporate through the nearly spherical surface of the drop. The evaporation increases the concentration of the protein, eventually resulting in supersaturation and crystallization of protein. The drop can be monitored visually to observe the crystal(s) forming within it.

In the second version, a drop of protein solution is held between two rings (see figure) in air or in oil. The axial distance between the rings can be increased or decreased to lengthen or flatten the drop.

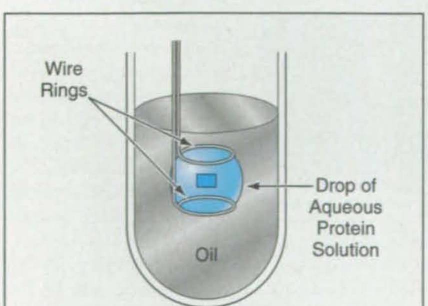
In the third version, a drop of protein rests on a single ring in a container of oil. The ring can be raised or lowered to control the position of the drop with respect to the top surface of the oil. Typically, the height is set so that the drop protrudes by a small, controlled amount, providing a small, controlled area for evaporation of water from the drop.

In the fourth version, as in the third version, a drop of protein solution rests on a single ring in a container, but in this case, the drop is positioned at an interface between two liquids that include solvents that are immiscible with each other and with the water of the aqueous protein solution. These liquids can be chosen, for example, to contain solutes (e.g., salts and precipitating agents) that are to be transported to the protein solution.

Other versions of the method have been proposed. For example, rings could be made in noncircular shapes to obtain different evaporative conditions. Alternately, combinations of three or more rings could be used to suspend multiple adjacent drops and to control flows of solutes among drops by exploiting such effects as surface tension and gradients of salinity.

This work was done by David A. Noever of **Marshall Space Flight Center.** *For further information, write in 29 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31047.



The **Rings Can Be Used to Flatten or Lengthen** the drop of protein solution, and/or to make the drop protrude partly above the top of the oil.

Crystallizing Proteins in Thin Wafers

Crystals are grown in thin gaps between parallel flat plates.

Marshall Space Flight Center, Alabama

An experiment has demonstrated the feasibility of a method of crystallizing proteins in thin, nearly two-dimensional wafers. The method exploits a combination of capillary action and diffusion within a growth chamber or well bounded by two smooth, closely spaced, parallel plates. The ability to produce thin, nearly two-dimensional crystalline protein wafers raises the possibility of novel applications in optoelectronics and electron microscopy in biomolecular systems.

The method (see figure) is best explained by describing the experiment, in which tetragonal crystals of lysozyme were grown from an aqueous

continued on page 81

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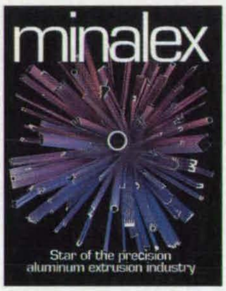

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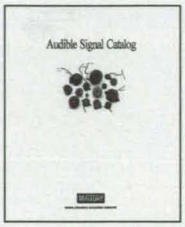

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Catalog features new line of audible signal products including miniature piezoelectric and electromagnetic devices. Choose from audio indicators, sirens, back-up alarms, low frequency audible indicators (buzzers), and more. Ideal for beepers, radar detectors, smoke alarms, home appliances, and many other applications. North American Capacitor Co., 7545 Rockville Rd., Indianapolis, IN 46214; Tel: 317-273-2537; Fax: 317-273-2400.

North American Capacitor

For More Information Write In No. 341

ADVANCED COMPOSITE TRAINING

Abaris Training offers 14 different "hands-on" workshops in advanced composite materials technology. These workshops cover fabrication, repair, manufacturing, tooling, print reading, adhesive bonding, ultrasonic inspection of composites, resin transfer molding, and several engineering workshops. Emphasis is placed on glass, carbon, and aramid fiber materials and processes, utilizing vacuum bagging, and oven and autoclave curing. Three workshops are Canadian D.O.T. approved. For a free brochure, call toll-free: 1-800-638-8441; Fax: 702-827-6599; http://www.abaris.com. Abaris Training Resources, Inc., 5401 Longley Lane, Suite 49, Reno, NV 89511.

Abaris Training Resources, Inc.

For More Information Write In No. 342

VIBRATION ISOLATION & IMPACT ABSORPTION

New, full-color brochure describes the dynamic properties of Sorbothane, the unique vibration isolation and impact absorption material. New test data details the damping properties of Sorbothane compared to other elastomers. Sorbothane is a patented viscoelastic polymer. Includes information on Sorbothane's new line of advanced vibration isolation/shock absorption products, as well as applications engineering, manufacturing capabilities, and the many applications for Sorbothane. Sorbothane, Inc.; Tel: 330-678-9444; Fax: 330-678-1303; E-mail: webmaster@www.sorbothane.com; http://www.sorbothane.com.

Sorbothane, Inc.

For More Information Write In No. 343

MEASURE FOR WINDOWS

Acquire data directly into your Microsoft Excel worksheets with Measure for Windows. Use National Instruments' plug-in data acquisition boards or any serial instrument for your acquisition. Set up your acquisition and control operations with easy-to-use dialog boxes. Automate your experiments with VBA. Call for a free demo disk. National Instruments; Tel: 512-794-0100 or 800-433-3488; Fax: 512-794-8411; E-mail: info@natinst.com; http:/www.natinst.com.

National Instruments

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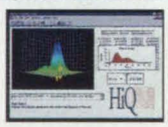

FREE HIQ EVALUATION SOFTWARE

National Instruments offers HiQ® for Windows, featuring ActiveMath™ and visualization tools for Microsoft Office. HiQ on Windows NT or Windows 95 uses ActiveX™ (OLE) for integration with Microsoft Office and Microsoft's OpenGL 3D graphics library, making advanced technical calculation, data visualization, and documentation solutions more cost-effective and simpler for technical professionals. Call for your FREE HiQ evaluation software. National Instruments, 6504 Bridge Point Pkwy., Austin, TX 78730; Tel: 512-794-0100 or 800-433-3488; Fax: 512-794-8411; E-mail: info@natinst.com; http://www.natinst.com.

National Instruments

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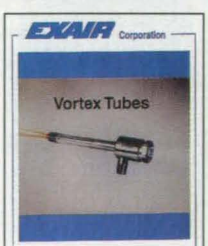
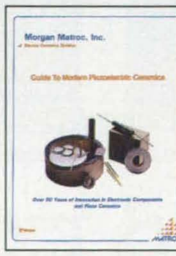


VORTEX TUBES

Data sheet describes how EXAIR Vortex Tubes produce up to 10,000 Btu/hr. with no moving parts. Tubes convert an ordinary supply of compressed air into two streams: one hot and one cold. Temperatures are adjustable from -50° to +250°F. Bulletin highlights advantages for a variety of industrial cooling applications. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com; http://www.exair.com.

EXAIR Corporation

For More Information Write In No. 346



PIEZOELECTRIC CERAMICS

A 28-page brochure is a design guide for piezoelectric ceramics in a variety of shapes and sizes. Piezo-electric and electromechanical properties for various PZT materials (lead zirconate titanate) are included, and various types of piezoceramic configurations, including stacks and bimorphs® are described. Tel: 216-232-8600; Fax: 216-232-8731.

Morgan Matroc Inc.

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AIR MOVERS

Air Amplifiers convey, vent, exhaust, cool, dry, and clean – with no moving parts. Using a small amount of compressed air as a power source, Air Amplifiers move large volumes of surrounding air to produce high-velocity outlet flows. Air amplifiers are compact, durable, portable, and maintenance-free. Applications include small parts conveying; venting fumes; and cleaning, drying, or cooling parts. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com; http://www.exair.com.

EXAIR Corporation

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NEW BRUSHLESS DC MOTORS CATALOG

Describes API Harowe's small-frame brushless DC motors in sizes 05 to 21. Available for a variety of applications, including industrial, commercial, medical and aerospace, these motors feature unique threaded bodies to accept gearheads and/or flanges. These motors are equipped with Hall-effect sensors and are capable of 75,000+ RPM. API Harowe Inc., 110 Westtown Rd., West Chester, PA 19382; Tel: 800-566-5274 or 610-692-2700; Fax: 610-696-4598.

API Harowe Inc.

For More Information Write In No. 349

BURST PRESSURE TESTER

Advanced Pressure Products has developed a fully automated computer controlled burst pressure testing system. The system is designed to determine the exact pressure of failures at controlled pressurizing rates.

- Test accuracy up to .05% of full scale
- Leak or burst pressure resolution within .01% of full scale
- Testing pressure designated by operator up to 60,000 PSI for hydraulic systems or 5,000 PSI for pneumatic systems. Advanced Pressure Products, 83 Brown Rd., Ithaca, NY 14850; Tel: 800-277-8258; http://www.pmiapp.com.

Advanced Pressure Products

For More Information Write In No. 350

POROSITY TESTER

PMI's Aquapore 2000A leads the industry in pore analysis of hydrophobic materials. By using water as the non-wetting fluid, the 2000A is designed to avoid problems associated with mercury in laboratory environments. The Windows®-based software can produce hard copy reports and interface with spreadsheet programs. The user-friendly software allows control, measurement, and data collection at the click of a mouse. Pure liquid (water or industrial alcohol) is used with precise pressure control. NO MERCURY REQUIRED! Porous Materials, Inc., 83 Brown Rd., Ithaca, NY 14850; Tel: 800-825-5764; http://www.pmiapp.com.

Porous Materials, Inc.

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METAL BELTS AND DRIVE TAPES

This general product brochure describes the various attributes that make metal belts and drive tapes an exceptional and exciting option for design engineers. Manufactured by Belt Technologies for 25 years, this unique family of products has helped design engineers overcome challenging application requirements in the electronics, aerospace, biomedical, optical and packaging industries. Belt Technologies, Inc., PO Box 468, Agawam, MA 01001; Tel: 413-786-9922; Fax: 413-789-2786.

Belt Technologies, Inc.

For More Information Write In No. 352

MASS FLOW APPLICATIONS HANDBOOK VOL II

VOL II of all-new applications handbook from ABB K-Flow graphically illustrates a wide variety of coriolis flow process configurations with ABB K-Flow flowmeter system appropriate for each application. Updated applications involving Mass (Liquid, CNG, Multi-component), Density (SG, API, Brix), % Solids, % Liquids, PID, Ratio Blending, Batching, Proportioning, and others are included.

ABB K-Flow

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PRESSURE GAUGE CALIBRATION SYSTEM

APP introduces the Complete Pressure Gauge Calibration System (CPGCS). The CPGCS provides the solution to a wide variety of pressure gauge testing and calibration needs. The system includes a precision pressure controller with a high-accuracy master pressure gauge, a manifold for easy connection of test pressure gauges (slave gauges) and a fully automated data acquisition system. Controlled by Windows®-based software, the system also provides flexible test and graphics output. The calibration process can be performed automatically or manually. Advanced Pressure Products, 83 Brown Rd., Ithaca, NY 14850; Tel: 800-277-8258; http://www.pmiapp.com.

Advanced Pressure Products

For More Information Write In No. 354

ALGOR PROVIDES "4-WAY" INFO ON THE WORLD WIDE WEB

Algor's Internet place has detailed information on four product lines. Discover Houdini, Algor's automatic CAD solid model to 8-node "brick" mesh converter. Learn about Algor FEA, including case histories. Preview engineering videos, books and multimedia. See all new integrated piping/vessel/plant design software. If you do not have Internet access, call for free info. Algor, Inc.; E-mail: info@algor.com; URL: http://www.algor.com; Tel: 412-967-2700; Fax: 412-967-2781.

Algor, Inc.

For More Information Write In No. 355

NEW INTERACTIVE CD-ROM BASED ON ENGINEERING "BEST-SELLER"

A comprehensive FEA CD-ROM/textbook that blends theory & real-world engineering examples. Dr. Constantine Spyrakos, well-known finite element stress and vibration analysis expert, has created a reference for all engineers from designers to "gurus." CD-ROM includes search capabilities, Internet-type browser & 3D, full-color graphics. Hard- and soft-cover books include every example problem on disk. APD; Tel: 800-482-5467; URL: http://www.algor.com/apd; E-mail: apd@algor.com.

APD

For More Information Write In No. 356

NEW KIND OF MULTIMEDIA VIDEO TEACHES FEA LESSONS

Finite Element Analysis in Action! is a new kind of instructional video for engineers. Available on VHS tape or interactive, multimedia CD-ROM, the video packs a lot of information into a short running time of only 26 minutes. Live lab experiments and FEA analysis are conducted to show how to better use any FEA software. Demonstrates specific modeling and analysis techniques. Tel: 1-800-482-5467; URL: http://www.algor.com/apd.htm; E-mail: apd@algor.com.

APD

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WORKBENCHES & SYSTEMS CD-ROM CATALOG

This interactive multimedia presentation covers Teclab's complete line of workbenches and laboratory systems furniture. Designed for Windows™, the CD-ROM presentation features hundreds of benches, including complete product specifications. Meeting the Challenge, Teclab's introductory video presentation, highlights unique features and benefits of a Teclab bench. You select what you want to see by simply clicking on the icons that interest you. Teclab, 6450 Valley Industrial Drive, Kalamazoo, MI 49009; Tel: 800-832-5227; Fax: 616-372-6116; http://www.teclab-bench.com

Teclab

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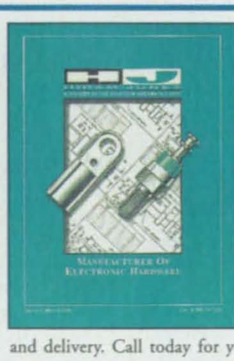

Hiram Jones Electronics, Inc./A Division of the Seastrom Hardware Group manufactures a complete line of standard miniature and subminiature terminals including: insulated test jacks, assembled standoffs and press-type terminals. All standard catalog items are available for immediate pricing and delivery.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

Hiram Jones Electronics, Inc.

