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Transferring Technology to American Industry and Government

August 1989
Volume 13 Number 8

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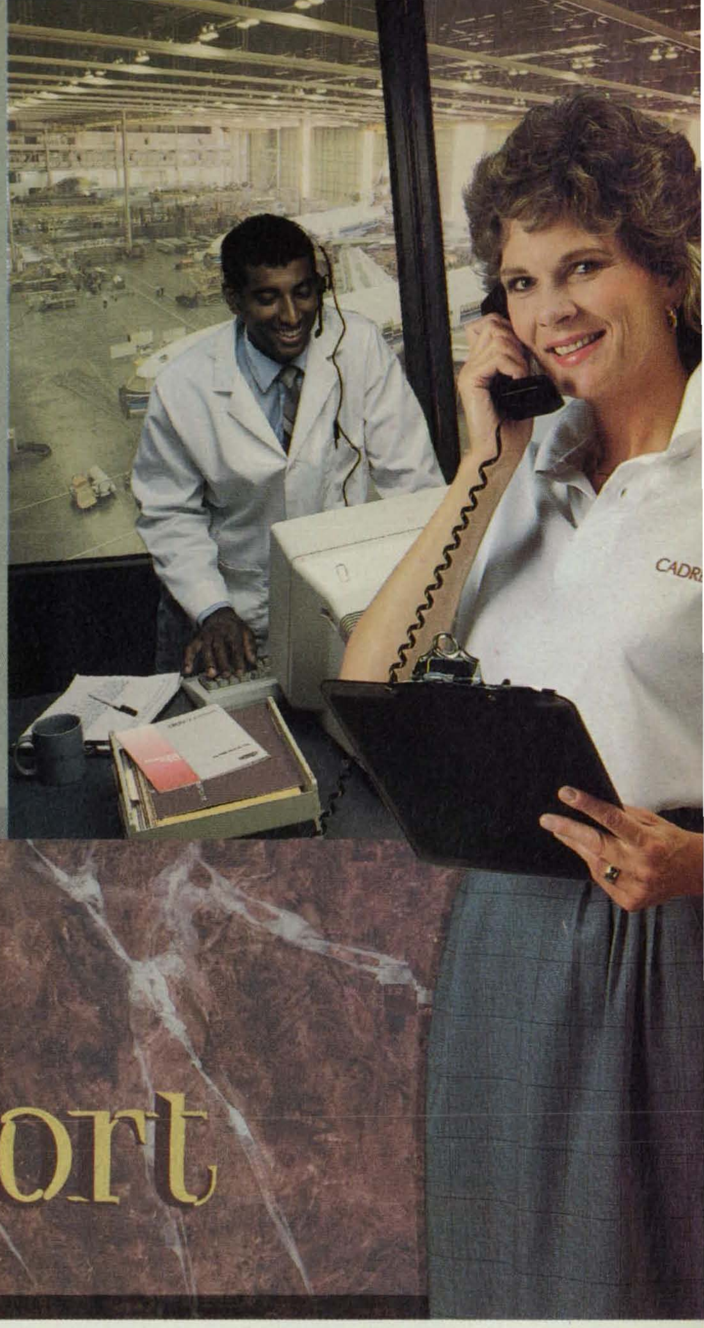

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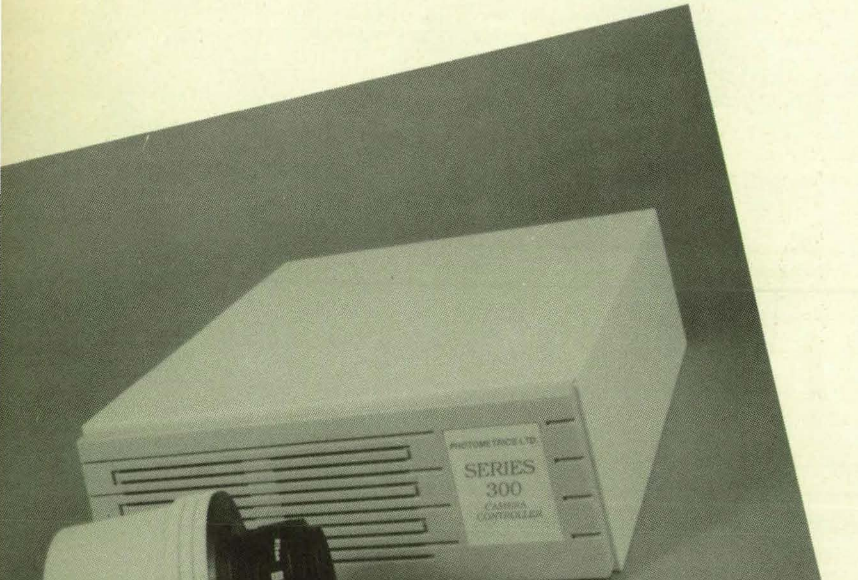

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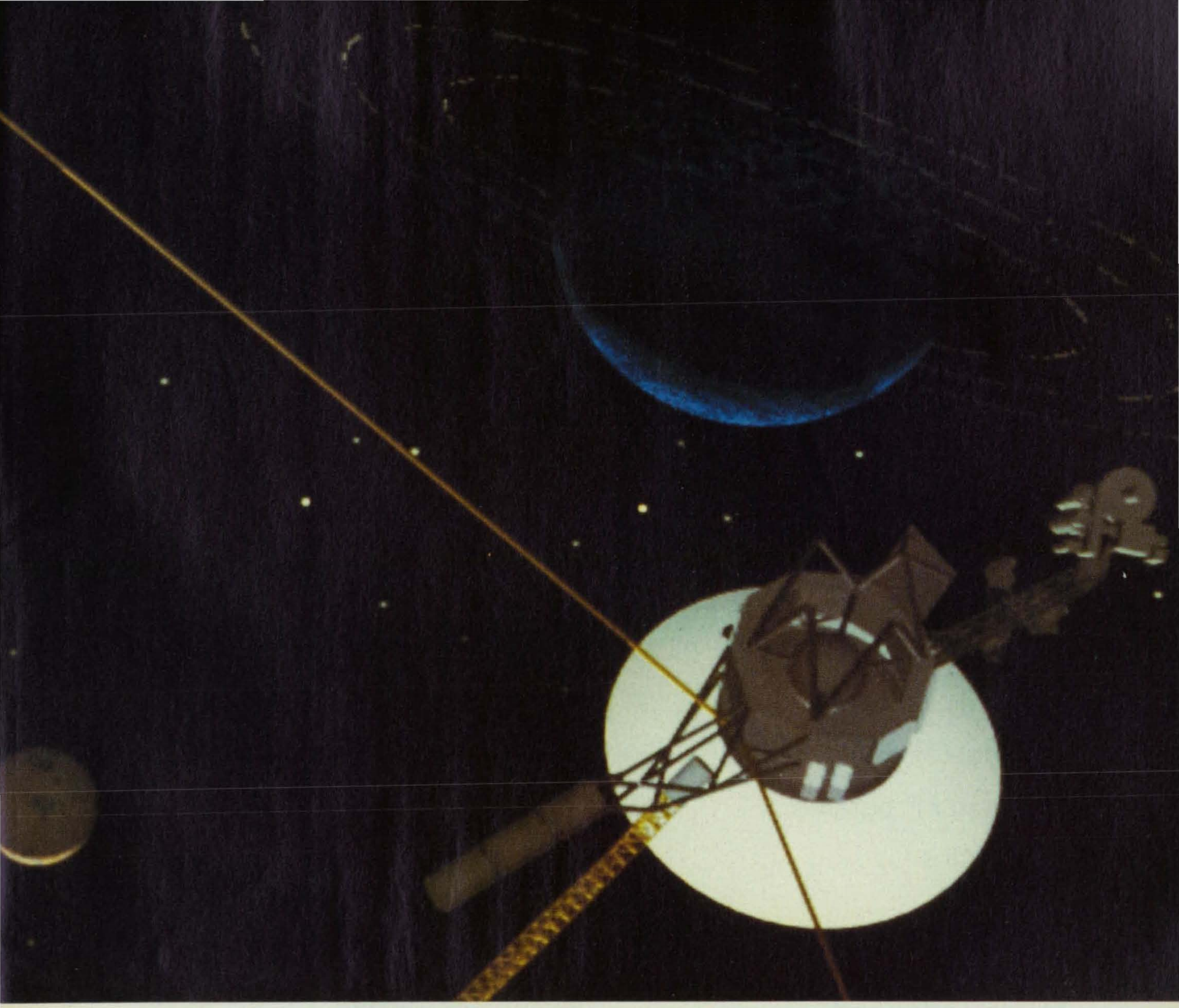

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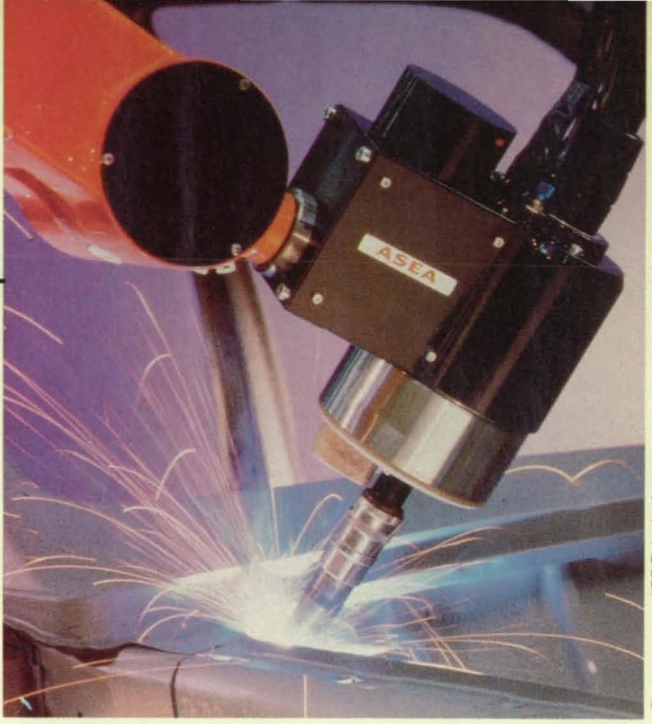

Photo courtesy ABB Robotics Inc.

A Wisconsin company has developed a laser-based system that defines the position, shape, and gap of a welding seam in three dimensions. Turn to the special section on Wisconsin science and technology beginning on page 59.

SPECIAL FEATURES

TECHNICAL SECTION

DEPARTMENTS

On The Cover: A new NASA-funded invention will enable computer users to control screen images with a wave of the hand. See page 18. *(Photo courtesy Sensor Frame Corp.)*

Photo courtesy Sensor Frame Corp.

Will new Technology make the mouse an endangered species? Turn to page 18.

For Your Convenience
We have combined the Subscription/Technical Support Package Form and the Reader Action Card into a single, easy-to-use form (page 91).

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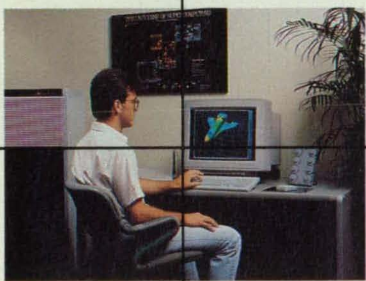

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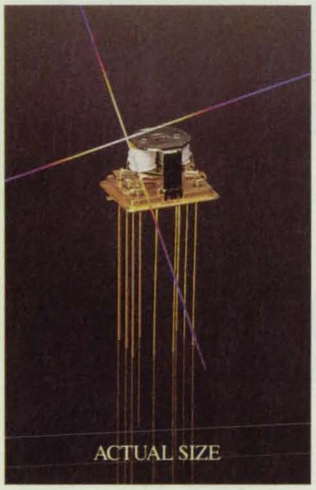

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 14). NASA's patent-licensing program to encourage commercial development is described on page 14.

Optical Processing With Photorefractive Semiconductors

An experimental phase-conjugate four-wave-mixing apparatus has been used to demonstrate the capabilities of GaAs for optical processing of information. With modifications, the apparatus performs any of three basic image-processing functions: transfer to a different light beam, enhancement of edges, and autocorrelation. (See 37).

Making MgO/SiO_2 Glasses by the Sol-Gel Process

Silicon dioxide glasses containing as much as 15 mole percent magnesium oxide have been prepared by a sol-gel process. Such glasses cannot be made by conventional melting because the ingredients are immiscible liquids. (See 50).

Monolithic Microwave Switching Matrix

A gallium arsenide integrated-circuit chip switches any of three microwave input signals to any of three output ports. Potential applications include switching and routing vast amounts of data between computers at extremely high speed. (See 22).

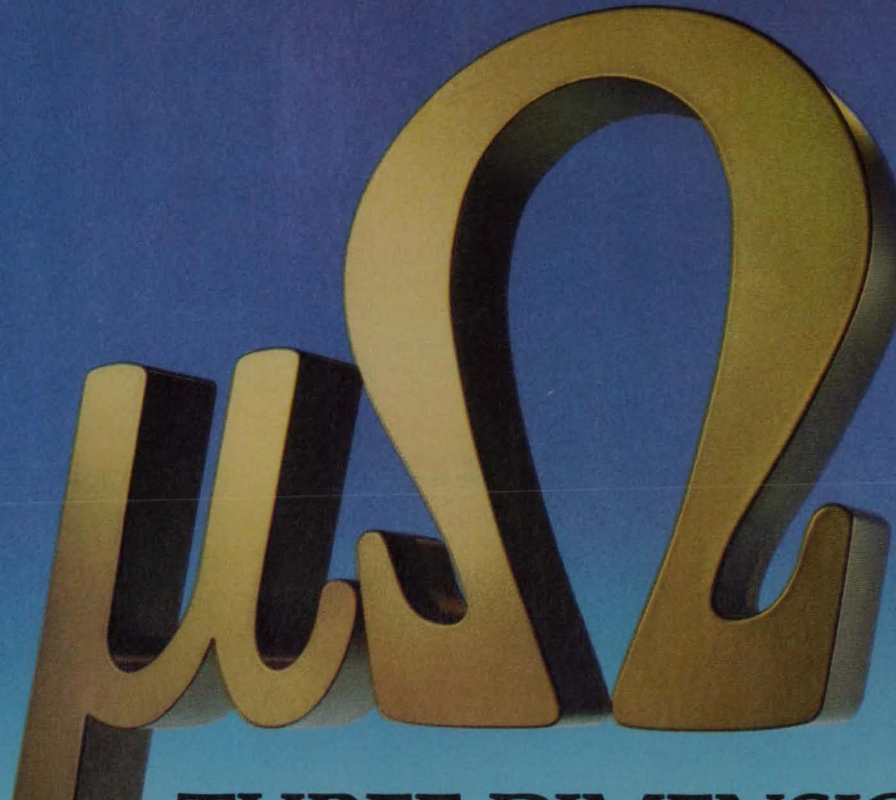
Silver Ink for Jet Printing

A metallo-organic ink containing silver is applied to printed-circuit boards and pyrolized in air to form electrically conductive patterns. The ink contains no particles of silver and can be applied to the boards by ink-jet printing heads. (See page 50).

Forging Long Shafts on Disks

A proposed isothermal-forging apparatus could produce long shafts integral with disks. In the proposed equipment, which is based on the modification of conventional isothermal-forging equipment, the required stroke could be cut by more than half. (See 79).

This symbol appears next to technical briefs which describe inventions having potential commercial applications as new products. The process for developing a product from a NASA invention is described at the top of this page.



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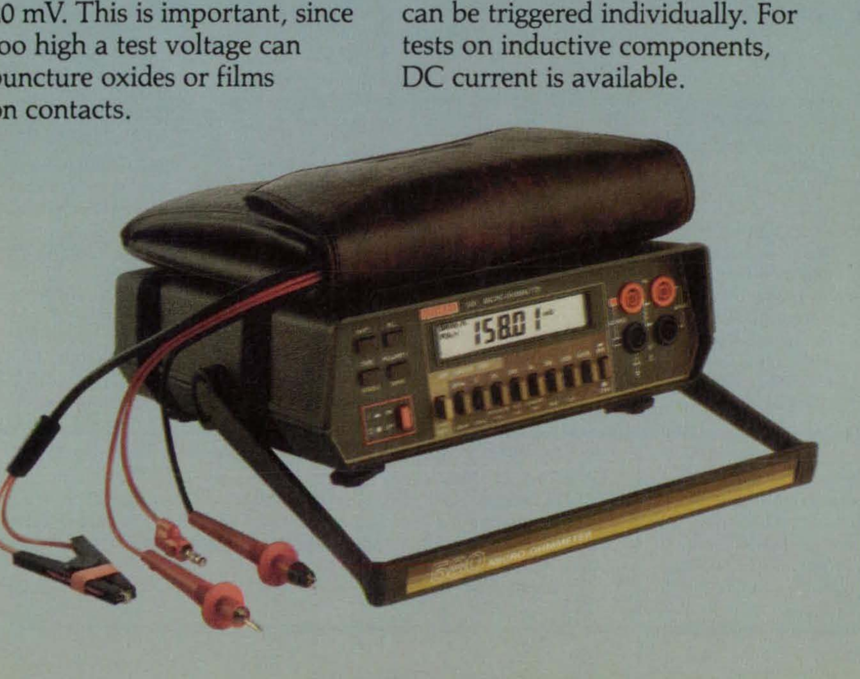
For a brochure or demonstration of the new Model 580 Micro-ohmmeter, call your local Keithley representative or the Product Information Center at the address below.



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We've outlined below NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network.

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How You Can Access Technology Transfer Services At NASA Field Centers: **Technology Utilization Officers & Patent Counsels**—Each NASA Field Center has a Technology Utilization Officer (TUO) and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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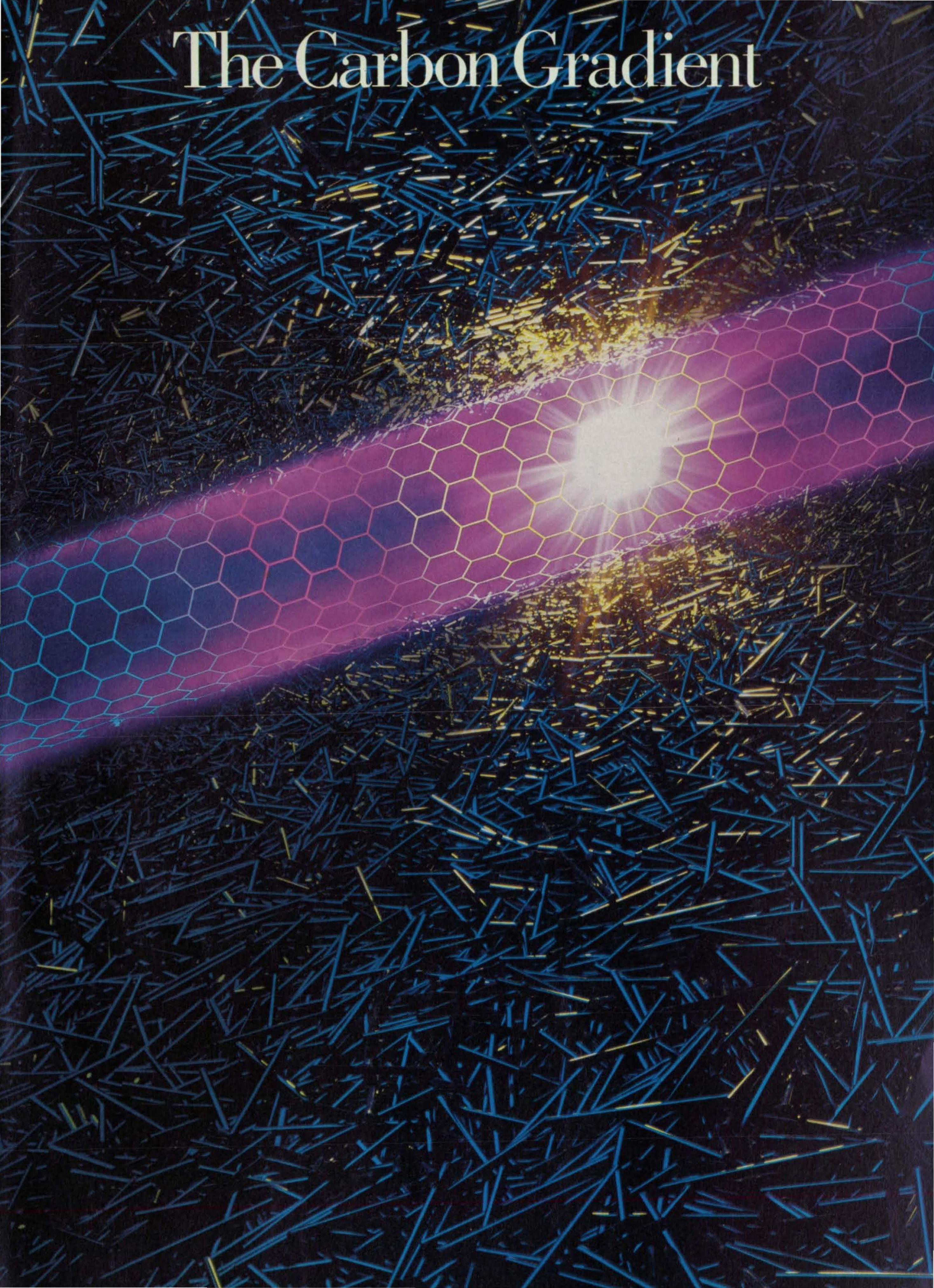
The Carbon Gradient



The Carbon Gradient

Hollow carbon filaments catalytically produced by submicron-size iron particles can be the template for larger carbon fibers used in composite structural materials. A scientist at the General Motors Research Laboratories has identified how these filaments grow and why they take their characteristic form.