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STEP & SERVO MOTOR CATALOG

Compumotor's 408-page catalog covers motion control products. The Engineering Reference section covers motor, drive & feedback technologies with illustrated examples, how-to section, and glossary of terminology. Second section covers Brushless Servo motors, amplifiers, controls, and support software. Third section features Microstepping, Ministepping & Linear Step Motor systems, indexers & encoders. Also, software to assist in the start-up and operation. Parker Hannifin Corp., Compumotor Div.; Tel: 800-358-9070; Fax: 800-328-8087.

Parker Hannifin Corp., Compumotor Div.

For More Information Write In No. 360

BERG PRECISION MECHANICAL COMPONENTS CATALOG

The B97 Catalog has 616 pages of specs and design data for over 60,000 precision mechanical components available from an extensive stock and custom manufacturing. Included are over 50 pages of new products and expanded lines: chains, belt drives, gears, assemblies, breadboards, linear components, hardware, fasteners, couplings, keys, shafts, clutches, bearings, and vibration damping components. W.M. Berg, Inc., 499 Ocean Ave., East Rockaway, NY 11518; Tel: 800-232-BERG; Fax: 800-455-BERG; http://www.wmberg.com.

W.M. Berg, Inc.

For More Information Write In No. 361

THE SOURCE FOR ELECTRONIC & MECHANICAL HARDWARE

Seastrom takes pride in offering one of the widest selections of standard electronic and assembly hardware available from stock. Seastrom's 66-A Catalog provides a complete source for over 45,000 products. For a free 550-page catalog, call 800-634-2356.

Seastrom Manufacturing Co. Inc.

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FREE LAMP CATALOG

Bulb Direct, Inc. sells replacement specialty lamps for A/V, photographic, stage, studio, video, micrographic, and graphic arts equipment, plus medical and electronic instruments. We offer brand names with two-day air delivery at no extra cost! New this year...Specialty Energizer Batteries. Bulb Direct Inc., 1 Fishers Rd., Pittsford, NY 14534-9511; Tel: 800-772-5267 or 716-385-3540; Fax: 716-385-4976.

Bulb Direct, Inc.

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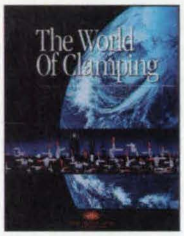

WORLD OF CLAMPING

The World of Clamping introduces DE-STA-CO's new line of high-strength composite clamps, details their remaining line of approximately 500 toggle clamps, and features expanded dimensional and application information. DE-STA-CO's toggle clamp line includes hold-down, latch, straight-line, and squeeze-action clamps. This catalog also contains DE-STA-CO's pneumatic and hydraulic clamping systems. (Catalog 197) DE-STA-CO, PO Box 2800, Troy, MI 48007; 810-594-5600; http://www.destaco.com; E-mail: cust.srv @destaco.com.

DE-STA-CO

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COOL ELECTRONIC CABINETS

Compact Cabinet Coolers are the low-cost, reliable way to cool and purge electronic control panels, eliminating CFCs, fans, and filters. The coolers incorporate a vortex tube to produce cold air from ordinary compressed air. No moving parts assures long life and maintenance-free operation. NEMA 4, 4X, and 12 models available. Literature gives selection data and specifications. EXAIR Corporation, 1250 Century Circle North, Cincinnati, OH 45246; Tel: 800-903-9247; Fax: 513-671-3363; E-mail: techelp@exair.com; http://www.exair.com.

EXAIR Corporation

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NEW! OPTICS & IMAGING CATALOG

Edmund Scientific's free 260-page catalog features our exclusive Integrated Optical Component Mounting System and one of the largest selections of precision off-the-shelf optics and optical instruments. Our precision off-the-shelf optics, TechSpec™ Optics and optical components can take you from design, to prototype, to final production. We provide technical design and production solutions. Over 8,000 scientific and technical products, including magnifiers, lasers, microscopes, telescopes, "machine vision," and video microscopy. Tel: 609-573-6259; Fax: 609-573-6233; E-mail: indopt@edsci.com.

Edmund Scientific Co.

Industrial Optics Division Dept. B971, N954

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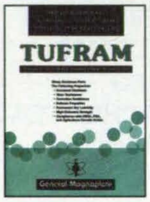

MAGNAPLATE-APPLIED TUFRAM® COATINGS PROTECT ALUMINUM

TUFRAM® surface-enhancement coatings protect aluminum and aluminum alloys against corrosion, abrasion, moisture, and wear. They create harder-than-steel, permanently dry-lubricated, non-stick surfaces that dramatically improve wear life, prevent chemical attack, and exhibit excellent release properties. Many meet USDA/FDA codes. General Magnaplate Corp., 1331 Rte. 1, Linden, NJ 07036; Tel: 800-852-3301; Fax: 908-862-6110; E-mail: info@magnaplate.com; http://www.magnaplate.com.

General Magnaplate Corp.

For More Information Write In No. 367

ELECTRONIC HARDWARE NEW CATALOG '97

Globe's FREE '97 Electronic Hardware catalog details the most comprehensive line, including: handles, ferrules, jack screws, standoffs, spacers, captive panel screws, panel screw retainers, thumb screws, shoulder washers, and more. Available in American or metric standards with over 40 protective finishes and performance materials, and 10 different metal and nylon materials. Globe Electronic Hardware, PO Box 770727, Woodside, NY 11377; Tel: 800-221-1505 or 718-457-0303; Fax: 718-457-7493; http://www.globe-elec-hdwe.com.

Globe Electronic Hardware

For More Information Write In No. 368

AUTOMATION CONTROLS & COMPONENTS

New Automation Controls & Components Selector Guide provides overview of pneumatic and electronic industrial automation components and controls available from Festo. Over 90 product categories in 24-page brochure, covering control systems, PLCs, Fieldbus manifolds, sensors, pneumatic cylinders, valves and accessories. Education/Training programs in automation control technologies described. Contact: Festo Corporation, 395 Moreland Road, Hauppauge, NY 11788; Tel: 516-435-0800.

Festo Corporation

For More Information Write In No. 369

POWDER METALLURGY DESIGN SOLUTIONS

This 20-page brochure, published by the Powder Metallurgy industry trade association, is yours free for the asking. It features cost-effective design solutions and new ways to handle parts fabrication. Metal Powder Industries Federation, 105 College Road East, Princeton, NJ 08540; Tel: 609-452-7700; Fax: 609-987-8523; http://www.mpif.org.

Metal Powder Industries Federation

For More Information Write In No. 370

1997 PCMCIA PRODUCTS CATALOG

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

Envoy Data Corporation

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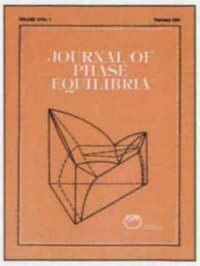

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ASM International

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EMI/RFI SHIELDING PRODUCTS

New catalog details hundreds of standard gaskets and grounding strip variations, engineered to meet the most common shielding applications. Standard as well as custom designed shields are manufactured from Beryllium, Copper, and other High-performance materials. Special finishes and a variety of mounting methods are offered. For World Class quality and service call 201-890-7455 or visit our Web Site at: HTTP://WWW.OMEGASHIELDING.COM; E-mail: SALES@OMEGASHIELDING.COM.

Omega Shielding Products Inc.

For More Information Write In No. 373

TOOLING COMPONENTS AND CLAMPS

This 570-page catalog contains an assortment of components including toggle clamps, modular fixturing, clamping devices, power workholding, chuck jaws, pins, knobs, drill bushings, leveling feet, and much more. Carr Lane Manufacturing Co., 4200 Carr Lane St., PO Box 191970, St. Louis, MO 63119-2196; Tel: 314-647-6200; Fax: 314-647-5736.

Carr Lane Manufacturing Co.

For More Information Write In No. 374

NEW DATA ACQUISITION CATALOG

Keithley MetraByte offers a new shortform catalog of analog and digital I/O boards, data acquisition software, and PC instruments products. This new catalog includes several application examples and technical selector guides that make it easy to compare specs. Keithley MetraByte, 28775 Aurora Rd., Cleveland, OH 44139; Tel: 800-552-1115; Fax: 216-248-6168; WWW: http://www.keithley.com.

Keithley MetraByte

For More Information Write In No. 375

DIGITAL PRESSURE SCANNER

Model DSA3017/3018 features Ethernet-ready TCP/IP protocol, 0-750 psi pressure range, ±0.05% FS accuracy, and 200 samples/channel/sec. Measures both gas and liquid pressures. Incorporates 16 temperature-compensated piezoresistive pressure sensors with a microprocessor and A/D in a self-contained module. Microprocessor-controlled internal valve performs online zero calibrations. Pressure data are output in engineering units. Scanivalve Corp.; Tel: 800-935-5151 or 509-891-9970; Fax: 509-891-9481.

Scanivalve Corp.

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ACCELEROMETERS

New 108-page catalog of Entran's Accelerometers with associated power supplies, amplifiers & signal conditioning. A broad selection: miniature to rugged, low and high ranges, wide frequency response for static and dynamic. Both damping and overrange stops available. Ideal for acceleration, vibration & shock testing in aerospace, industrial, automotive, military & research applications. Many items in "Off-the-Shelf" stock. Entran Devices, Inc., 10 Washington Ave., Fairfield, NJ 07004; Tel: 888-8-ENTRAN; Fax: 201-227-6865; E-mail: sales@entran.com; http://www.entran.com.

Entran Devices, Inc.

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STRETCHING THE POSSIBILITIES IN CHEMICAL PROCESSING

DuPont Dow Elastomers, a joint venture between the DuPont Company and Dow Chemical, offers high-performance products, including Viton® amd Kalrez®, that meet the sealing needs of the chemical-processing industry. Ensure product performance by specifying genuine Viton for your sealing materials. Kalrez parts have outstanding resistance to over 1600 chemicals at temperatures to 316°C, making it the best-selling material. DuPont Dow Elastomers offers you a broad range of innovative solutions to stretch the possibilities in sealing for the chemical processing industry.

DuPont Dow Elastomers

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CAD/CAM/CNC - WHAT TO KNOW BEFORE YOU BUY

New, free 112-page primer (H835) explores what to know before you invest in CAD/CAM/CNC technology. A comprehensive technical section covers: scanning, tooling, fixturing & stepper vs. servo motors. Application case histories in wood, plastic, model making, engraving, education and more show how CNC routers can expand business as well as provide quick payback. Includes selection specifications for 11 CNC router systems and 9 software packages. Techno-isel, 2101 Jericho Tpke., Box 5416, New Hyde Park, NY 11042-5416; Tel: 800-948-3246; Fax: 800-737-7436; http://www.techno-isel.com.

Techno-isel

For More Information Write In No. 379

AURUM® HEAT-RESISTANT THERMOPLASTIC POLYIMIDE

AURUM Thermoplastic Polyimide is the engineering plastic of choice for components facing harsh environments. It features 550°F heat resistance, high purity, exceptional PV values, toughness, and tensile strength to 39,000 psi. AURUM is injection-moldable and available in molding pellets & powder, film, extruded stock shapes, monofilaments, metal/polyimide laminates, thin wall tubing, and composite prepegs. AURUM is used in the automotive, aerospace, industrial equipment, and semiconductor industries. Mitsui Toatsu Chemicals, Inc., 2500 Westchester Ave., Ste. 110, Purchase, NY 10577; Tel: 914-251-4222; Fax: 914-253-0790.

Mitsui Toatsu Chemicals, Inc.

For More Information Write In No. 380

LOAD/FORCE/ TORQUE CATALOG

Catalog describes line of precision load, force, and torque sensors and related instrumentation from handheld to multichannel. Gram Sensors: 30 to 1K Grams; Load Cells: 2.5 to 400K lbs.; Load Buttons: 250 to 50K lbs.; Load Washers: 2K to 300K lbs.; Thru-Hole Load Cell: 5 to 30K lbs.; Torque Sensors: 10 in. oz. to 50K in. lbs.; Load Pins: 1.5K to 800K lbs. Transducer Techniques, Inc., 43178 Business Park Dr., Temecula, CA 92590; Tel: 909-676-3965; Fax: 909-676-1200; E-mail: tti@ttloadcells.com; http://www.ttloadcells.com.

Transducer Techniques, Inc.

For More Information Write In No. 381

TOOLS, TOOL KITS, CASES & TEST EQUIPMENT

Free 368-page color catalog features over 100 standard tool kits for installation, field service, and repair. Extensive stock case selection with tool kit modification details. Computer test equipment includes oscilloscopes, SIMM testers, EPROM testers, benchtop test equipment, and more. Contains photos, descriptions, specifications, price breaks, index, and order form. Specialized Products Co.; Tel: 800-866-5353; Fax: 800-234-8286.

Specialized Products Co.

For More Information Write In No. 382

NEW TEST & MEASUREMENT CATALOG

Keithley's new 1997 catalog features 300 pages of electronic test and measurement instrumentation including DMMs, electrometers, precision sources, voltmeters, ammeters, source-measure units, power supplies, switch systems, and much more. This valuable reference guide includes application examples to help design a test system, selector guides to compare important specs, plus complete product specifications. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139; Tel: 800-552-1115; Fax: 216-248-6168; http://www.keithley.com.

Keithley Instruments, Inc.

For More Information Write In No. 383

OMEGA'S PREMIER TO THE 21ST CENTURY™ EDITION

OMEGA Engineering is proud to announce the release of its Data Acquisition Handbook, "The Universal Guide to Data Acquisition and Computer Interfaces – Premier to the 21st Century™ Edition." This new Handbook contains 600-plus pages of products and valuable technical information. Over 140 pages are dedicated to new and unique products. OMEGA Engineering; Tel: 800-TC-OMEGA (800-826-6342) or 203-359-1660: E-mail: info@omega.com; http://www.omega.com.