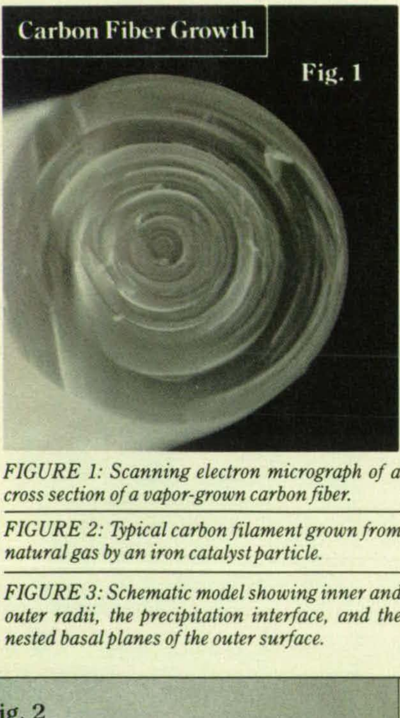
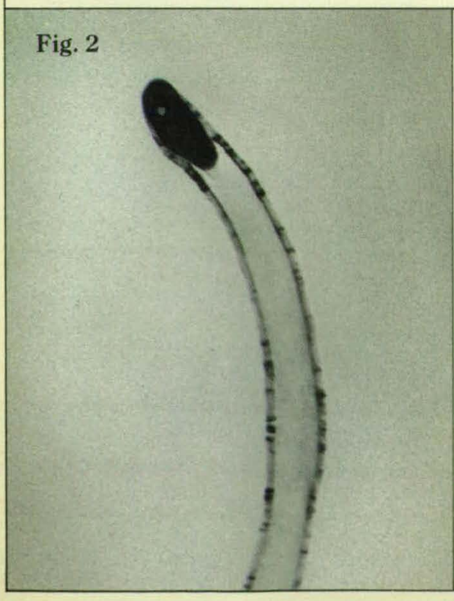
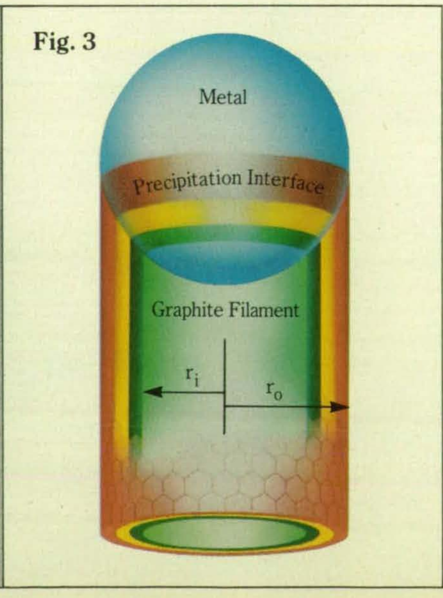


FIGURE 1: Scanning electron micrograph of a cross section of a vapor-grown carbon fiber.

FIGURE 2: Typical carbon filament grown from natural gas by an iron catalyst particle.

FIGURE 3: Schematic model showing inner and outer radii, the precipitation interface, and the nested basal planes of the outer surface.





Dr. Gary Tibbetts was measuring the diffusion rate of carbon in iron when his carefully planned experiment took an unexpected turn. Dr. Tibbetts, a physicist at the General Motors Research Laboratories, had been introducing carbon to the inside surface of a hot stainless steel tube while extracting carbon from the outer surface.

At the end of one particular trial, he found the inside surface covered with a mass of black "whiskers." His initial investigations verified that the fibers were made of carbon and that they had characteristics typical of the crystal structure of graphite. But the question of how they formed was not so easily answered. The search for an answer would change the course of his investigation and dominate his research for the next ten years.

The fibers that surprised Dr. Tibbetts were made up of concentric layers primarily composed of basal (0001) plane graphite, resembling in cross section the annular rings of a tree (Figure 1). Research showed that they were formed by vapor deposition of carbon on a hollow central filament. The central filament itself was grown by catalytic action on a small metal particle (Figure 2).

These long, slender, uniform filaments had been widely observed since the availability of the electron microscope. Still, no valid explanation had been advanced to account for their hollow structure. Many scientists thought that surface diffusion of carbon-containing molecules around the catalytic particle caused the hollow core.

Instead, Gary Tibbetts proposed a model in which carbon atoms from decomposing hydrocarbons diffuse through the bulk of the catalytic particle and precipitate as graphite in the growing filament. The diffusion process is driven by the carbon gradient–the difference between carbon concentrations at the adsorbing surface of the particle and at its opposite, precipitating surface (Figure 3).

The exterior surfaces of these carbon cylinders expose the basal plane of graphite because the (0001) plane has a surface free energy at 970°C of about 77 erg cm^{-2}, while a typical surface perpendicular to the basal plane has a surface energy in excess of 4000 erg cm^{-2}. The free energy required for filament growth, therefore, will be a minimum when the exterior surface is made up of basal planes–as observed in these filaments.

The entire filament, then, should consist of nested, rolled-up basal planes of graphite. Bending these planes into cylinders, however, requires that extra elastic energy be provided during the precipitation process. The core is left hollow because too much energy would be required to bend the planes near the axis into very small diameter tubes.

In describing the total energy necessary for filament formation, Dr. Tibbett's model takes into account the chemical potential change ($\Delta\mu_o$)when a carbon atom precipitates from the dissolved phase, as well as the energy required to form the surface, plus the energy needed to bend the basal planes into nested cylinders.

The change in chemical potential ($\Delta\mu$) driving the precipitation can be expressed as follows:

$$\Delta\mu = \Delta\mu_o - \frac{2\sigma\Omega}{r_o - r_i} - \frac{E a^2 \Omega}{12(r_o^2 - r_i^2)} \ln(r_o/r_i)$$

where σ is the energy required to form a unit area of (0001) graphite; Ω is the volume of a carbon atom in graphite; r_o and r_i are the outside and inside radii of the filament, respectively; E is the filament modulus; and a is the interplanar spacing.

A filament catalyzed by a particle of radius r_o will adjust its r_i to give the largest $\Delta\mu$–in fact, r_i may be directly calculated by maximizing $\Delta\mu$. Doing so yields results that compare nicely with experimental values.

Understanding the growth of the hollow core of the filaments was one key to producing them in abundance. "From there," says Gary Tibbetts, "it is a simple step to thicken the filament into a macroscopic fiber by vapor deposition of carbon on the exterior surface. The deposited carbon has a high degree of orientation parallel to the tube axis, giving the fiber exceptional stiffness.

"Fibers of this type should be excellent for making chopped-fiber composites using plastic, ceramic, metal, or cement matrices. GM's Delco Products Division is already building a pilot plant to develop a low-cost production process that would permit the use of vapor-grown fibers in high-volume applications."

THE MAN BEHIND THE WORK

Dr. Gary G. Tibbetts is a Senior Staff Research Scientist in the Physics Department of the General Motors Research Laboratories.

Gary received his undergraduate degree in physics from the California Institute of Technology. He holds both an M. S. and a Ph. D. in the same discipline from the University of Illinois.

Dr. Tibbetts joined General Motors after two years of postdoctoral work as Guest Scientist at the Technical University of Munich. Since coming to the Labs in 1969, Gary has pursued interests ranging from carbon filaments, to surface physics, to chemical vapor deposition. He has published almost forty papers on the results of his research.

Gary is a member of the American Physical Society, the American Carbon Society, and the Materials Research Society. In 1988, he was a GM Campbell Award Winner. Gary lives in Birmingham, Michigan, with his wife and their three daughters.

Mission Accomplished

Controlling Computers

Photo courtesy Sensor Frame Corp.

A new computer interface uses optical sensors — each consisting of a rectangular image sensor chip mounted behind a lens assembly — to track finger movements in real time.

There's a fast and efficient new way to communicate with your computer: Just set aside the keyboard and let your fingers do the talking.

An emerging technology called the Sensor Frame enables the use of hand gestures, such as waving and pointing, to control on-screen action. Users can reach into the screen and directly manipulate graphic images as if they were real objects.

"It's a more natural, intuitive way to interact with computers," said Paul McAvinney, the Sensor Frame's inventor. "If you let people handle spatial things, you're taking advantage of something they knew long before they heard the word computer."

McAvinney's patented device looks like a deep picture frame mounted over the front of a video monitor. Optical sensors embedded in the corners of the frame detect hand movements and reproduce them on the screen. Fingers placed in the frame block a continuous infrared light source and cast shadows onto the sensor array. An onboard 68000-based controller then triangulates the positions and sizes of the fingers based on the sensor data.

The device can concurrently track the independent movements of the fingers in real time, which permits, for example, the simultaneous translation, rotation, and scaling of an object with a single gesture. The ability to combine these actions into one fluid motion distinguishes the Sensor Frame from touch screens, mice, and other input methods that are limited to pointing, McAvinney said.

The Carnegie-Mellon University researcher was inspired to build a computer system that would respond to hand signals because he "always wanted to conduct an orchestra." He devised a scheme to connect multiple synthesizers to a computer, but needed a way to control the various pieces. "I figured I could project an orchestra layout onto the computer screen," he recalled, "and then just wave at a section to tell it to play faster or louder. That required my developing a multiple-finger gesture sensor."

McAvinney began experimenting with various image sensors in the early 1980s and eventually developed an optical gesture-sensing system that could be applied to control many different computer tasks. The technology interested NASA scientists, who saw its potential for spacecraft operation and robot manipulation. In 1986, the Space Agency provided partial funding for McAvinney's work on an optical device capable of tracking up to three fingers of one hand in a plane. This version of the Sensor Frame treats each finger movement as a separate gesture, limiting recognition to simple gestures such as toggling two switches simultaneously.

Last spring, NASA awarded McAvinney's Sensor Frame Corporation $500,000 to build an advanced system that will track fingertips in three dimensions and enable such complex gestures as grasping and rotating a knob. The 3D Sensor Frame may be used as an interface for soft or virtual control panels on board Space Station Freedom, according to Linda Orr, Manager of the Graphics Analysis Facility at NASA's Johnson Space Center. "An astronaut could control a number of onboard systems from a single display terminal," Orr said. "He'd just call up the appropriate screen and manipulate a virtual dial to make adjustments." One Sensor Frame could replace numerous instrumentation panels, saving precious space on the orbiting facility.

Training Comes First

McAvinney currently has Sensor Frame test units at the Software Engineering Institute and Carnegie Mellon University's Computer Music Laboratory, both in Pittsburgh. A production version of the two-dimensional tracking system should be

With A Wave Of The Hand

ready by early 1990, with the 3D model to follow about a year later. The first model will cost about $8000.

Software exists for interfacing to various versions of the UNIX operating system; OS/2 and MS-DOS interfaces may be available in a few years. "We're going after the high-end workstation market first," said Eric Colburn, Engineering Manager for Sensor Frame Corp.

Sensor Frame's main competition will come from the DataGlove developed by VPL Research of Redwood City, CA. The sensor-lined glove translates hand and finger movements into electrical signals that are carried by thin cables to a computer. An image of the glove follows the hand's movement on the screen, allowing the glove wearer to virtually touch and hold graphic objects.

While the Sensor Frame restricts hand movements to the small area surrounding the screen, the DataGlove wearer is free to move about the room. Sensor Frame is more precise in its measurements, however,

Inventor Paul McAvinney plays his VideoHarp, a computerized musical instrument that duplicates the sounds of an entire orchestra.