OMEGA Engineering

For More Information Write In No. 384

OMEGA/EEM CATALOG DISTRIBUTION

OMEGA Engineering and EEM (Electronic Engineers Master), published by Hearst Business Communications, have launched a new venture to jointly distribute literature. The program includes the four-volume EEM set featuring electronic products, equipment, and services, along with OMEGA's two-volume set in process measurement and control products. OMEGA Engineering; Tel: 800-TC-OMEGA (800-826-6342) or 203-359-1660; E-Mail: info@omega.com; http://www.omega.com.

OMEGA Engineering

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INTERNALLY GAGED FORCE TRANSDUCERS

Catalogs describe a complete line of force transducers manufactured by Strainsert. Transducers include: flat load cells, tension and compression from 250 to 2 million pounds; clevis pins with 0-10 vdc and 4-20 ma outputs; tension links up to 400,000 pounds; load-sensing bolts and studs; and load indicators. "Special" designs are invited. Strainsert, Union Hill Industrial Park, West Conshohocken, PA 19428; Tel: 610-825-3310; Fax: 610-825-1734.

Strainsert

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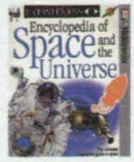

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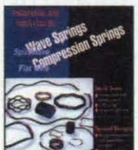

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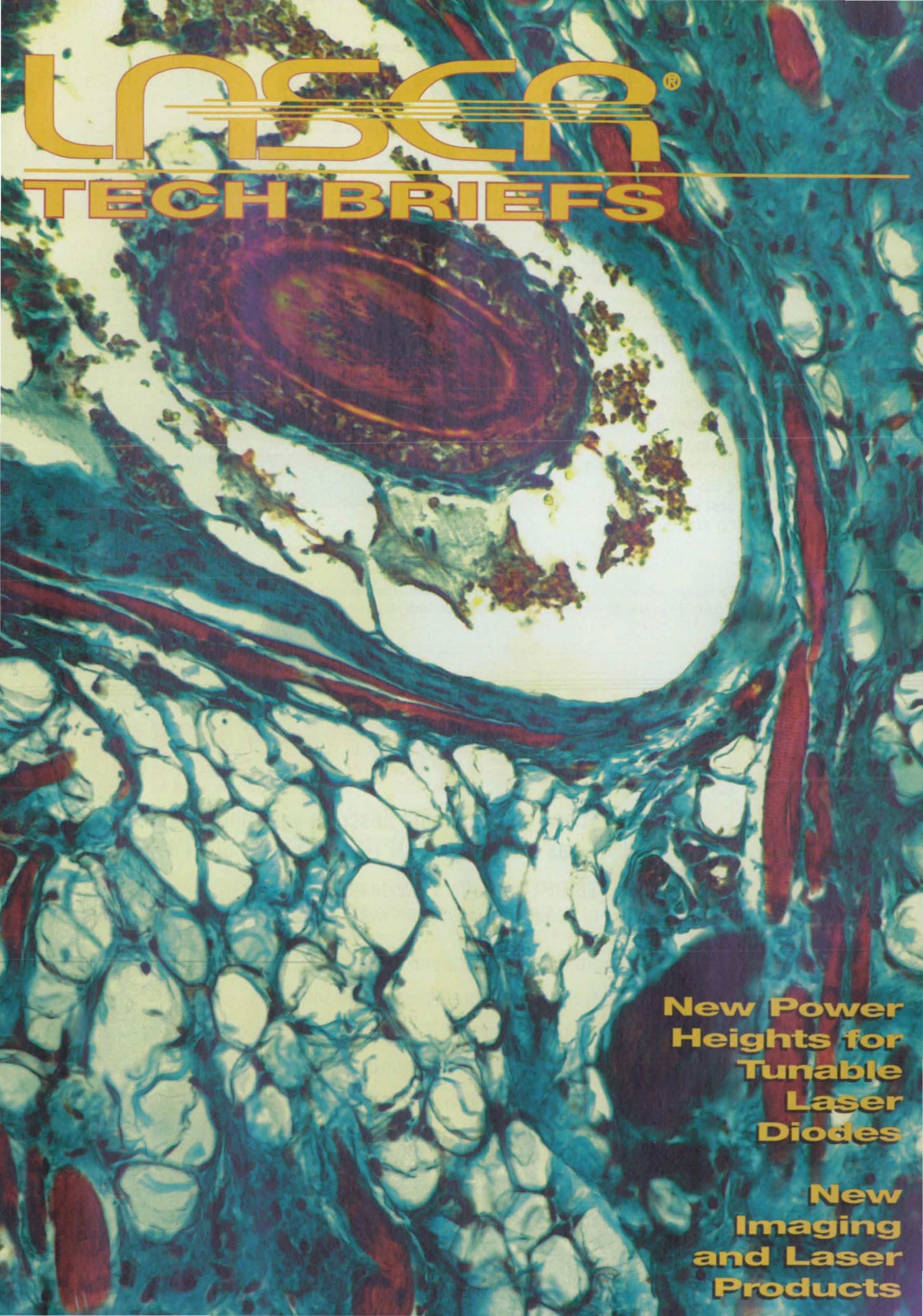
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FEATURE

DEPARTMENTS

On the cover:
A virtual color image of a human cell acquired by computer-automated microscopy with a Kodak 4.2i camera and a Coreco F64 image processor. *Image courtesy Coreco, St. Laurent, Quebec, Canada, and Advanced Imaging Concepts, Princeton, NJ.*

NEWS BRIEFS

Notes from Industry and the Federal Laboratories

Acton Research Corp. of Acton, MA, produced two very high-rejection vacuum ultraviolet (VUV) optical filters for the University of Wisconsin. They will be used in the Wide-Field Imaging Survey Polarimeter (WISP), a suborbital rocket payload funded by NASA to be used to obtain wide-field polarimetric images of the comet Hale-Bopp in the VUV. Shipped in December of last year, the filters provided had a dollar value of $37,755. The launch of the rocket to observe the comet is scheduled for this month from White Sands, NM.

With 1996 sales showing an 86-percent increase over the previous year, **Big Sky Laser Technologies** undertook a major expansion of its Bozeman, MT, facilities, the new space to be split among production, engineering, and customer service. With the current phase, planned to be complete at the end of last month, the total expansion will amount to 80 percent. Greg Smolka, director of sales and marketing, attributed much of the growth to the company's medical OEM lines, particularly Nd:YAG and Er:YAG, but also pointed to continued strong growth in the CFR line of pulsed YAG lasers for scientific, military, and industrial applications.

Big Sky has added a new shock and vibration testing capability that will enable on-site testing of lasers over any customer-specific shock and vibe curve. The lab features a new Unholtz-Dickey S062 vibration system—a "state-of-the-art test station," according to director of engineering Jamie Barbula, that will make possible refinement of "our rugged designs, thereby increasing system reliability....Many of our customers are mounting their lasers in helicopters or airplanes or transporting them into the field, so reliability, substantiated through testing, is critically important."

As of February 1, the integrated optics arena has a new player: **BBV Design B.V.** Based in Enschede, the Netherlands, the company provides design services and training in efficient design techniques for integrated optics device development. General manager of the new company is Martin Amersfoort, formerly of Bellcore. Also on staff is Meint Smit, inventor of the arrayed waveguide grating, a key component in many dense wavelength division multiplexing applications. Design experience and tools are provided by BBV Numerical Engineering, developers of the hierarchical design approach in integrated optics, and BBV Software, the world's largest supplier of integrated optics design software. BBV Design B.V.'s address is Hengelosestraat 705, 7521 PA Enschede, the Netherlands; +31-53-4836342; Fax: +31-53-4337415; E-mail: Amers@bbv.nl.

Late last year, **Semiconductor Laser International** (SLI) of Binghamton, NY, acquired an exclusive license from Northwestern University Center for Quantum Devices to develop, manufacture, and market aluminum-free high-power semiconductor lasers worldwide. The patented technology, which is said to increase power levels dramatically, was developed by Prof. Manijeh Razeghi of Northwestern, who agreed to act as advisor to SLI in commercial implementation. With the new year, Dr. Geoffrey T. Burnham, SLI's president and CEO, announced that demand was so great that work would begin on a second phase of its manufacturing facility, substantially ahead of schedule, that would double its size. By February, the manufacturing facility's first phase, comprising 15,000 sq. ft. and a 4,000-sq.-ft. clean room, was in full production and order backlog had reached $1.3 million.

The facility is equipped with the world's first molecular beam epitaxy crystal growth reactor incorporating the patented U.S. Air Force technology known as desorption mass spectrometry, a yield-increasing method for which SLI also has an exclusive license.

Most recently, the company acquired a second Northwestern license for technology developed by Prof. Razeghi: the buried-ridge laser device. Burnham noted the technology allowed for good electrical confinement, "which can be utilized in the digital storage industry, specifically the digital video disc or DVD, which holds eight times more data than a conventional CD."

Meadowlark Optics of Longmont, CO, broke ground for its new research and manufacturing facility in Frederick, CO, in February. The plant, approximately 20,000 sq. ft. in size, will occupy five acres in the 75-acre Meadowlark Business Park being developed by the company's president and CEO Tom Baur and his wife Jeanne. Meadowlark employs 39 researchers, engineers, and production workers in the manufacture of polarization optics. The company expects to move into its new quarters during the summer.

Last month **LightPath Technologies** of Albuquerque, NM, introduced a new class of lenses fashioned from its GRADIUM™ axial gradient index glass (see *Laser Tech Briefs*, "New Products," October 1996, page 13a). The new fast GRADIUM lenses provide a 10- to 20-fold increase in tightness of focus and smallness of spot size compared with conventional homogeneous singlet lenses, according to LightPath. The fast GRADIUM line includes 12 ultrafast lens types in sizes ranging from 5-80 mm, at 5-125-mm focal lengths.

In February the company announced an agreement with **DR Technologies** of San Diego, CA, to jointly seek U.S. government contracts for GRADIUM applications. LightPath is currently working on a $225,000 subcontract through DR Technologies to provide first a glass, then an acrylic, solar "light conduit" for a graded index solar concentrator for space satellite power. The team will together target $500 million of Defense Department programs for early-stage R&D projects that have commercial possibilities, and $24.6 million of Defense Advanced Research Projects Agency (DARPA) funds earmarked for a new breed of optical sensors. LightPath also announced a three-year strategic alliance with **Hikari Glass Co.**, a Japanese lens and prism manufacturer, to increase the presence of GRADIUM in Asian markets.

The Optoelectronics Group of **EG&G** Inc. has consolidated its operations, eliminating the names of its nine divisions and reorganizing them by product categories under Paul Beech, Dr. Werner Rech, and Andre Buser as general managers.

The business units folded into the Group contributed almost 20 percent of EG&G's sales total of $1.6 billion in 1996. They include Canada of Vaudreuil, Quebec (laser diodes, detectors, receivers); Judson of Montgomeryville, PA (infrared detectors); Electro-Optics of Salem, MA (strobe systems, flashlamps, thyratrons, spark gaps, rubidium atom frequency standards); Power Systems of Covina, CA (high-reliability power supplies); Reticon of Sunnyvale, CA (image sensors, CCD cameras); Heimann Optoelectronics of Montgomeryville, PA, and Wiesbaden, Germany (IR sensors, image tubes, flashtubes); IC Sensors of Santa Clara, CA (micromachined accelerometers, pressure transducers, microvalves); Vactec of St. Louis, MO (photocells, photodiodes, sensors); and Amorphous Silicon, Santa Clara, CA (amorphous silicon large-area imagers).

POWER PLAY: TUNABLE LASER DIODES HIT NEW HEIGHTS

Developments in high-power wavelength-tunable laser diode technology are revolutionizing optical instrumentation. Compact, highly reliable low-cost tunable laser diodes have attained the output power levels, beam quality, and spectral purity of conventional solid-state and dye laser systems. The emergence of this commercially viable technology is opening up new applications in chemical analysis, process control, nonlinear frequency conversion, millimeter-wave generation, materials characterization, and scientific research.

With partial support from a NASA Ames Research Center SBIR program, SDL of San Jose, CA, has recently demonstrated and is currently commercializing the first high-power single-frequency continuously tunable laser diode system suitable for high-precision spectroscopy. In contrast to previously available moderate-power external cavity tunable laser diode sources, this new system increases the available diffraction-limited single-frequency power to more than 1 watt. Such power enables efficient nonlinear frequency conversion to wavelengths throughout the UV, visible, and mid-IR spectral regions.

As part of the NASA SBIR program mentioned above, SDL developed a complete mid-IR source that combined two 1-W laser diode systems in a nonlinear crystal to provide broadly tunable narrow-linewidth 4.3-μm radiation for high-resolution carbon dioxide absorption spectroscopy. Because this mid-IR source is based upon near-IR laser diodes, it has several advantages over other mid-IR lasers, including high reliability, lower power consumption, room-temperature operation, and compact size.

The high-power tunable laser diode system is based on a continuously tunable master-oscillator power-amplifier (CT-MOPA) architecture that combines the excellent spectral properties of low-power external cavity tunable laser diodes with the high diffraction-limited power attainable from semiconductor optical amplifiers. The master oscillator, consisting of a laser diode coupled to an external cavity, generates 10-25 mW of single-frequency continuously tunable radiation with less than 2 MHz of frequency jitter. To maintain a compact overall laser size and minimize thermal and mechanical fluctuations, the entire oscillator laser cavity volume is kept to less than 4 cubic inches. The oscillator's output beam is coupled into a semiconductor power amplifier, boosting the optical power to greater than 1 W. The amplifier's output is diffraction-limited and maintains the narrow spectrum of the master oscillator.

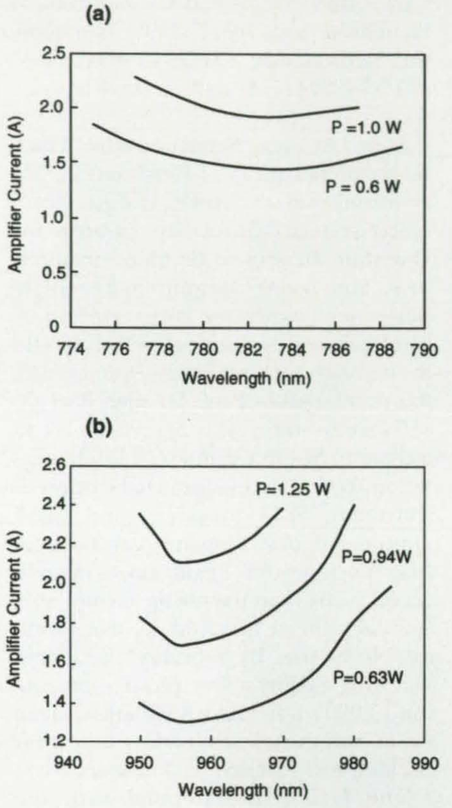

Figure 1. **Amplifier current vs. CT-MOPA laser wavelength** for different power levels for (a) 785-nm laser and (b) 965-nm laser.

A Commercial Version

The broad gain spectrum of the semiconductor material allows the output wavelength to be tuned over tens of nanometers by tuning the oscillator. The tuning ranges for CT-MOPA systems operating near 780 nm and 965 nm, shown in Figure 1, demonstrate up to 35 nm of tunability. SDL has recently introduced the TC40, a commercial CT-MOPA laser system. Illustrated in Figure 2, the TC40 provides 0.5-W single-frequency continuously tunable diffraction-limited radiation with complete electronic fine and coarse wavelength control. The technology used in CT-MOPA systems has been demonstrated throughout the 650-1140-nm wavelength range.

The high power, spectral purity, and spatial coherence of the CT-MOPA output beam enables its efficient conversion, using nonlinear materials, to the UV, visible, and mid-IR spectral regions. Several gases of industrial and scientific importance, including CO_2, CO, and CH_4, have strong molecular vibrational transitions in the mid-IR, between 3 and 5 μm, that can be used for high-sensitivity gas concentration measurements. Many atomic species have absorption spectra in the UV and visible. Conversion to the mid-IR may be accomplished by difference-frequency mixing (DFM) of two near-IR laser wavelengths in a nonlinear crystal to generate radiation at the difference of their frequencies. By mixing two tunable near-IR laser diode systems, the entire 3-5-μm spectral range can be covered.

SDL developed the mid-IR DFM source illustrated in Figure 3 for CO_2 spectroscopy. Beams from two CT-MOPA laser diodes, one tunable between 775-790 nm and the other between 950-985 nm, are combined in a dichroic beamsplitter and focused into a crystal of periodically poled $LiNbO_3$ (PPLN). The latter is a nonlinear material that allows efficient conversion to the mid-IR of any near-IR wavelengths by appropriate choice of poling period for quasi-phasematching. Because of the broad tunability of the two near-IR systems, this mid-IR source can generate light over the 3.6-4.7-μm wavelength range.

In the configuration shown, the mid-IR system is arranged to optimally produce radiation near 4.3 μm, in order to tune through the fundamental vibra-

Figure 2. The **SDL TC40** high-power single-frequency continuously tunable commercial laser system.

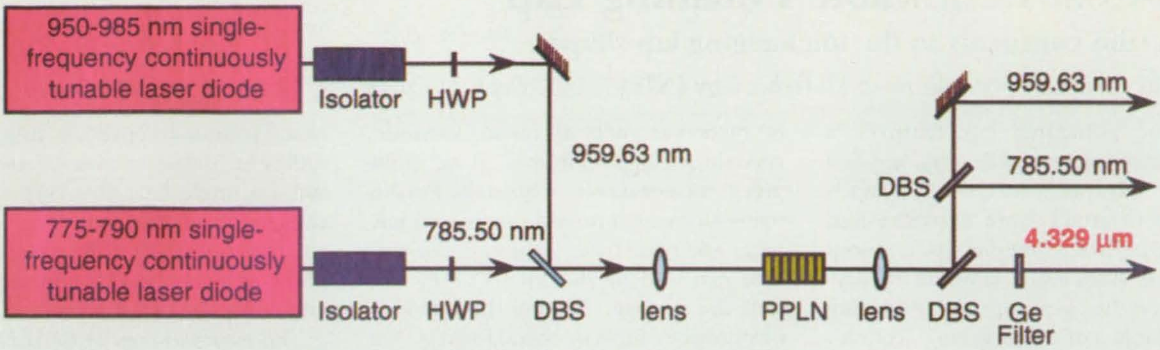

Figure 3. Schematic diagram of the **tunable narrow-linewidth mid-IR radiation source** (HWP: half-wave plate; DBS: dichroic beamsplitter).

tional absorption lines of CO_2. The absorption spectrum is measured by sending the mid-IR beam through a cell containing 10 torr of CO_2 and electronically tuning the frequency of the 785-nm laser diode system using a piezoelectric actuator in the master oscillator's cavity. The absorption spectrum is shown in Figure 4 and demonstrates a mid-IR linewidth of less than 30 MHz (0.001 cm^{-1}). This linewidth is the convolution of the two near-IR laser linewidths, independently measured to be less than 10 MHz each. The transmission spectrum through a germanium etalon, shown in Figure 4, demonstrates the smooth continuous tunability of the mid-IR source. The narrow linewidth combined with the continuous tunability allows clear resolution of several different carbon dioxide isotopes.

The NASA Connection

Mid-IR laser sources are of interest to NASA because many geologically and biologically important gases have strong absorption lines in this spectral region. Absorption spectroscopy can perform simple, direct measurements of gas concentrations. Measurement of the ratio of $^{12}CO_2$ to $^{13}CO_2$ is particularly important for tracing material sources and studying biological activity. Future missions to Mars may include onboard mid-IR laser sources for sample analysis. Mid-IR spectroscopy has several additional NASA applications, including monitoring gas concentrations in spacecraft cabins, measuring atmospheric gas concentrations, and analyzing meteorites.

Both the mid-IR source and the high-power CT-MOPA laser sources have many potential commercial applications. Mid-IR gas sensing can be used for pollution monitoring of factory and automobile emissions. The broad wavelength coverage allows measurement of many pollutants, including NO, HF, and CO. Spectroscopic measurements throughout the visible to mid-IR can be used for process control in semiconductor manufacturing, where monitoring of moisture content, metallizations, epitaxial depositions, and optical coatings can increase device yields. Several atomic species with absorption lines in the UV and blue regions of the spectrum can be monitored by frequency-doubling the CT-MOPA output. Deployment of high-power laser diodes based on the CT-MOPA's amplifier technology is already occurring in industrial chemical processes and analysis. For these applications, a wavelength-stabilized laser with <10 GHz linewidth is used as an excitation source for Raman spectroscopy. Measurement of the Raman-shifted spectrum from a sample can be performed noninvasively and returns a quantitative analysis of the chemical composition.

The development of high-power single-frequency continuously tunable laser diodes will enable further expansion of new spectroscopic applications. By offering performance that was previously available only from tabletop-sized complex laser systems, this laser diode technology will bring powerful analytical techniques out of development laboratories and into widespread commercial use.

For further information, contact Steve Sanders, Staff Scientist at SDL; (408) 943-4231; Fax: (408) 943-4260.

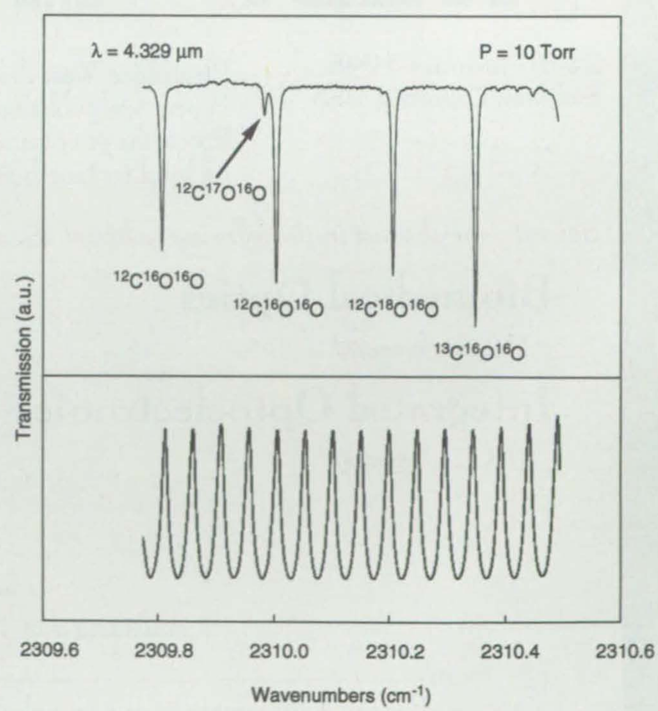

Figure 4. **Absorption spectrum of CO_2** measured using the laser-diode-based mid-IR source. The lower curve shows the transmission through a germanium etalon.

Low-Cost Renewable Polishing Lap

A thin film conforms to the unchanging lap shape.

National Institute of Standards and Technology (NIST), U.S. Dept. of Commerce, Gaithersburg, Maryland

A new polishing lap features a replaceable, deformable film applied to a lap substrate's surface. The lap is resistant to attack from corrosive and reactive polishing media; its textured surface is sufficiently resilient to provide good finishes without hindering dimensional controlling and accuracy of the texturing.

A lap substrate having a localized texture and an overall shape (flat, concave, or convex) to conform with the workpiece is covered with a replaceable lap film that is deformed to correspond to the texture of the substrate's surface. The peaks of the lap substrate provide the desired overall shape while the valleys retain the polishing media and the accumulated material removed from the workpiece. The film contacts the polishing media and the piece being treated.

The textured lap substrate can be made from numerous sufficiently rigid materials such as metal, ceramic, crystalline, glass-ceramic, glass, polymeric, or composite materials. Porous materials, which provide their own texture, are preferred, although the texture can also be machined or etched into the surface. The lap film, of various polymer films or metal foils, is thin and uniform to deform to the substrate surface, chemically resistant, and impermeable. Vacuum, pressure, heat, chemicals, electrostatic or magnetic fields, or mechanical force can be used to deform and/or hold the film in place.

Covered, the lap substrate surface does not degrade or change during use. Chemically aggressive substances can be used. Thin films can be made to fit well without wrinkling, and provide sufficient resilience to achieve good finishes without losing the accuracy of soft fabric laps. Contaminated films can be easily removed and replaced so that an entire production process, using several different abrasives, can be performed using a single lap. This lapping device can be used for grinding, lapping, and/or polishing substrates, such as semiconductor wafers, optical lenses, and computer hard disks.

This work was done by Chris Evans and Bob Parks at the **National Institute of Standards and Technology**. *The invention has been reduced to practice. For more technical information, contact Dr. Evans at (301) 975-3484; FAX (301) 869-0822; E-mail: cjevans@nist.gov. A patent is pending, and exclusive and nonexclusive licenses are available. Licensing inquiries may be directed to Marcia Salkeld, Licensing Assistant, NIST, Department of Commerce, Building 820, Room 213, Gaithersburg, MD 20899-0001; (301) 975-4188; FAX (301) 869-2751. Refer to NIST Docket No. 94-043.*

Laser-Diode-Source Module With Fiber-Optic Coupling

A flexible design enables the use of alternative components and coupling schemes.

Marshall Space Flight Center, Alabama

A module of optoelectronic equipment has been developed to satisfy requirements to (1) couple light from a laser diode into a single-mode optical fiber and (2) send a portion of the light through a reference cell. The module incorporates the following components:

- A laser diode in a TO-type can;
- A thermoelectric cooler;
- A collimating lens;
- An optical isolator;
- A beam splitter for the reference and fiber beams;
- A commercial fiber collimator;
- A mount that holds the fiber collimator and that is adjustable in translation along, and rotation about, the two coordinate axes perpendicular to the nominal optical axis;
- A reference cell; and
- A reference detector.

The module features a flexible design that enables the use of different laser diodes and different reference cells and that provides the option for either fiber-optic or free-space coupling of the laser beam. The design also facilitates adjustments to maximize coupling of laser light into the fiber and minimizes both optical interference fringes and reflection of light back into the laser diode.

This work was done by Fritz Bien, Michael E. Gersh, Neil M. Goldstein, and Jamine Lee of Spectral Sciences, Inc., for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0026. Refer to MFS-26438.

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Noise-Cancelling Fiber Optic Microphone

A directional, refractive-based optical microphone permits communication in both electrically and acoustically noisy environments.

Armstrong Laboratory, Crew Systems Directorate, Wright-Patterson Air Force Base, Dayton, Ohio

A Micro-Optics Technologies Inc. team has developed a noise-cancelling fiber optic microphone (NCFOM) that has immunity to electromagnetic interference and reduced sensitivity to ambient acoustic noise. Made without magnetic materials, it is about 26 mm in diameter and 20 mm thick, about the size of currently used boom-mounted electroacoustic microphones. The NCFOM can be used for voice communication in environments that contain electrical, magnetic, and acoustic interference.