Photo courtesy Sensor Frame Corp.

and eliminates the constraints involved with wearing a glove. "If you want to use a keyboard, you can just take your hand away from the screen and type," explained Ms. Orr. "You don't have to keep donning and doffing a glove."

Early applications of the Sensor Frame are likely to be in the area of training and simulation. Due to the high cost and risk of training personnel on real equipment, many groups (especially the military) are turning to computer-based systems that simulate equipment with software and display images of controls and instruments on banks of video monitors. One major drawback is that existing input devices do not let trainees use the virtual system in the same way they would the real McCoy. "It's just not very realistic," commented Colburn, "and that hampers the training effectiveness." On a conventional system equipped with a touch screen, the trainee can only point at the displays with one finger. "He can't turn a knob or grab a lever," said the engineer. "But with a Sensor Frame, he can sit in a virtual cockpit, for example, and operate the controls essentially the same way he would during an actual flight."

New CAD Tool

When coupled with CAD software, the Sensor Frame will enable design engineers to "sculpt" new parts right on the screen — stretching, twisting, and squeezing graphic objects into an endless variety of shapes. "You could reach into the screen and grab a virtual tool, perhaps a drill or a wrench, and instantly modify a part's design," McAvinney said. Add on a voice recognition system and "you could just say the name of the tool you want and it would instantly appear on the screen."

The inventor hopes to one day combine the 3D tracking device with a stereolithography machine — which employs a laser to extrude parts from liquid plastic — to create a new type of CAD workstation he calls an "interactive fabricator." It would enable rapid production of prototypes. The designer would specify or modify an object's shape using spatial gestures and virtual tools. A host computer would then send instructions to the stereolithography device to fabricate a prototype, which may take only a few minutes, McAvinney said.

"If we can significantly shorten design time," he predicted, "designer productivity will increase and customization will be easier. Learning time for the designer will also be shorter if he can see immediate feedback on his ideas."

Interactive fabricators might come in handy on future space missions, he said. "If you had a fabricator aboard the spacecraft, you wouldn't need to lug as many spare parts into orbit. On a large space station or planetary outpost you could have bins of various raw materials to create replacement parts from. And if in the course of your research you found you needed a totally new type of tool or instrument, you could use the fabricator to design and extrude it right there in space. It wouldn't hold up your work."

A One-Man Orchestra

This year, Sensor Frame technology came full circle when McAvinney introduced a prototype musical instrument that emulates the sounds of an entire orchestra. Dubbed the VideoHarp, it is based on gesture-sensing techniques used in the Sensor Frame. The instrument has clear plastic sides and is rimmed with neon tubing. An optical sensor inside the harp measures the positions and sizes of the user's fingers as they slide across the glowing surface. The information is fed to a synthesizer, which produces music corresponding to the hand signals. Waving your hand in one direction will evoke violin strains, for instance, while pointing to another area will bring a horn section to life.

Though he has fulfilled his dream of conducting an orchestra, McAvinney is not satisfied. He next wants to build a VideoHarp the size of a concert stage. Dancers would move across the massive instrument, creating their own musical accompaniment, while melding man and machine in a way the Sensor Frame only hints at. □

Sensor Frame's main competition: VPL's DataGlove, shown here in use with NASA's Virtual Workstation.

Electronic Components and Circuits

Reflection Oscillators Containing Series-Resonant Crystals

Transistors operate beyond their normal rated frequencies.

Goddard Space Flight Center, Greenbelt, Maryland

A crystal-controlled transistor reflection oscillator is easily tunable and stable, consumes little power, and costs less than do other types of oscillators that operate at the same frequencies. This unusual combination of features is made possible by a design concept that includes operation of the transistor well beyond the 3-dB frequency of its current-versus-frequency curve. The concept takes advantage of newly available crystals that resonate at frequencies up to about 1 GHz.

The top of the figure shows a bipolar-transistor version of the oscillator. The emitter of transistor Q is connected with variable (tuning) capacitor C_1 and series-resonant crystal X. The emitter is also connected to ground through bias resistor R_1. The base is connected to the parallel combination of inductor L and capacitor C_3 through dc-blocking capacitor C_4 and is forward-biased with respect to the emitter by resistors R_3 and R_4. Impedance *Z* could be the 220-Ω resistor shown or any small impedance that enables the extraction of the output signal through coupling capacitor C_2. If *Z* is a tuned circuit, it is tuned to the frequency of the crystal.

The circuit shown at the bottom of the figure is approximately equivalent, at the frequencies of interest, to the circuit shown above and can be used to determine the conditions for oscillation. The analysis of this circuit shows that the input admittance at the base includes a negative conductance and a parallel capacitive susceptance reflected from C_1 and X on the emitter side. The conditions for oscillation (zero net conductance and zero net susceptance) are approximated by

$$\frac{1}{j\omega L} + j\omega C_3 + j\omega C_1(1+\omega_t R_x C_1)\ \frac{\omega^2}{\omega_t^2} = 0$$

from which

$$\frac{1}{\omega L} - \omega C_3 - \omega C_1\,(1+\omega_t R_x C_1) = 0$$

and $\quad Y_L - \omega^2 C_1/\omega_t = 0$

where ω = the angular frequency of oscillation; $\omega_t = 2\pi f_t$; R_x = the series resistance of the crystal at resonance; and Y_L = the admittance related to the total losses in the base circuit, including both the losses in inductor L and the losses in resistors R_3 and R_4.

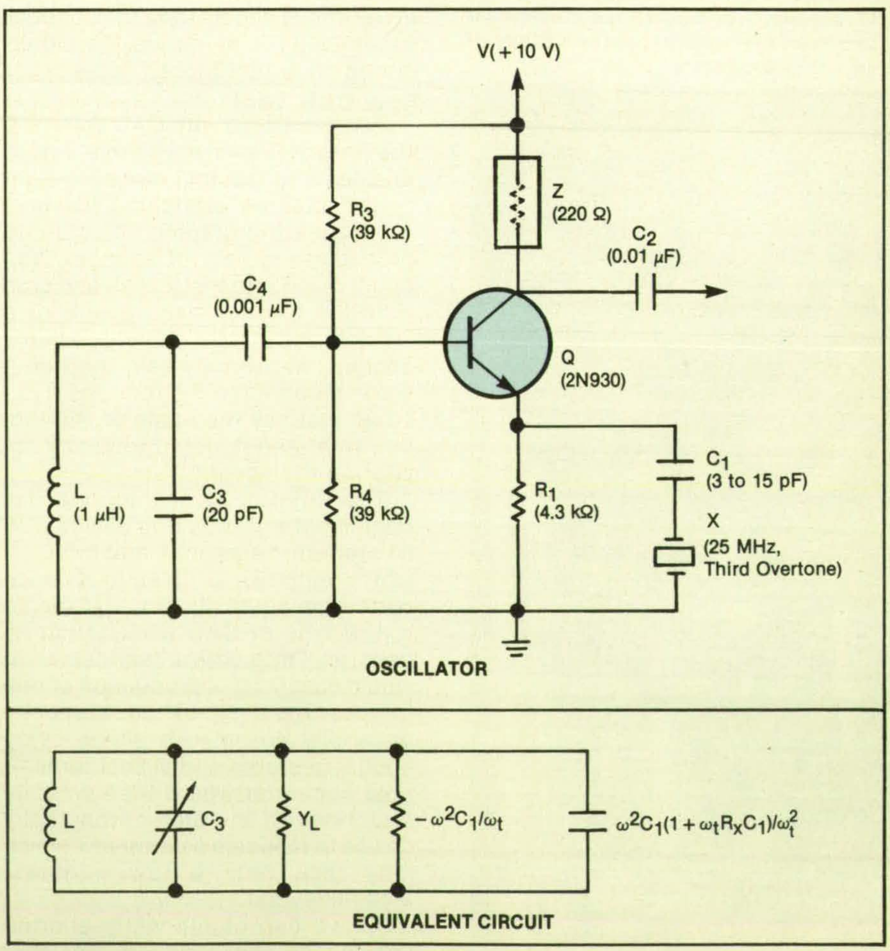
The second equation shows that the parallel combination of R_3 and R_4 must be selected to provide an amount of positive conductance that balances part of the negative conductance reflected from the emitter side at the frequency of oscillation. Alternatively, one can consider the oscillation to take place at the frequency for which this condition is satisfied. An approximate solution of the first equation is

$$\omega^2 = 1/L(C_3 + C_1/4)$$

This is useful in determining the approximate frequency of oscillation and the major elements that determine that frequency.

This work was done by Leonard E. Kleinberg of **Goddard Space Flight Center**. *For further information, Circle 123 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 *[see page 14].* *Refer to GSC-13173*



The **Crystal-Controlled Reflection Oscillator** (above) operates at a frequency far beyond the usual 3-dB rolloff frequency of the transistor. The components shown here are only representative. The equivalent circuit (below) is used to analyze the conditions of oscillation.

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Circle Reader Action No. 657

Multiplying Video Mixer

Transparent or opaque overlays can be put on background images.

NASA's Jet Propulsion Laboratory, Pasadena, California

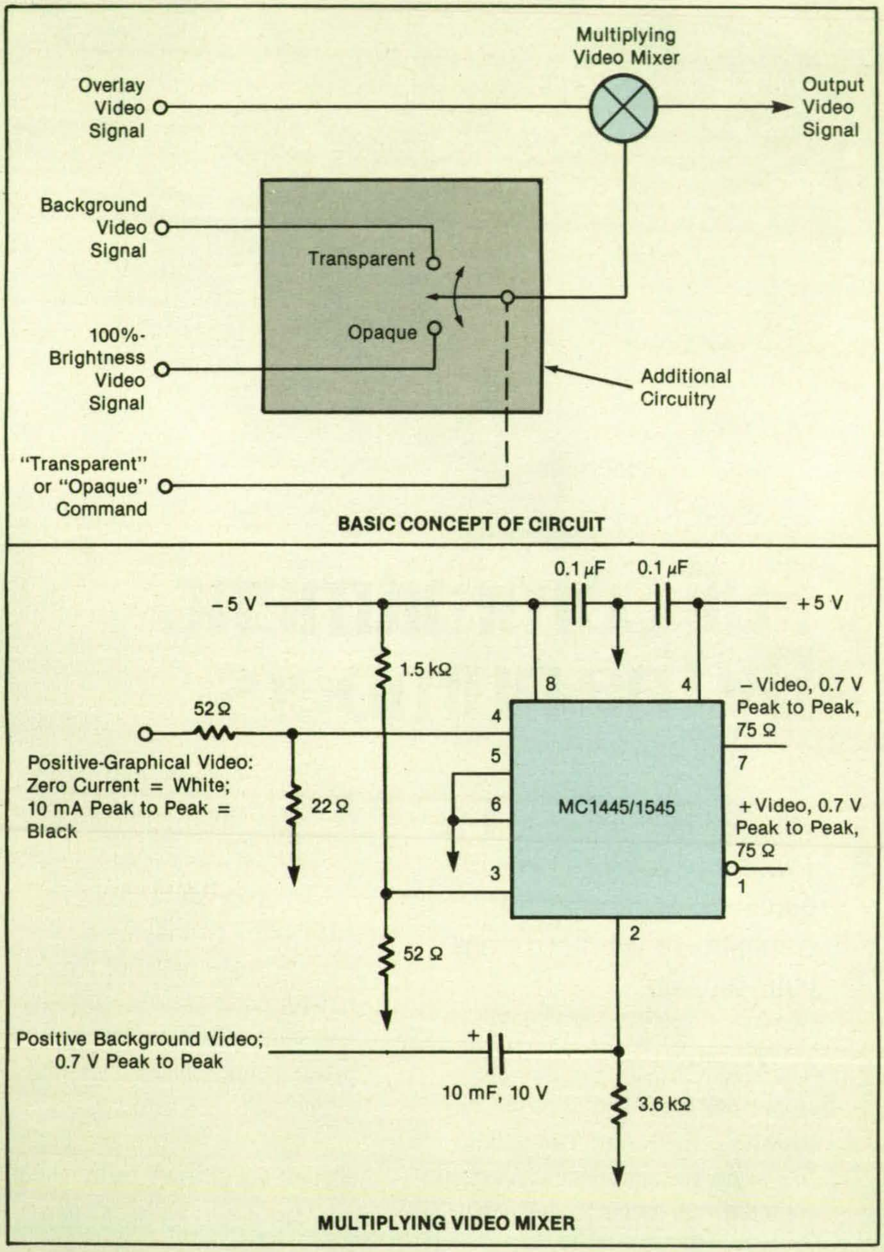
A video mixing circuit places a transparent overlay image on all or a portion of the normal image (denoted here as the "background" image) on a television screen. The overlay might be computer-generated graphics, text, or another image. If additional circuitry is included, the overlay can also be made opaque.