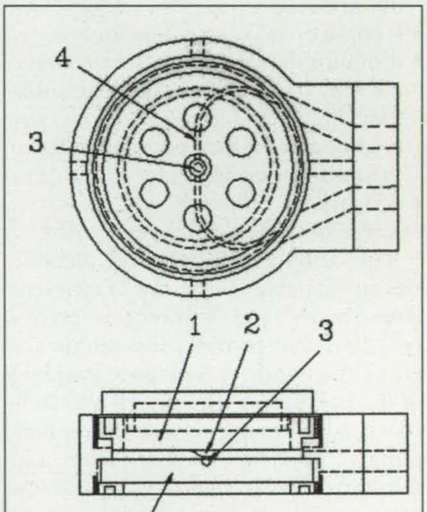
The NCFOM is a new design that depends on refraction rather than reflection for signal detection. Two multimode 200-micron-core optical fibers with cleaved ends face one another. A spherical sapphire microlens 1 mm in diameter is attached to the center of a flexible polyester diaphragm 25.4 microns thick, with a diameter of 2.2 cm, using a two-part epoxy. The diaphragm is positioned so that the lens is placed between the two fiber ends. The figure shows a diagram of the microphone.

One fiber of the NCFOM is connected to a light-emitting diode with 850-nm emission, and is used to transmit light through the lens. The other fiber, used to receive the light that has passed through the lens, is connected to a photodiode for detection. The fiber pair is aligned with respect to the lens so that light from the transmitting fiber is focused into the receiving fiber. The lens moves with the diaphragm in response to pressure variations, thus changing the location of the focused light. This action modulates the light acquired by the receiving fiber and creates a pressure-dependent signal.

Decreasing the sensitivity of the microphone to the planar wavefronts of far-field noise results in noise-cancellation performance. It is achieved by venting the microphone so that these planar wavefronts, arriving at the same time at the front and the rear of the diaphragm, nullify one another. The microphone is then more sensitive to near-field sources.

The acoustic noise-cancellation performance was assessed by measuring the signal-to-noise ratio (SNR) when a simulated voice signal was placed 2 cm in front of the microphone under test and a noise source was present 60 cm away and at various angles relative to the same microphone. At present the NCFOM shows about a 7-dB SNR in this test compared to a conventional electroacoustic noise-cancelling microphone's 13-dB SNR. Work is continuing on the improvement of the noise cancellation of the fiber optic microphone.

The NCFOM has a 90-dB dynamic range, a frequency range from 20 to 6000 Hz, and an open-circuit sensitivity of -30 dB at 1000 Hz (referenced to 1.0 V/Pa). The microphone's body is connected by two multimode optical cables terminated in ST connectors to an electronic interface box that houses the light source and detector and a circuit that provides an output for standard intercom systems. The NCFOM can be used by the aviation community as well as the chemical industry and electrical utilities, and for medical purposes such as allowing patients undergoing magnetic resonance imaging scans to communicate with hospital staff.



Top (upper) and side (lower) views of the **Fiber Optic Microphone**: (1) diaphragm mount, (2) diaphragm, (3) lens, and (4) optical fiber mount.

This work was done by James P. Stec, Bradley M. Jost, and Jeffrey C. Buchholz of Micro-Optics Technologies Inc. for the **Armstrong Laboratory, Crew Systems Directorate, Wright-Patterson Air Force Base**. *(Additional funding was provided by NASA Langley Research Center.) US Patent 5,262,884 has been issued for the NCFOM.*

Inquiries concerning rights to commercialize this invention may be addressed to James P. Stec, Micro-Optics Technologies Inc., 8608 University Green, #5, PO Box 620377, Middleton, WI 53562; (608) 831-0655; FAX (608) 831-5821.

Efficient, Fundamental-Transverse-Mode, Diode-Pumped Lasers

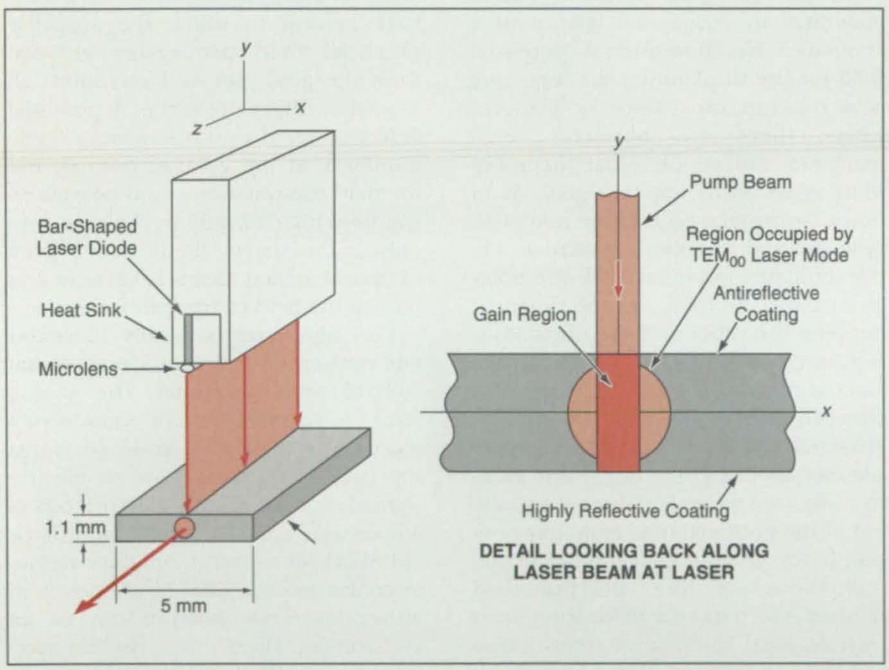
Intra-cavity apertures are not necessary for operation in the fundamental transverse mode.

Goddard Space Flight Center, Greenbelt, Maryland

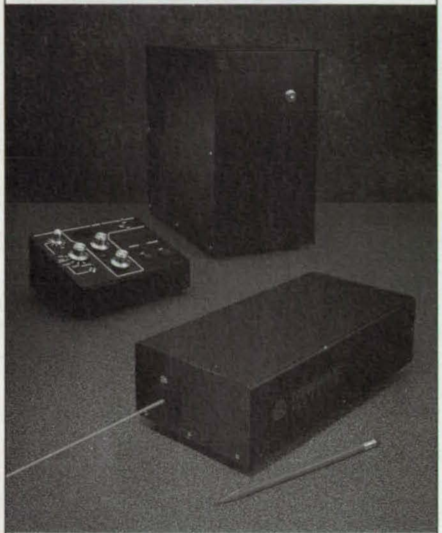
A class of efficient, rugged, solid-state lasers is based on a combination of (1) side pumping by diode lasers and (2) configuring the gain regions, in conjunction with the side pumping, so that the fundamental transverse electromagnetic mode (TEM_{00}) is automatically selected. The configuration overcomes the practical limitation on power available for longitudinal pumping by devices that were on the market when the information for this article was submitted. It also eliminates the need for the intra-cavity apertures that are used in older side-pumping configurations to ensure operation in the TEM_{00} mode. Typically, an intra-cavity aperture induces substantial loss in energy or power, and diffraction around the aperture can degrade the quality of the emitted laser beam.

The figure schematically illustrates a typical laser of this class. The pump beam is a thin sheet of light generated by a bar-shaped laser diode placed above and aligned parallel with the gain region of the laser crystal. The beam is collimated by a cylindrical microlens and aimed at the TEM_{00}-mode region of the laser crystal. Thus, the pump beam overlaps the TEM_{00}-mode region, which, as explained below, contains part of the gain region.

The lasers of this class exploit a modified version of the principle that if the gain region of the laser crystal is smaller than the region occupied by the TEM_{00} laser mode, then the selection of



This **Diode-Pumped Solid-State Laser** exploits a combination of side pumping, a gain region that is narrower than the TEM_{00} mode in the x dimension, and reflection losses at the top and bottom surfaces of the laser crystal to suppress non-TEM_{00} modes in the *y* dimension.



the TEM_{00} mode is assured. In the modified version that applies here, the gain region of the laser crystal is constrained in the following sense: The longitudinal (z-axis) dimensions of the gain region and the TEM_{00}-mode region in the laser crystal are the same, while the gain region of the laser crystal is narrower than the TEM_{00}-mode region in one of the lateral dimensions (the x axis in the figure).

Selection of the TEM_{00} mode in the other lateral dimension (the y axis in the figure) is accomplished by using the gain region as an aperture; that is, by exploiting the losses induced by the top and bottom of the laser crystal. To obtain optimum performance of the laser, it is necessary to balance the need for complete absorption of the pump beam (for which the crystal should be made deeper in the y dimension) against the need to use the top and bottom of the laser crystal as an aperture to strip off electromagnetic modes of higher order along the y axis.

This work was done by Robert Afzal and Mark Selker of **Goddard Space Flight Center**. *For further information,* ***write in 23*** *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-13602

Analog/Digital Potential-Mapping System for Robotic Guidance

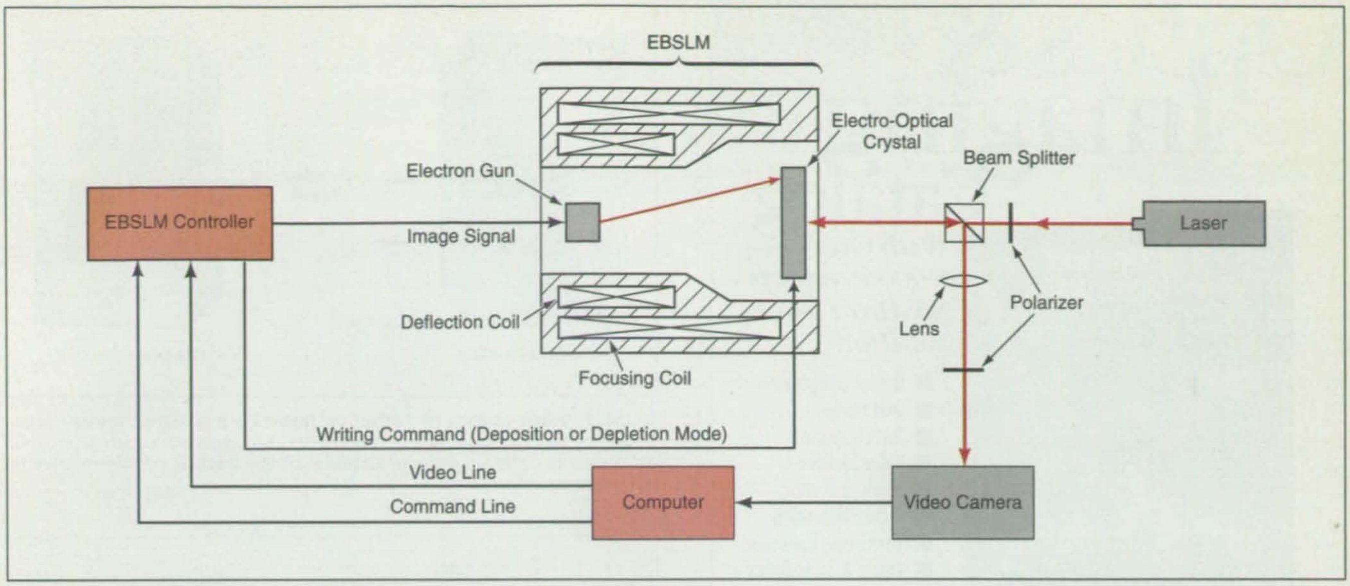
A potential field around obstacles and a goal is simulated.

Ames Research Center, Moffett Field, California

An analog/digital electronic system generates an image that represents a simulated two-dimensional potential field for use in planning the trajectory of a robot across a floor or platform where there are obstacles (e.g., machines and people) that the robot must avoid on its way to a goal. As in other implementations of the potential-field method of robotic guidance, (1) the simulated potential field resembles an electrostatic field, (2) the potential between the robot and the obstacles is repulsive (as between objects of like electric charge), while the potential between the robot and the goal is attractive (as between objects of opposite electric charge), and (3) one seeks to compute a trajectory along the gradient of the potential field from any position to the goal. In typical other implementations of the potential-field method, the potential fields sometimes include local minima wherein robots can become trapped. One advantage of the present system is that it simulates a potential field without any minima other than that of the goal; in effect, the system is designed to guarantee an all-"downhill" obstacle-avoiding path from any location to the goal.

The system generates a gray-scale video image, in which increasing brightness in a given pixel represents increasing repulsive local potential. Starting with bright areas for the obstacles and a dark spot for the goal, the image is generated in an iterative feedback process in which the attractive potential field propagates outward from the goal spot and surrounds all obstacles, filling the scene. A potential field generated in this way has a single minimum at the goal, as desired, but the field computation could take excessive time if performed by digital means only. In this system, the inherent speed of optical analog means is harnessed to reduce the field-computation time.

The figure schematically illustrates one version of the system. Under digital control by a computer, the analog image is written by use of a modulated electron beam that is scanned across the back (left) surface of an electro-optical crystal in an electron-beam-addressed spatial light modulator (EBSLM). At a given time, the computer commands the EBSLM to operate in either an electron-deposition or an electron-depletion mode. In the electron-deposition mode, the electro-optical crystal is biased at a high voltage and charge accumulates on the back surface of the crystal in the places exposed to the electron beam. In the electron-depletion mode, the electro-optical crystal is biased at a low voltage and there is net depletion of charge from places exposed to the electron beam. In either mode, the charge pattern that remains after electron-beam writing gives rise to an electric field that alters the index of refraction of the crystal in



Analog Image Processing in the EBSLM and associated optical components speeds the computation of a simulated potential field in which a robot is repelled by obstacles and attracted by a goal, with an all-"downhill" path from any robot location to the goal.

a corresponding pattern.