The circuit is a multiplying mixer. In a full-color television system, one such mixer would be needed for each of the three primary colors, and the multiplicity of mixers would provide great flexibility in the choice of contrasts, components of the overlay in different colors, intensities, and degrees of transparency or opacity.

The background video brightness signal is fed into one input terminal of the circuit, while the overlay brightness signal is fed into the other input terminal (see figure). The amplitude of the background brightness signal is thus modulated by the overlay brightness signal, resulting in a video image in which the background image appears as though viewed through the overlay.

The additional circuitry (not shown in detail) would provide a choice of transparent or opaque overlays. In the transparent mode, the mixer would function as described above. In the opaque mode, the additional circuitry would replace the background-image brightness signal with an auxiliary full-brightness signal in the overlay region. Thus, the overlay image would be a full-brightness image modulated by the overlay video signal and would contain no background image at all; that is, the overlay would appear opaque.

This work was done by Neil W. Heckt of Boeing Aerospace Co. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 129 on the TSP Request Card.*
NPO-17332



The **Multiplying Video Mixer**, combined with the additional circuitry, would place transparent or opaque overlay images on normal (background) video images.

Monolithic Microwave Switching Matrix

A packaged circuit chip switches with little crosstalk and can be stacked with others.

Lewis Research Center, Cleveland, Ohio

A gallium arsenide integrated-circuit chip switches any of three microwave input signals to any of three output ports. Measuring 4.9 mm on a side, the chip contains nine field-effect transistor (FET) crosspoint switches. It is housed in a custom-designed package (see figure) with standard connectors for easy integration into a system.

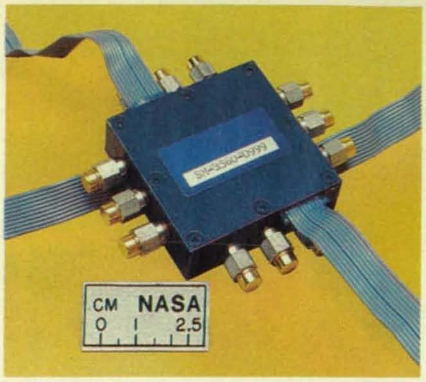
Potential applications include switching and routing vast amounts of data between computers at extremely high speed. On a communication satellite, the chip could switch microwave signals to and from Earth stations and other satellites.

The FET's on the chip are operated as passive switches and consume no static power and insignificant amounts of switching power. The chip and package provide about 60 dB of isolation between channels over the range of a signal frequencies from 3.5 to 6 GHz. Fixed-gain buffer amplifiers may be incorporated around the periphery

of the chip to ensure an insertion loss of 0 dB in all switching states.

The chip module can be cascaded with similar modules into large arrays that can handle as many as 100 inputs and 100 outputs. Such an array would consume only 10 W, occupy only 500 in.^{3} (8,200 cm^3), and weigh only 30 lb (14 kg). An equivalent 100-by-100 cross-point switch in hybrid technology would consume 1,000 W, have a volume of 12,000 in.^{3} (almost 200,000 cm^3), and weigh more than 500 lb (230 kg). Moreover, the hybrid switch would cost about 30 times as much as the modular integrated switch does.

This work was done by Gene Fujikawa of **Lewis Research Center** *and Daniel R. Ch'en and Wendell C. Petersen of Microwave Monolithics, Inc. For further information, Circle 56 on the TSP Request Card.*
LEW-14813



The **Packaged Monolithic Crossbar Switch** can route any of the three inputs on the left to any of the three outputs on the bottom (one of which is obscured by a ribbon cable from the controlling computer). The connectors at the top and right of the package can link the switch to other switching modules like this one.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Prediction of Critical Crack Sizes in Solar Cells

Cracks on edges are more critical than are those on the broad surfaces.

A report presents a theoretical analysis of cracking in Si and GaAs solar photovoltaic cells subjected to bending or twisting. This is an important topic because cells can fracture from the extension of preexisting flaws during the stress of testing or use. The approach and results of this study may be useful in the development of guidelines for the acceptance or rejection of slightly flawed cells during manufacture.

The propagation of cracks from flaws initially on the edge or on one of the broad surfaces of a circular wafer is analyzed from a fracture-mechanics point of view. Fracture mechanics defines a critical crack size for a given level of operating stress as the size below which an initial crack can withstand the first application of stress but beyond which the crack propagates rapidly to fracture. Repeated loading or time under load may cause a subcritical crack to grow to the critical size, whereupon the part suddenly fails.

The basic equations of fracture mechanics are used to derive an equation for the critical crack size in the opening-mode propagation of an edge or broad-surface crack in a wafer subjected to bending. (This is the predominant mode of failure observed in the field.) Similarly, an equation is derived for the critical size of an edge crack in the tearing-mode propagation of a wafer subjected to twisting. These critical sizes depend in part on the Young's moduli and critical-stress-intensity factors of the material (which are different in different crystalline orientations with respect to the cracks and stresses) and on the Poisson's ratio of the material.

Using the known properties of Si and GaAs, the equations were used to obtain plots of crack sizes in solar cells made of these materials as functions of the bend or twist radii, with the thicknesses of the cells as a parameter. The analysis was also extended to predict critical sizes for cracks in a Ge substrate coated with a thin film of GaAs.

The analysis leads to the following general conclusions:

- The cracks in a silicon wafer subjected to bending are more critical than in one subjected to twisting.
- An edge crack is more critical than is a surface crack. Thus, an edge can be finished to increase the strength of a wafer.
- For a given bending or twisting load, the allowable critical crack size in a thinner wafer is greater than that in a thicker wafer.
- The calculated allowable critical crack sizes of Si and Ge are nearly equal. The critical crack size in a GaAs wafer is approximately 3.5 times as small as that in an Si wafer under the same load. This suggests that GaAs wafers cannot be handled in the same manner as that of Si or Ge wafers.

This work was done by Chern P. Chen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analytical Determination of Critical Crack Size in Solar Cells," Circle 60 on the TSP Request Card.*
NPO-17637

Encapsulants and Corrosion in Photovoltaic Modules

Experiments and computer simulations give insights and point the way to further study.

A paper reports studies of the effects of moisture on photovoltaic modules, presenting data that may be useful in further quantitative studies of such phenomena. It gives measurements of sorption, Arrhenius activation-energy constants for bulk conduction, and bulk and surface conductivities of the encapsulants ethylene vinyl acetate (EVA) and polyvinyl butyral (PVB). It also gives surface conductivities of a borosilicate and a soda-lime glass and interface conductivities of the encapsulant/glass composites. The measured data were used in a computer simulation of two-dimensional conduction to analyze the ionic-conduction characteristics of PVB- and EVA-encapsulated modules.

The paper notes that the encapsulant plays an important role in electrochemical processes in a photovoltaic module. The selection of an encapsulant affords the major opportunity for controlling the rates of transfer of ionic charge in a module. The encapsulant serves as a solid-state electrolyte in interactions that involve the electrodes and is the medium through which metal ions dissolved from the conductors are transported. The encapsulant is important in electrochemical corrosion, in which a difference in voltage between two electrified cells in a module or between an electrified cell and a grounded frame drives chemical reactions at the cell/encapsulant and frame/encapsulant interfaces and gives rise to leakage currents between these electrified parts.

The paper indicates how variations in the design parameters affect the levels of leakage currents in the modules. It points out likely leakage-current paths in modules at various temperatures and humidities. It compares the results of field and laboratory tests of the same specimens and notes the greater severity of the outdoor environment.

This work was done by Gordon R. Mon, Liang-Chi Wen, and Ronald G. Ross, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Encapsulant Free-Surfaces and Interfaces: Critical Parameters in Controlling Cell Corrosion," Circle 132 on the TSP Request Card.*
NPO-17352

Relationship Between Latchup and Transistor Current Gain

A commonly stated condition on the sum of αs is found to be erroneous.

A theoretical study takes a new look at the current-vs.-voltage behavior of silicon controlled rectifiers (SCR's), four-layer complementary metal oxide/semiconductor (CMOS) devices, and similar devices susceptible to latchup. For the purposes of this analysis, "latchup" denotes the transition of such a device from a lower-current-conducting steady state to a distinct higher-current-conducting steady state. The study focuses upon the conventional two-coupled-transistor model of a one-dimensional SCR. Although this model gives an oversimplified view of latchup in CMOS circuits, it is useful for qualitative predictions of electrical characteristics.

The currents in and voltages across the transistors in the model are assumed to behave according to the Ebers-Moll equations. The npn and pnp transistors are characterized by normal-mode, short-circuit, common-base current gains α_1 and α_2, respectively; by the open-emitter collector saturation currents I_{CO1} and I_{CO2}, respectively; and by the thermal voltage V_T.

The Ebers-Moll equations are solved to obtain an exact equation for the current I flowing through the device as a function of the collector-junction voltage V_C:

$$I = [(I_{CO1}+I_{CO2})/(1-\alpha_1-\alpha_2)][1-\exp(V_C/V_T)]$$

If, as is physically reasonable for at least some devices, it is assumed that the αs for the inverted mode are negligible and that the emitter junctions are sufficiently forward-biased so that the exponential of the bias voltage over the thermal voltage is much greater than 1, then the current can be expressed approximately as a function of the terminal voltage, V, by

$$[I_{EO1}I_{EO2}/(I_{CO1}+I_{CO2})^2]\exp(V/V_T) = (I')^2/[1-(1-\alpha_1-\alpha_2)/I']$$

where I_{EO1} and I_{EO2} are the open-collector emitter saturation currents and $I' = I/(I_{CO1}+I_{CO2})$.