There is an important difference between the two modes: patterns written in the electron-depletion mode have sharp edges and remain within their original boundaries, whereas patterns written in the electron-deposition mode expand beyond their original boundaries (because of secondary emission of electrons from the surface of the crystal). Initially, the dark goal spot is written in electron-deposition mode and begins to expand. Then the bright obstacle patches are written in electron-depletion mode. The resulting image is digitized and sent to the computer for processing into a feedback pattern, which is then written in the electron-deposition mode to enhance the expansion of the dark goal spot. This sequence of operations is repeated to obtain further enhancement and expansion of the dark spot. During each cycle of the iteration, the computer compares the image with the image from the preceding cycle. When the difference between the two images is less than some small amount related to the noise level, the iteration is terminated and the average of the images is used to compute the potential field.

This work was done by Max B. Reid of **Ames Research Center**. *For further information, write in 42 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,483,168). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-11997.

Improved Video Sensor System for Guidance in Docking

The principal advantage over a prior system would be greater speed.

Marshall Space Flight Center, Alabama

A proposed video sensor system to be mounted on a tracking vehicle would automatically determine the relative orientation of a tracked vehicle during approach. The proposed system is intended to replace a current video sensor system that functions similarly and is used to guide the approach, which ends in the docking of the two vehicles with each other. The principal advantage of the proposed system would be greater speed.

A description of the current system is prerequisite to understanding the proposed system. The current system (see Figure 1) includes a video camera and two pulsed lasers of different wavelengths on the tracking vehicle. Three reflective targets are mounted at the corners of a triangle on one surface of the tracked vehicle, and a fourth reflective target is mounted at the tip of a stalk that protrudes from the surface. The reflective targets are covered by filters that absorb light at one of the laser wavelengths.

At the beginning of an operating cycle, the tracked vehicle is illuminated by a pulse of light from one of the lasers, and a frame grabber captures the resulting video image of the targets. Next, the other laser emits a pulse of light and the frame grabber captures the resulting video images. The two images are digitized and subtracted from each other in a fast computer, leaving only a digitized image of the targets. The orientation of the tracked vehicle relative to the tracking vehicle is then computed from the known geometric relationships among the positions of the targets in the image, the positions of the targets relative to each other, and the orientation of the video camera. A large fraction of time of each operating cycle is taken by the image-subtraction process; this limits the frequency with which orientation data can be updated and makes the system vulnerable to losing track of rapidly moving targets.

The proposed system would be based on similar principles but would implement them in a different way to reduce the time taken by the image-subtraction process. The camera in the proposed system (see Figure 2) would incorporate a prism assembly, wherein the beam of light focussed by the camera lens would be split to form images on two charge-coupled-device (CCD) imaging arrays. An absorptive filter would be placed in front of one CCD

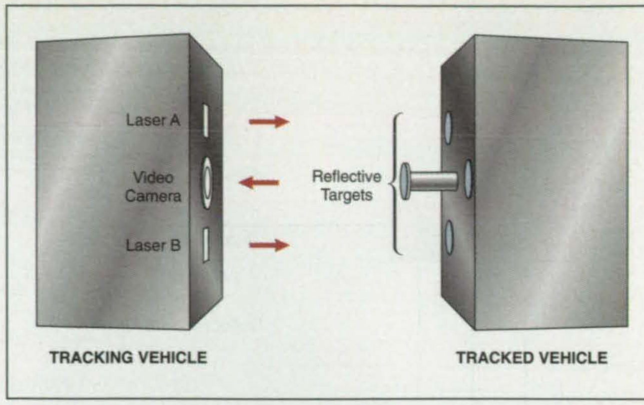


Figure 1. **Video Images of Reflective Targets** are acquired under illumination by two different lasers, digitized, subtracted from each other, and processed to determine the orientation of the tracked vehicle relative to the tracking vehicle.

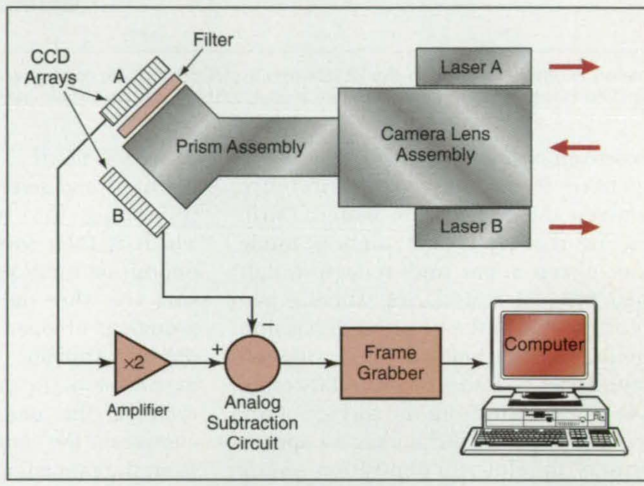


Figure 2. The **Video Signals Would Be Subtracted** from each other while still in analog form; this would take much less time than does subtraction of digital image data.

array. The analog output from the CCD array with the filter in front of it would be amplified by a factor of 2, and the analog output of the other CCD array would be subtracted from it. The analog output of the subtraction circuit would contain only the images of the targets because the subtraction would remove the background image. The analog output of the subtraction circuit would be fed to a frame grabber for digitization. The digitized image would then be processed to calculate orientation as in the current system.

The image-acquisition process takes about 30 ms, and the digital subtraction process takes about 250 ms for a 1,024 × 1,024 array on a 40-MHz digital signal processor. In comparison, the analog subtraction process takes negligible time. Thus, depending on the time taken by the orientation-calculation process, the proposed system might offer a considerable speedup over the current system. Another advantage of the proposed system is that unlike the current system, there would be no possibility of jitter between the subtracted images, because in the proposed system, the two subtracted images would be formed simultaneously.

This work was done by Tom Sutherland of **Marshall Space Flight Center**. *For further information, **write in 30** on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31150.

Scheme for Single-Mode Pumping of a Solid-State Laser

Best features of two older schemes would be combined.

Goddard Space Flight Center, Greenbelt, Maryland

A proposed scheme for side pumping of a solid-state laser rod efficiently in a single desired waveguide mode (the TEM_{00} mode) would combine the advantages of older end- and side-pumping schemes: It would afford efficiency approaching that previously attainable only through end pumping with focusing of the pump laser beam to a diameter of the order of tenths of a millimeter to match the desired mode; at the same time, it would afford the power scalability attainable only through side pumping by multiple laser diodes.

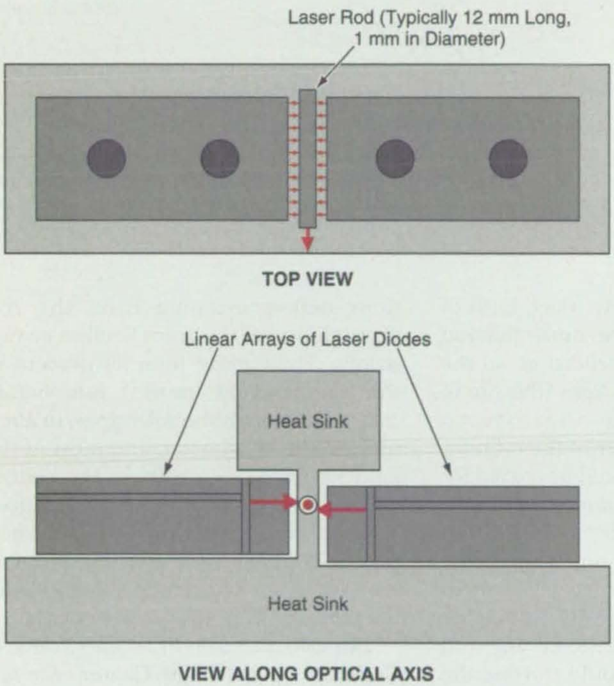


Figure 1. **Two Linear Arrays of Laser Diodes** would pump the laser rod from opposite sides.

The scheme calls for side pumping by arrays of laser diodes that would be aligned so that the light would enter at angles favoring a high degree of absorption and conversion to laser light. The laser rod [which could be made of neodymium:yttrium aluminum garnet (Nd:YAG) or other suitable crystalline laser material] would be about 1 mm in diameter — unusually narrow for a laser rod but a convenient size for manufacture. This diameter would be only slightly wider than the region occupied by the major part of the electromagnetic energy in attainable laser modes; thus, in comparison with older side-pumping schemes involving wider laser rods, this scheme would cause a greater portion of the cross section of the laser rod to contribute to laser action and a lesser portion to merely convert the absorbed pump light to heat.

The laser head (see Figure 1) would include the laser rod and arrays of laser diodes mounted in a heat sink. The pump light would enter the laser rod from the two arrays of laser diodes through two longitudinal stripes, each 100 µm wide and located

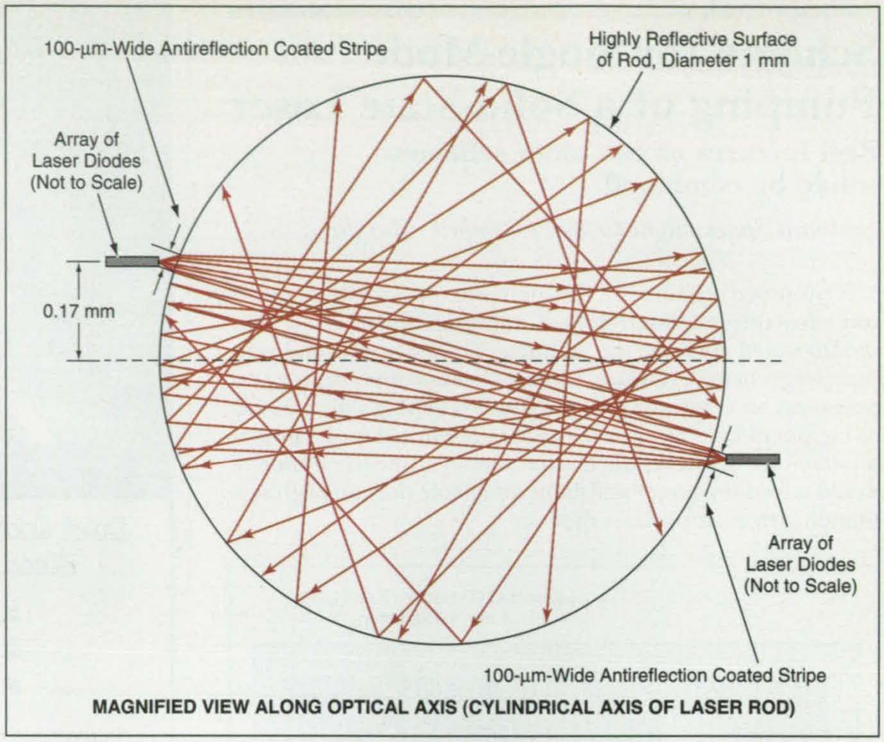


Figure 2. **Multiple Reflections** would confine the pump light in the laser rod, increasing the effective optical path length for pump light to about 4 times the diameter, thus increasing the utilization of the pump light.

diametrically opposite the other. Each of these stripes would be antireflection (AR) coated for low reflection at the wavelength of the pump light (809 nm in the case of the laser diodes used to pump Nd:YAG). The remainder of the cylindrical surface of the rod would be coated for high reflection at the pump wavelength.

The sideways offset between the two arrays of laser diodes is an essential feature of the pump geometry, shown in more detail in Figure 2. With this geometry, pump light that entered the rod from the laser diodes would traverse the cross section several times, confined to the interior of the rod by reflection. Raytrace calculations show that pump light would typically undergo three reflections before escaping from the rod through one of the antireflection coated stripes. Thus, more than 90 percent of the pump would travel 4 mm before escaping through the AR stripes, in a rod of only 1 mm diameter, and most of the path would lie generally in the central region, where coupling to the desired laser mode would be greatest. A 4-mm path in Nd:YAG for a wavelength of 809 nm results in 84-percent absorption of the pump light in the laser medium.

This work was done by D. Barry Coyle of **Goddard Space Flight Center**. *For further information,* ***write in 32*** *on the TSP Request Card.*
GSC-13636

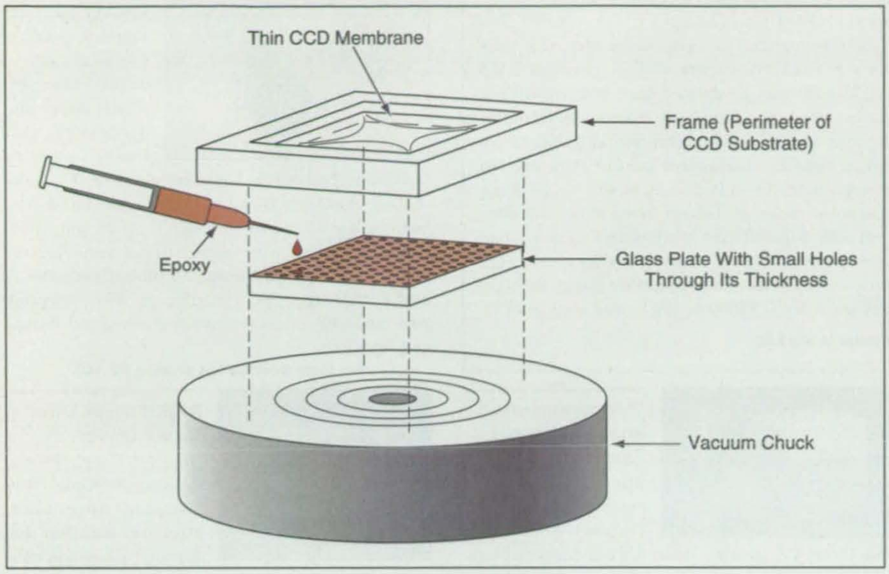
Making Structural Supports for Thinned CCD Membranes

Structural supports would be added after high-temperature processing instead of before.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for adding structural supports to membranes has been proposed. The technique is intended for use in fabricating charge-coupled devices (CCDs) and other microelectronic devices that are required to be very thin (7 to 15 µm in the case of some advanced CCDs) and to remain flat during use.