Whether or not the αs depend on the current, the first equation predicts that the condition $\alpha_1+\alpha_2 = 1$ will result in a high current. Consequently, this condition has been quoted frequently in literature as the condition for latchup. However, the study examines the current-versus-voltage behavior predicted by these equations and shows that reliance on this condition can lead to contradictions and physically unrealistic conclusions. In particular, the study reaches the following conclusions:

- The condition $\alpha_1+\alpha_2 = 1$ is neither necessary nor sufficient for latchup, and indeed it has no special significance at all.
- If small signal alphas are defined in terms of large signal alphas in the usual way, then the condition that the small-signal-alpha sum is unity is not a general criterion for locating switching and holding points.
- Although the condition $\alpha_1+\alpha_2 = 1$ has nothing to do with whether or not a device will latch up, it is relevant to the destructiveness of a latchup in the event that it occurs. For example, if $\alpha_1+\alpha_2 < 0.9$ under all conceivable operating conditions, then there is sufficient margin to prevent destructively high current in the event of a latchup, regardless of external circuitry.
- The way to predict the holding and switching voltages and currents of a two-terminal device is to plot its current-versus-voltage curve from equations that represent the device correctly under all bias conditions, rather than to make a "shortcut" search for the conditions under which $\alpha_1+\alpha_2 = 1$.

This work was done by Larry D. Edmonds of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Latchup Related Implications of the Condition that the Sum of the Transistor Alphas Is Unity," Circle 18 on the TSP Request Card.* *NPO-17561*

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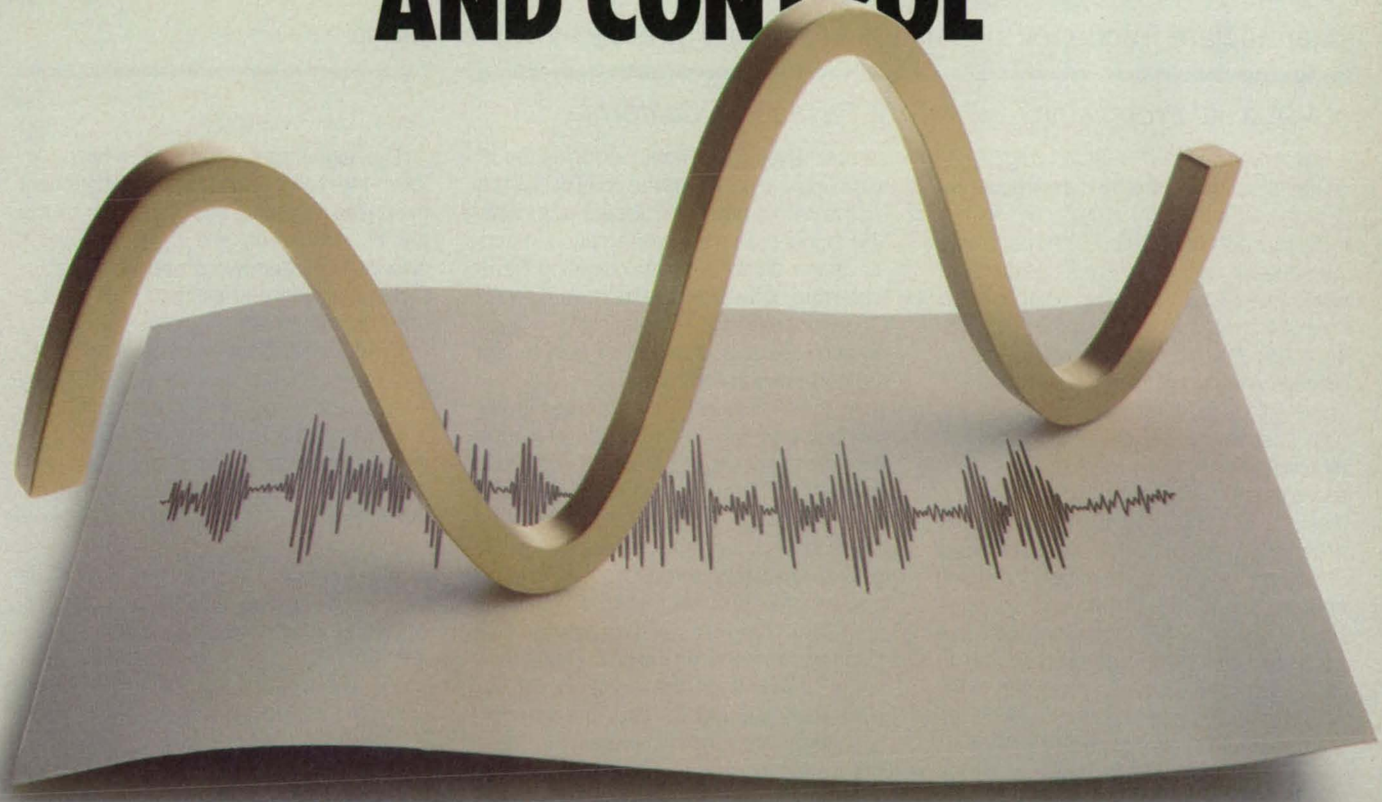

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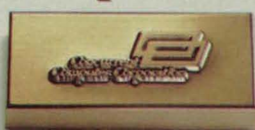

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Hybrid Analog/Digital Receiver

Intermediate-frequency signals are processed directly by digital means.

NASA's Jet Propulsion Laboratory, Pasadena, California

An advanced hybrid analog/digital receiver processes intermediate-frequency (IF) signals that carry digital data in the form of phase modulation. The receiver is intended for use in the Deep Space Network, but presumably the basic design could be modified for such terrestrial uses as communications or laboratory instrumentation where signals are weak and/or noise is strong.

The receiver uses IF sampling and digital phase-locked loops to track the carrier and subcarrier signals and to synchronize the data symbols. The digital processing scheme avoids such inherent deficiencies of analog systems as dc offsets in mixers and amplifiers and the need for precise radio-frequency (RF) calibration and adjustment. In addition, the digital scheme provides more flexibility and reliability while reducing the size and cost of the receiver.

The receiver (see figure) consists of three modules: an IF assembly, a signal-processing assembly, and a test-signal assembly. The IF assembly performs the IF sampling and serves as the point of closure for the carrier and symbol feedback loops. The signal-processing assembly contains all of the digital signal-processing hardware and software necessary to operate the feedback loops. The test-signal assembly provides modulated IF signals to test the other two assemblies.

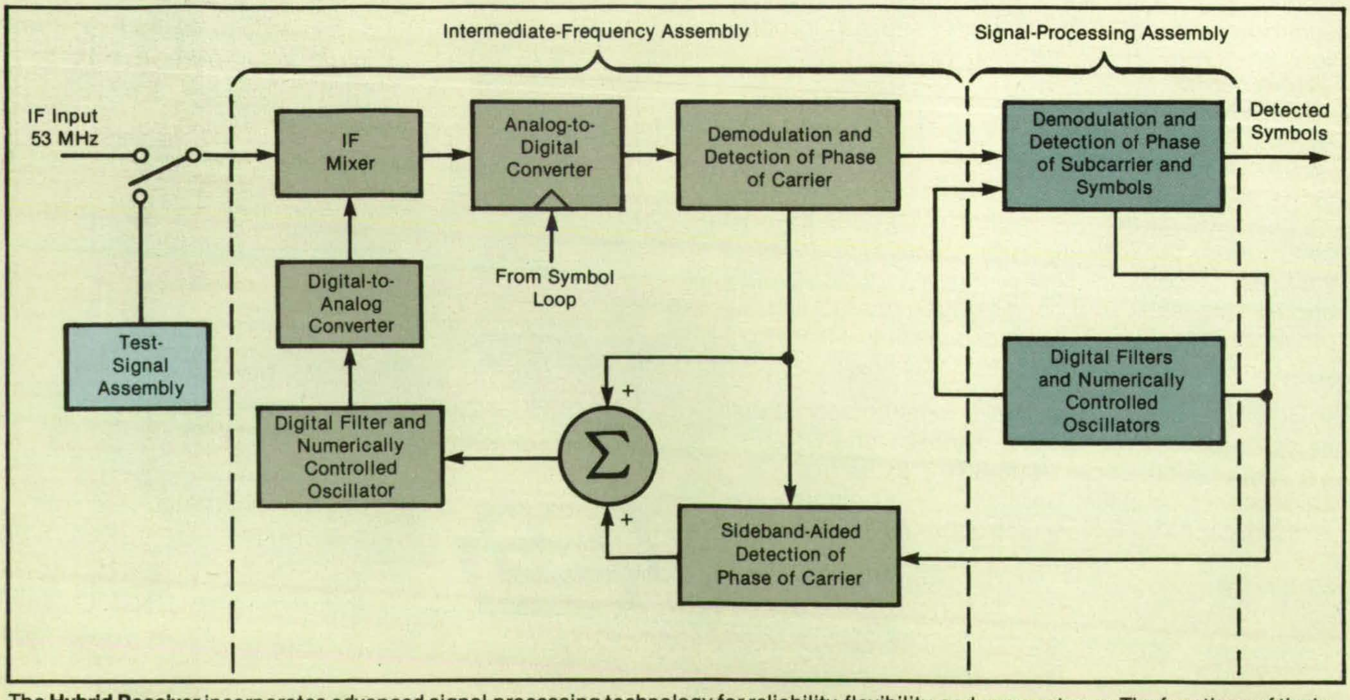
In the IF assembly, the carrier is not demodulated to analog baseband for the detection of phase but instead is locked in phase to one-quarter of the sampling clock, or roughly 5 MHz. This signal is then digitized and passed to the signal-processing assembly for demodulation and phase detection. This technique removes the effect of any bias in the analog-to-digital converter because the dc component is out of band when the signal is digitally mixed to baseband. Locking to a submultiple of the sample rate also eases the implementation of the carrier-demodulation function.

The signal-processing assembly performs the digital operations that implement the phase detectors and loop filters for the carrier, subcarrier, and symbol loops. It also contains hardware and software for fast acquisition and estimation of the parameters of signals.

In the test-signal assembly, the reference frequencies can be generated by internal oscillators that supply fixed frequencies or by external synthesizers. An internal noise generator injects noise into the signal. Signal-to-noise ratios and modulation indices are controlled by attenuators.

This work was done by D. H. Brown and W. J. Hurd of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 47 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 14]. Refer to NPO-17262.



The **Hybrid Receiver** incorporates advanced signal-processing technology for reliability, flexibility, and compactness. The functions of the intermediate-frequency and signal-processing assemblies are implemented digitally by a combination of high-speed computer equipment and computer programs.

Reduction of Stresses in Growing Silicon Webs

The cooling pattern is enhanced by a simple modification of the susceptor lid.