Heretofore, it was common practice to bond CCD substrates adhesively to structural supports by use of epoxies prior to thinning the substrates to final device thicknesses. This practice is unsuitable for fabrication of advanced CCDs because it is necessary to subject the substrates to postthinning processes at temperatures > 300 °C, at which epoxies disintegrate. Before applying the proposed technique, a CCD substrate would be thinned everywhere except at its perimeter, where a frame would be left to facilitate handling. The substrate would then be subjected to high-temperature processing. Being unsupported in the middle, the resulting CCD membrane could become wavy.



Wrinkles in the Membrane would be smoothed out when the membrane and glass plate were placed on the vacuum chuck. Excess epoxy would be drawn out by the vacuum chuck.

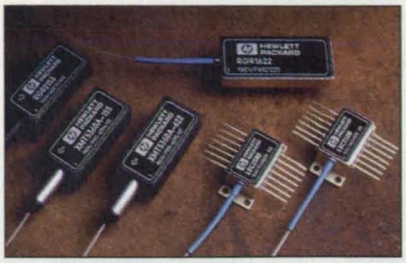
A small glass plate with many small, evenly spaced holes through its thickness would be prepared for use as the structural support. One face of the glass plate would be coated with an epoxy and placed in contact with the CCD membrane. The opposite face of the glass plate would be placed on a vacuum chuck (see figure). The suction in the chuck would act through the holes in the glass plate to flatten the membrane by drawing the membrane tightly against the plate. The suction would also draw excess epoxy through the holes. The plate and membrane could then be removed from the vacuum chuck because surface tension in the epoxy would continue to hold the membrane and plate together until they became permanently bonded together by curing of the epoxy.

This work was done by Shouleh Nikzad and Michael E. Hoenk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, **write in 99** on the TSP Request Card.*

NPO-19655

NEW PRODUCTS

Product of the Month



1500-nm Distributed Feedback Laser

Hewlett-Packard Co., Dallas, TX, specifies its new LSC2500 laser source for operation under ATM standards at SONET OC-48 and STM-16 speeds of 2.488 Gb/s. The directly modulated distributed feedback laser, intended for long-haul telecommunications, fiber optic sensors, cable television, and instrumentation, is capable of distances greater than 200 km over single-mode fiber. With a -20 to +65 °C operating temperature range, it delivers more than +3.8 dBm output with slope efficiency adjustable to more than 0.06 mW/mA. The package includes a photodiode for output monitoring, a thermistor for monitoring heatsink temperature, and a Peltier-effect thermoelectric cooler. A heatsink mounting flange is incorporated into the industry-standard 14-pin butterfly package. Price is $1000 in 1000-piece quantities.

For More Information Write In No. 800

Laser Line Projectors

Lasiris Inc., St.-Laurent, Quebec, Canada, introduces the LC series laser line generators with fixed pattern heads and factory-set focus adjustment. Features include uniform non-Gaussian intensity distribution, an ultrathin line down to 25 μm, over-temperature and over-voltage protection, electrostatic discharge protection to more than 8000 V, and CDRH and IEC compliance. The company also cites the series' compact and rugged design and low cost.

For More Information Write In No. 801

980-nm Fiber Bragg Grating

3M Specialty Optical Fibers, West Haven, CT, offers a fiber Bragg grating for the stabilization of external cavity semiconductor pump lasers. When the grating is pigtailed to a 980-nm pump laser for erbium-doped fiber amplifiers, a small amount of the light is reflected back and mixes in the laser's cavity, locking the lasing mode to the Bragg wavelength. The grating is provided in the center of a 2-m section of 3M photosensitive fiber. It has a reflectivity of 2-5 percent and temperature sensitivity of 0.012 nm/°C, and is proof-tested to 100 kpsi.

For More Information Write In No. 802

"Megaresolution" Image Analysis Camera

The Motion Analysis Systems Division of Eastman Kodak Co., San Diego, CA, adds the Model 6.3i camera to its Megaplus family. The company says the camera, with its full-frame CCD sensor array of 3072 (h) × 2048 (v) pixels, offers the highest resolution in the family. Each 9-μm-square pixel has the 100-percent fill factor common to the Megaplus line. Available in 8-bit or 10-bit versions, the camera has an aspect ratio of 3:2, making it suitable, according to Kodak, for LCD flat-panel inspections. The rear panel has a connection for DC power (12-28 V) and an output to drive an external strobe unit.

For More Information Write In No. 803

High-Power Laser Diode Driver

Newport Corp., Irvine, CA, calls its Model 5405 laser diode driver a cost-effective solution for driving high-power continuous-wave laser diodes. With the 40-A 5-V output, two laser diodes may be operated in series. The company can supply a complete control system using one of several high-power laser diode mounts. An external modulation input port has a 3-dB bandwidth of 2.5 kHz, and can be used for external voltage control of the output current set-point. Using a thermopile detector such as Newport's 818T series, front-facet power can be detected and displayed in watts.

For More Information Write In No. 804

High-Speed Digital CCD Camera

Nikon Inc., Melville, NY, has added the E2Ns to its digital still camera series. Its buffer memory can store up to six frames, and it can shoot up to 3 frames per second. Its 2/3-in. 1.3 million pixel CCD sensors have a low-pass filter that virtually eliminates RGB moire. The video output plus preview mode uses an analog video output terminal (NTSC or PAL) for connection to any TV monitor equipped with standard input terminals. Its multiple image compression modes include BASIC, NORMAL, and FINE, as well as uncompressed TIFF for the highest quality.

For More Information Write In No. 805

Nd:YAG Marking System

Synrad, Mulkiteo, WA, has teamed with Power Path Technology, Sunnyvale, CA, to produce a compact diode-pumped Nd:YAG marking system. Intended for applications where space is at a premium, the YAG marking kit, which features Synrad's SH series marking head, can be set up and operating in just a few hours, Synrad says. About the size of a small loaf of bread, the unit plugs into a conventional 15-A wall outlet, needing no high voltages, special wiring, or three-phase service. The company says the laser can operate virtually maintenance-free for more than 10,000 hours.

For More Information Write In No. 806

Visible-Beam Diode-Pumped Solid-State Laser

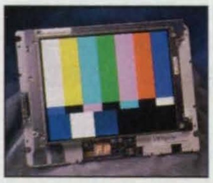
Spectra-Physics Lasers, Mountain View, CA, offers the Millennia II™, a 2-watt continuous-wave diode-pumped solid-state (DPSS) laser emitting in the green region at 532 nm. The air-cooled system is compact (18" × 6" × 6") and requires only a 110-V or 220-V single-phase outlet. The device, with a simple linear cavity, is pumped with the output from a fiber-coupled diode laser bar. The company says it is useful for semiconductor wafer inspection, disk texturing, particle scattering, reprographics, and spectroscopy.

For More Information Write In No. 807

Color/Monochrome Solid-State Imagers

Electrim Corp., Princeton, NJ, adds two cameras to its line of solid-state electronic imaging cameras. The color EDC-1000E enables the user to digitize an RGB color image at up to 652 × 494 pixels with 24-bit color depth. The monochrome EDC-1000N provides 256 gray scales at 652 × 494-pixel resolution. The cameras' low-noise (15 electrons per pixel) frame-transfer CCD image sensors operate in progressive-scan mode. Pixels are 7.4 microns square, and data collection rate is up to 2 MB/s. Price of the EDC-1000E is $900 and of the EDC-1000N $800.

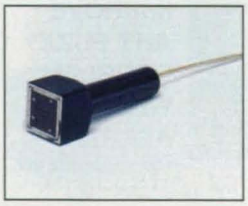
For More Information Write In No. 808



Video Interface Display

PC Video Conversion, San Jose, CA, offers the *VIDisplay* video interface display, a device that enables OEMs and integrators of display systems to show full-motion full-color television-compatible video on LCD panels intended for PC notebook use. The unit accepts composite (NTSC, PAL, and SECAM) and Y/C (S-VHS) inputs, and various interface modules enable compatibility with several manufacturers' LCDs. *VIDisplay* weighs less than a pound and is less than 1 1/3 inch thick, including the panel. The company says application areas include military, surveillance, multimedia kiosks, and portable displays.

For More Information Write In No. 809



MXN Fiber Optic Array

Fiberguide Industries, Stirling, NJ, offers custom ultra-high-precision two-dimensional (MxN) fiber optic arrays for LSI circuits for high-speed electronic switching. They consist of single-mode or multimode fibers, or combinations of them. Fibers are positioned on a customer-specified grid within +/-4 μm, and can be placed as close as 150 μm center to center. Arrays can be manufactured with as few as 25 or as many as 1000 fibers, and can be terminated and packaged per customer-specified requirements. Individual fibers are tagged with array position.

For More Information Write In No. 813

continued from page 75

solution of 4 percent lysozyme and 2 percent sodium chloride, and with sodium acetate as a buffer that was used to titrate the solution to pH 4.0. A drop of this solution was placed in one of two hemispherical depressions on an otherwise flat glass microscope slide; a drop of an aqueous solution of sodium chloride in greater concentration (to serve as a precipitating solution) was placed in the other depression. Then a second, flat glass microscope slide was placed on top of the first slide, along with spacers to maintain a gap of 30 μm.

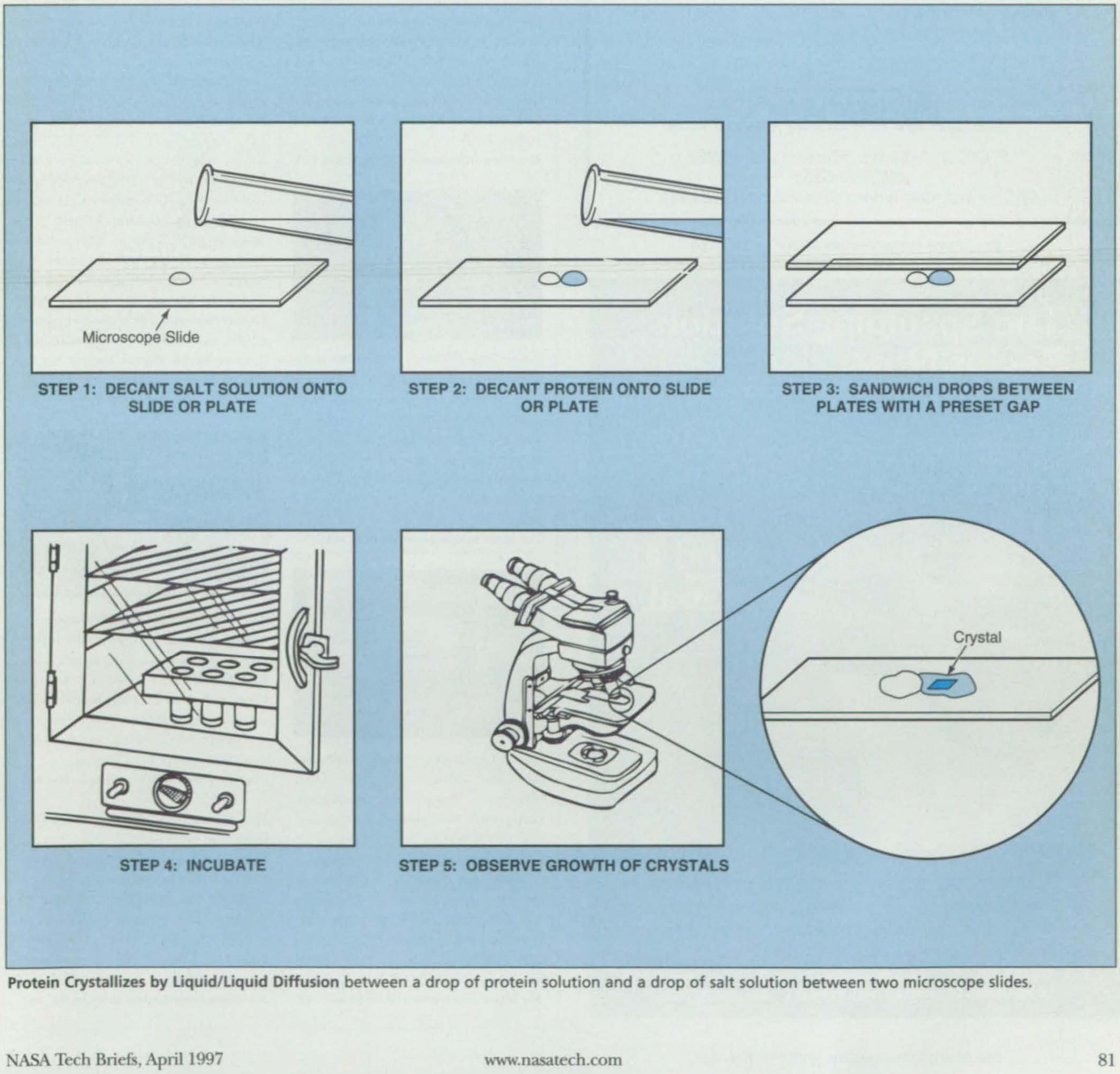
By capillary action, both solutions were drawn from the depressions and spread across the plates in the gap. Eventually, the two solutions met, forming a nearly one-dimensional contact front. At this front, protein crystals grew by what amounted to an approximately two-dimensional version of the established liquid/liquid-diffusion method. The lysozyme crystals that were formed along the front were nearly two-dimensional.

One of the advantages of the small-gap, parallel-plate configuration is that it inhibits the undesired mixing of the two solutions that occurs in the older three-dimensional version of the liquid/liquid-diffusion method. Another advantage of this configuration is that it is well-suited for optical observations and measurements of rates of growth. Yet another advantage is that the thickness of the crystalline protein wafer can be chosen to produce desired effects; for example, in some cases, crystals of higher quality can be obtained by making the wafers thinner.

Because of the predominance of capillarity and liquid/liquid diffusion in this method, gravitation and bulk diffusion exert little or no discernable effect on the crystallization process and thus their adverse effects on the quality of crystals are eliminated. Still another advantage of the present approach is that it provides an additional degree of freedom for optimizing crystallization conditions; for example, the parallel plates can be coated with films that repel or are preferentially wetted by selected constituents of protein solutions.

This work was done by David A. Noever of **Marshall Space Flight Center.** *For further information,* ***write in 11*** *on the TSP Request Card.*

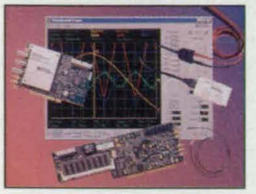
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31048.



Protein Crystallizes by Liquid/Liquid Diffusion between a drop of protein solution and a drop of salt solution between two microscope slides.

New on the Market

Product of the Month



National Instruments, Austin, TX, has introduced the DAQ Instruments PCI, ISA, and PCMCIA **instrumentation computer interfaces**. The DAQScope™, DAQMeter™, and DAQArb™ are compatible with Windows NT/95/3.1 and provide features comparable to standalone oscilloscopes, digital multimeters, and waveform generators, respectively. They include the VirtualBench™ Scope, VirtualBench-DMM, and VirtualBench-Arb virtual instruments, which work with application software packages such as LabVIEW®. The interfaces allow users to build instruments with Internet connectivity that can send E-mail and interface to Microsoft Word and Excel. Instrument drivers are available for use with C/C++ and Visual Basic. DAQScopes are priced from $995; DAQMeter from $695; and DAQArb from $2,995.

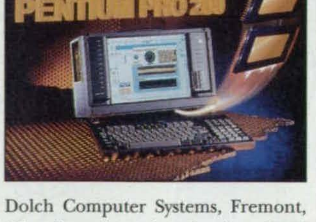
For More Information Write In No. 730

Modgraph, Woburn, MA, has introduced **industrial color monitors** in 15", 17", and 20" sizes, with filtered positive-pressure fan-cooling, sheet-metal construction. Available in panel-mount or rack-mount configurations with a choice of resistive, capacitive, or SAW integrated touch-screens, the displays are auto-scanning with universal power supplies and resolutions from 640 x 480 to 1600 x 1280.

For More Information Write In No. 731

Gaska Tape, Elkhart, IN, offers **polymeric foam tape** that resists temperature extremes, abrasive chemical environments, and moisture. Compatible with most plastics and synthetic plastic products, the tape is available with skin on two sides and with single- or double-sided, water- or solvent-based adhesives.

For More Information Write In No. 732



Dolch Computer Systems, Fremont, CA, has introduced the Dual MegaPAC™ Pro portable **instrumentation and test platform** equipped with two 200-MHz Pentium Pro CPUs for testing and data acquisition. It provides multi-tasking/multi-threading power to users requiring multiple add-in card slots and drive bays. The system accommodates a five-drive, 45-Gb RAID and/or up to eight ISA/PCI expansion cards.

For More Information Write In No. 733

A family of MIL-STD 1750A and 1750B **microprocessor** cores from CPU Technology, Pleasanton, CA, offer performances ranges from 5 DAIS MIPS to 50 DAIS MIPS for processor upgrades or replacement. They include an integrated Memory Management Unit (MMU) and can be configured to match timing and errata of existing parts.

For More Information Write In No. 734

Symmetric Research, Kirkland, WA, has introduced the DSPA64/DSPHLF DSP-based 64-channel **A/D data acquisition/processing boards**. Features include 1 Mb of DSP memory buffering, 16 bit A/D converter, 64-input channel multiplexer array, and 138 kHz aggregate sampling rate. Connected by a 16-conductor ribbon cable, the DSPA64 communicates data in serial digital format to the DSPHLF card installed in the PC.

For More Information Write In No. 736

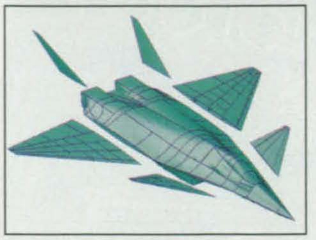
The GM Series **gas detection and monitoring systems** from Keithley Instruments, Cleveland, OH, detect combustible and toxic gases in concentrations as low as 10 ppb. Fixed system diagnostics monitor sensors, pumps, and controllers continuously and warn of system/component failure.

For More Information Write In No. 735

PFA **tubing, tube fittings, and valves** from the SWAGELOK® Companies, Solon, OH, offer corrosion resistance to a variety of system media. Tubing is available in standard and high-purity grades. Tube fittings include male connectors and elbows, unions, tees, caps, and plugs. Plug valves provide pressure rating of 4.1 bar at 21°C.

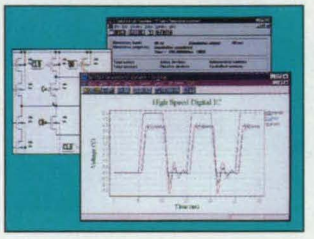
For More Information Write In No. 737

New on Disk



MSC/SuperModel **aerospace structure assembly software** from The MacNeal-Schwendler Corp., Los Angeles, CA, enables automatic assembly of airframe, launch vehicle, satellite, and engine models. It assembles submodels into a complete supermodel, and automates management of the component and assembly models.

For More Information Write In No. 700



Tanner Research, Pasadena, CA, has announced T-Spice Pro Version 4.0 **circuit simulation software** for Windows 95 and NT for analog and mixed-signal IC applications. Features include the W-Edit Waveform Viewer that allows the user to view simulation results as they are generated; expression plotting; a table-based simulator; and waveform smoothing. Pricing starts at $4,495.

For More Information Write In No. 701

AGX Corp., Metersoft Division, Culver City, CA, offers Metersoft for Windows version 3.0 **process/industrial metering software** for use with multiple meters, controllers, counters, and other measuring devices with RS232C or RS485 serial interface for PC connection. Applications include temperature, pressure, and flow monitoring/logging and control. Configuration, display, creation of virtual meters, and data logging functions are provided. A four channel DOS version costs $195; 4-, 8-, 16-, and 32-channel Windows versions cost $295, $395, $695, and $895, respectively.

For More Information Write In No. 714

Stat-Ease Corp., Minneapolis, MN, has released DESIGN-EXPERT® 5 **statistical design of experiments software** for Windows, which enables users to optimize products, processes, and systems. It offers a numerical optimization function that finds maximum desirability for dozens of responses simultaneously, real-time rotatable 3D plots for visualizing response surfaces, and interactive 2D graphics that allow users to explore plot contours. The cost is $995.

For More Information Write In No. 704

SolidWorks 97 3D **mechanical design software** from SolidWorks Corp., Concord, MA, features more than 175 custom-driven enhancements, including assembly and part modelings, sheet metal design, more than 65 new drafting and detailing capabilities, and Internet extensions. The Windows/NT program also features multi-thickness shelling, parting line drafts, and enhanced import/export functions. It costs $3,995.

For More Information Write In No. 705

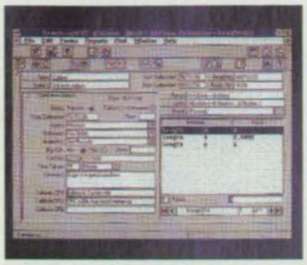
Version 6.2 of STRIM for Styling **industrial design software** from Matra Datavision, Andover, MA, creates surfaces of any number of sides within multiple boundaries. The software offers real-time quality control, dynamic reflection, dynamic scanning plane, and on- and off-line curvature map display. Other features include light reflection simulation, advanced sweeping functions, and direct sketching on scanned images.

For More Information Write In No. 703

SPSS, Chicago, IL, offers Neural Connection™ 2.0 **neural network computing software** for Windows 3.1 or later. It features a Bayesian network; model parameters and weights that allow users to document results; and 17 data management, modeling, forecasting, and presentation tools. The cost is $995.

For More Information Write In No. 702

New on Disk



Search-Light™ **gage calibration and management software** from Quality Measurement Systems, Macedon, NY, enables gage location, inventory, usage, and calibration history. The Windows program is available in two versions: System SL for 1 to 1,000 gages; and System SLX for more than 1,000 gages. The software tracks information needed for ISO 9000 compliance.

For More Information Write In No. 709

Larson•Davis Laboratories, Provo, UT, offers RTA Technologies' ENM Version 3.06 **environmental noise prediction software**, which calculates the effects of distance, barriers, ground effects, wind, and temperature gradients on noise levels. The Windows 3.1/95 program features four data-entry and visualization modules, up to 1,000 sources and multiple receivers, auto batching, and optional programs for special algorithms.

For More Information Write In No. 710

Emultek, Herndon, VA, has announced Rapid 3.5 **embedded systems simulation software**, which enables the creation of fully functional prototypes and simulations of embedded products and other interactive systems. Enhancements include User Defined Objects (UDOs) reusable building blocks for creating applications, and User Defined Functions (UDFs), clusters of activities and conditions grouped together to serve a specific function, and which can be combined with UDOs to create customized working models. The Windows 3.x/95/NT program costs $6,000.

For More Information Write In No. 711

STONE*rule*® ATMCS **composite tooling design software** from Prescient Technologies, Boston, MA, creates autoclave tooling substructures within native CAD environments for automated manufacture of composite parts. It generates four-view drawings and bill of material data, calculates tool base planes, and incorporates company-configurable design considerations including tool dimensions and CAD layering standards. The program operates within CATIA on UNIX workstations.

For More Information Write In No. 706

EPLAN/Wiechers & Partner, Brookfield, WI, has announced EPLAN 21® **control system design software**, which includes features for automating project tasks such as wire, device, and page numbering; cross referencing of devices and potentials; and generating system documentation. The Windows-compatible CAE program is a 32-bit, object-oriented package.

For More Information Write In No. 712

ESPRIT/X version 9.1 **CAM software** from DP Technology, Camarillo, CA, enables 3D machining, advanced milling, and multiple-axis turning operations. The program runs on Windows NT, and HP and Sun platforms running under UNIX. It includes simultaneous 5-axis machining capabilities for multi-surface machining and Z-level machining capabilities for high-speed milling.

For More Information Write In No. 713

Parametric Technology Corp., Waltham, MA, has announced Release 1.1 of PT/Products, a suite of **design and manufacturing software** that is compatible with Pro/ENGINEER products for Windows NT and 95. Included are PT/Modeler™ 3D solid modeling system, PT/ImporTools™ for diagnosing and repairing imported surface data, PT/Render™, PT/Library™ with more than 34,500 fasteners, PT/Mill™ and PT/Turn™ parts-building tools, and the PT/Developer's Toolkit™.

For More Information Write In No. 707

New Literature

A 16-page catalog of **miniature pneumatics** is available from CompAir Pneumatics, Kittery, ME. Featured are 2-, 3-, and 4-way miniature valves, light-touch pushbuttons, pneumatic timers, two-hand anti-tie-down, pressure switches, pulse generators, and pnuematic logic.

For More Information Write In No. 720

The *ProScan* line of programmable, motorized **microscope stages** is highlighted in a brochure from Prior Scientific, Rockland, MA. These stages are compatible with virtually all new and existing inverted and upright microscopy systems.

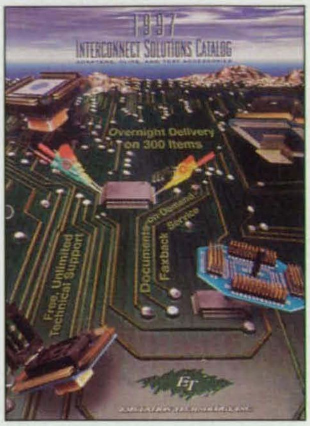
For More Information Write In No. 721

A four-page brochure from New England Electropolishing Co., Fall River, MA, features **electropolished stainless steel parts**, and describes how the electropolishing process removes burrs and improves the surface finish of parts without buffing or tumbling.

For More Information Write In No. 722

E.I.L. Instruments, Hunt Valley, MD, has released the Test & Measurement Handbook & Buyer's Guide, Vol. 9, featuring more than 450 pages of **test and measurement equipment**. Included are electronic test equipment, power measurement equipment, calibrators, testers, programmers, and telecommunications test equipment.

For More Information Write In No. 723



Emulation Technology, Santa Clara, CA, has released a 216-page catalog of **interconnect adapters and accessories**. Included are emulator tools, logic analyzer/scope adapters, programming adapters, production/test adapters, debugging accessories, prototyping adapters, field-configurable adapters, and custom adapters.

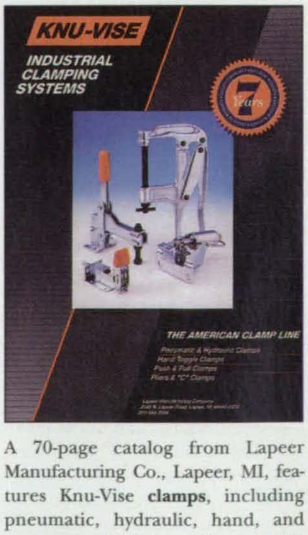
For More Information Write In No. 724

A 32-page catalog of **electronic switches** from SSAC, Baldwinsville, NY, features time delay relays, encapsulated timing modules, universal timers, alternating relays, three-phase voltage monitors, current sensors, liquid level controls, flashers, tower and obstruction lighting controls, and accessories.

For More Information Write In No. 725

Voltek, Division of Sekisui America Corp., Lawrence, MA, offers a brochure describing **closed-cell polyolefin foam**. Data is provded for the Volara®, Volextra®, and Minicel® product groups.

For More Information Write In No. 726



A 70-page catalog from Lapeer Manufacturing Co., Lapeer, MI, features Knu-Vise **clamps**, including pneumatic, hydraulic, hand, and push and pull clamps; pliers and "C" clamps; and accessories. All parts are heat-treated.

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