NASA's Jet Propulsion Laboratory, Pasadena, California

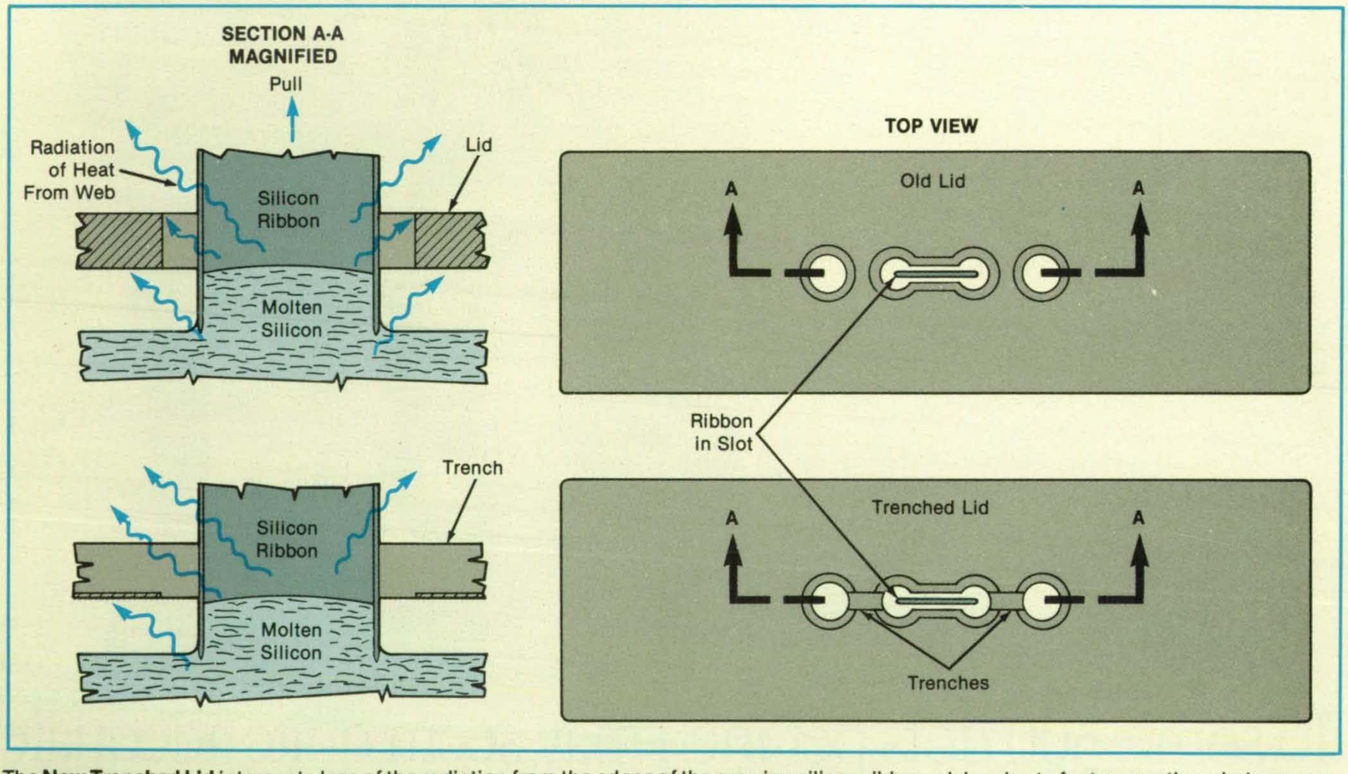
Cutting a trench in a susceptor lid (see figure) allows the edges of a growing ribbon of silicon to cool more rapidly. The edges thus cool and solidify at more nearly the same rate as does the center of the ribbon, and thermal stress in the ribbon is reduced. Because of the more-effective edge cooling, a wider ribbon can be grown, and it can be withdrawn at a faster rate. The productivity of a dendritic-web growth furnace is thereby increased.

In the previous version, the susceptor lid intercepted a greater portion of the heat radiation from the solidifying melt at the edges of the ribbon than that from the middle of the ribbon. The edges of the ribbon therefore could not lose heat as quickly as the middle could, and the resulting concave upward isotherm in the ribbon gave rise to undesirable thermal stresses. Such stresses can cause the ribbon to buckle and break, thus interrupting growth and requiring a new startup. Even if the ribbon does not break, the stresses can be incorporated in the ribbon.

With the trenched lid, the radiation from the melt is still intercepted, as it should be. However, less radiation from the ribbon edges is intercepted. As a result, the heat loss across the ribbon is more nearly uniform, and, consequently, thermal stresses are reduced.

An experimental furnace with the new lid produced about 80 percent more material per unit time than the old one did. The trenched lid enabled the growth of a ribbon 4.2 cm wide, whereas ribbons grown with the untrenched lid had deformed at that width. In addition, the ribbon grown with the new lid is thinner and can therefore be used more efficiently in semiconductor devices. A trenched lid with a slot to accommodate a 5.2-cm-wide ribbon is under construction. Eventually, ribbons 6 to 7 cm wide are likely to be grown in trenched slots.

This work was done by C. S. Duncan, E. L. Kochka, Paul A. Pitrowski and Ray G. Seidensticker of Westinghouse Electric Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 40 on the TSP Request Card.*
NPO-17137



The **New Trenched Lid** intercepts less of the radiation from the edges of the growing silicon ribbon, giving rise to faster growth and a temperature distribution that results in lower residual stress.

Force/Torque Display for Telerobotic Systems

A CRT depicts forces and torques on an object held by a robotic arm.

Langley Research Center, Hampton, Virginia

A pictorial cathode-ray-tube (CRT) display of force and/or torque (F/T) data for telerobotic systems can be used as an output monitor from a multiaxis sensor or as a command display. In its elementary form, the display consists of two initially concentric, easily readable circles positioned over a crosshair reticle. The relative positions of the two circles with respect to the reticle and to each other are programmed to represent forces and torques acting along orthogonal *x* and *y* axes, derived from signals from an F/T sensor.

The interpretation of the CRT display is simple if the two circles are considered as opposing ends of a cylindrical or conical object, such as a steel peg of the type commonly used in very basic telerobotic task-

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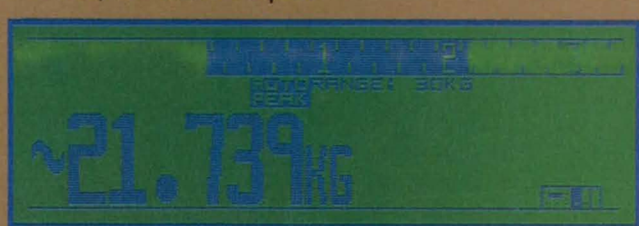

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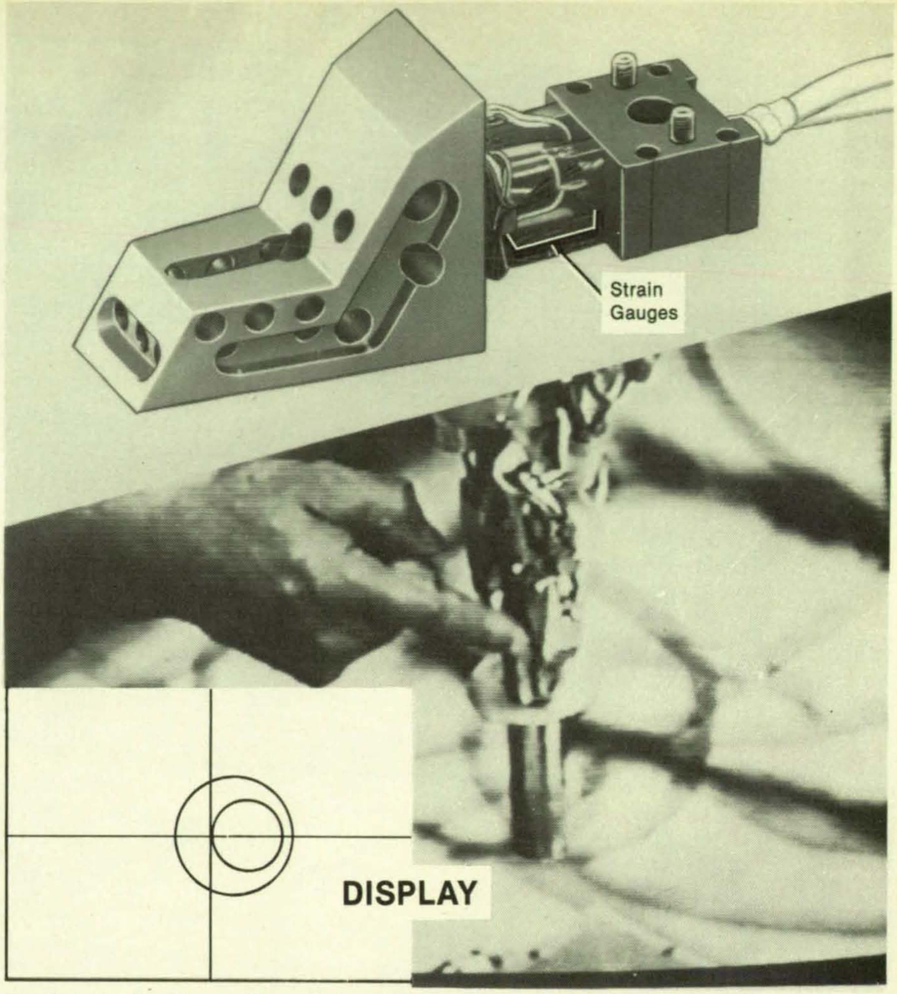
board experiments. The display is programmed to depict the relative positions and shapes of the circular ends of the peg as they would be acted upon by the forces and torques.

A force acting at the longitudinal center and orthogonal to the axis of the peg would cause a pure translation and is programmed to appear on the display as coincidental movement of the centers of the two circles with respect to the reticle. Forces acting on the peg may produce torques tending to cause the peg to rotate and are programmed to appear as differential movements of the two circles, as shown in the figure. A *z*-axis force that tends to compress or elongate the peg may be displayed as changes in the diameters of the circles, and torsion (torque about the longitudinal axis) may be represented as the rotation of an index mark on a circle.

This concept has already been implemented at NASA Langley Research Center. The graphical presentation has been generated on two different graphics systems, one in color and one in black and white. High-level programming facilitates the use of additional convenient features in the software that extend the usefulness of the sensor data and display. For example, the bias values of a sensor may be subtracted to correct for drift or offset of the sensor. Also, predetermined values of force and torque may be subtracted from those displayed to create a highly accurate reference for any combination of forces and torques. This display is especially useful in laboratory experiments, to monitor the performance of an automated system and for presenting data on the status of a system to an operator at a control station.



The **Relative Positions of Two Circles** represent forces and torques acting on an object, derived from signals from an F/T sensor composed of strain gauges.

This work was done by Marion A. Wise of **Langley Research Center**. *No further documentation is available.*
LAR-13727

Correction and Use of Jitter in Television Images

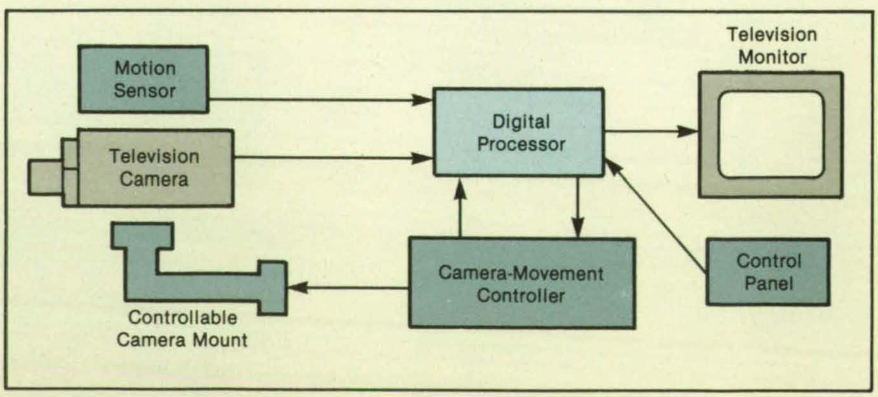
Suppression of vibrations and measurements of depth are among potential uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed system would stabilize a jittering television image and/or measure the jitter to extract information on the motions of objects in the image. In an alternative version, the system would control the lateral motion of the camera to generate stereoscopic views to measure distances to objects. In yet another version, the motion of the camera would be controlled to keep an object in view.

The heart of the system would be a digital image-data processor called a "Jittermiser" (for jitter minimizer), which would include a frame buffer and logic circuits to correct for jitter in the image (see figure). Signals from motion sensors on the camera would be sent to the logic circuits and processed into corrections for motion along and across the line of sight. These would include the zoom setting of the lens, which would provide data for scaling the motion of the image to the motion of the camera. The logic circuits would expand, contract, and/or laterally shift the image to compensate for the motions of the camera so that, when transmitted to the television monitor, the image would contain only the true motion in the scene.

If the buffer and logic circuits take too



The **Motion of the Television Camera** would be measured and/or controlled to compensate for motion in the image and/or extract useful information from it.

long to correct for the jitter, they could reintroduce jitter into the image. If, for example, the corrected image lags n frames behind the motion signals, this jitter would represent the difference between the locations and orientations of the camera at present and n frames ago. When this jitter becomes unacceptable, the system could respond by selecting a less-complete, faster image-processing algorithm.

The image-processing capability could be exploited to stabilize only a portion of a jittering image — for example, to get a stationary view of a vibrating object. By use of a keyboard, joystick, or other control, one could select the coordinates of a component so that the processor could locate the component digitally in its frame buffer. Thereafter, the processor would shift the image digitally to keep the component at the same position on the television screen, whether or not the camera is jittering. This function could be combined with feedback control of the camera to keep a moving object within view. The outputs of the system could include data on the motion of the object — for example, the velocity of a balloon as a measure of wind.

For the measurement of distances to objects or for stereoscopic viewing, the processor would both control and measure the lateral motion of the camera. From the parallax motions of each component of the image, the distance from the camera to the corresponding object could be computed. The processor could then superimpose depth labels on the television image to show the distance to each object of interest. The processor could shift the components of the image so that they would appear at their true depths when viewed stereoscopically.

This work was done by Daniel B. Diner and Derek H. Fender of Caltech and Antony R. H. Fender of LAMA Engineering, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 126 on the TSP Request Card.* NPO-17499

Design of Feedforward Controllers for Multivariable Plants

Controllers are based on simple low-order transfer functions.

NASA's Jet Propulsion Laboratory, Pasadena, California

Mathematical criteria have been derived for the design of feedforward controllers for a class of multiple-input/multiple-output linear plants. The controllers are represented by simple low-order transfer functions, which are obtained without reconstruction of the states of commands and disturbances.

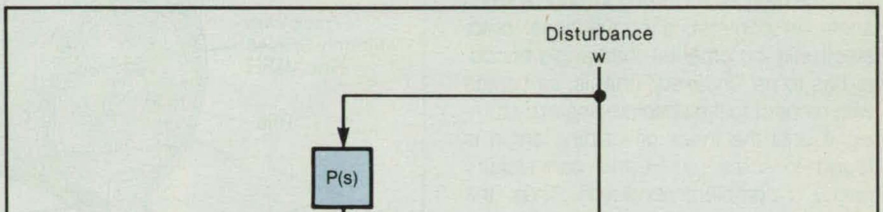
For the system shown at the top of the figure, the plant is described by

$$Y(s) = G_c(s)\boldsymbol{U}(s) + G_d(s)\boldsymbol{W}(s)$$

and the open-loop control law is

$$U(s) = P(s)\boldsymbol{W}(s) + Q(s)\boldsymbol{V}(s)$$

where s is the Laplace-transform complex frequency, $\boldsymbol{U}$ is an $m \times 1$ vector representing the control input to the plant, $\boldsymbol{W}$ is an $\hat{m} \times 1$ vector representing the measurable disturbance input to the plant, $\boldsymbol{V}$ is an $\ell \times 1$ vector representing the command input, $\boldsymbol{Y}$ is an $\ell \times 1$ vector representing the output of the plant, and G_c and G_d are the $\ell \times m$ and $\ell \times m$ transfer-function matrices that relate the control and disturbance inputs, respectively, to the output. The problem is to determine the transfer-function matrices $P(s)$ and $Q(s)$ of the feedforward controllers so that, in the steady state, the output $\boldsymbol{y}(t)$ (where t = time) obeys the command $\boldsymbol{v}(t)$ and does not include a response to the disturbance $\boldsymbol{w}(t)$. The plant is assumed to be stable.



The **Feedforward Controllers** P(s) and Q(s) enable the plant to track the command v while remaining unresponsive to the disturbance w in the steady state. The feedback controller K(s) can be added independently of P(s) and Q(s) to stabilize the plant or to make the control system less susceptible to variations in the parameters of the plant.

The linearity of the system permits the decomposition of the problem into two separate subproblems: the rejection of the disturbance by $P(s)$ when $\boldsymbol{v} = 0$ and the tracking of the command by $Q(s)$ when $\boldsymbol{w} = 0$. The main result of the analysis of the rejection subproblem is a requirement that the zeros of a specific rational vector composed of elements of $P(s)$ and of a specific formulation of $G_c(c)$ and $G_d(s)$ contain the poles of $\boldsymbol{W}(s)$. There must be at least as many control inputs as outputs ($m \geqslant \ell$), and the poles of the disturbances must not coincide with the transmission zeros of the plant. Provided that these requirements are satisfied, the designer can choose any of a wide variety of transfer functions and is free to make $P(s)$ consist of relatively-simple proportional, derivative, and low-order dynamic terms.

The main result from the tracking subproblem is a requirement that the zeros of another specific rational vector composed of elements of $Q(s)$ and of the same specific formulation of $G_c(s)$ and $G_d(s)$ contain the poles of $\boldsymbol{V}(s)$. The poles of the commands must not coincide with the transmission zeros of the plant, and, as before, there must be at least as many control inputs as outputs. As in the case of $P(s)$, the designer is otherwise free to choose simple proportional, derivative, and low-order dynamic terms.

If the plant is unstable, it can be stabilized by a feedback controller described by K(s), as shown in the lower part of the figure. K(s) can be based on the open-loop plant, selected independently of P(s) and Q(s) by methods developed previously.

For a plant with appreciable time constants, a disturbance-feedforward controller P(s) produces immediate corrective control action to counteract the effects of disturbances on the outputs of the plant, whereas a feedback controller is ineffective until the disturbance has acted on the plant for some time and the output is perturbed. Consequently, unlike feedback controllers, feedforward controllers are capable of decoupling of the disturbances and matching of the commands.

As in the case of all open-loop controllers, the disturbance-rejection and command-tracking properties of the feedforward system are lost in the face of unpredictable variations in the parameters of the plant. However, when these variations are known a priori and the feedforward controllers are "updated" to cope with these variations, then the steady-state output-control properties are preserved. Although feedback is not required when the plant is stable, the use of feedback is often recommended to reduce sensitivity to these variations and thereby increase the robustness of the overall control system.

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 88 on the TSP Request Card.*
NPO-17177

Rapidly-Indexing Incremental-Angle Encoder

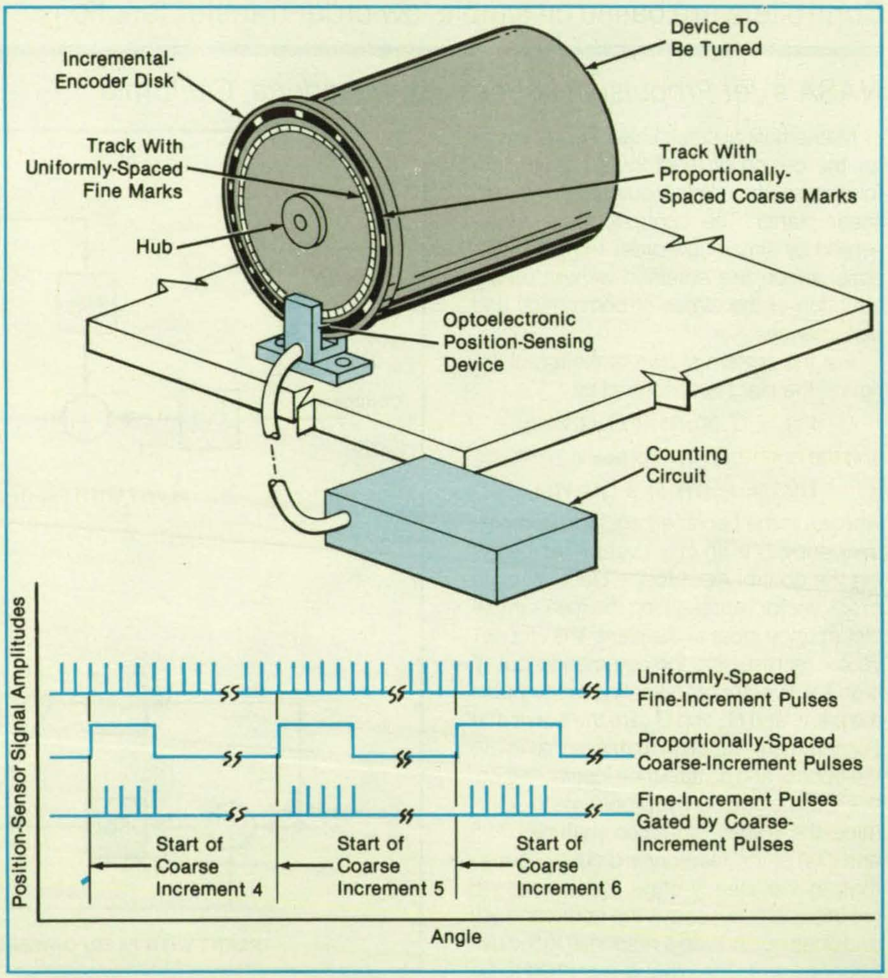
The absolute position can be determined after rotation through a small angle.

Goddard Space Flight Center, Greenbelt, Maryland

An optoelectronic system that measures the relative angular position of a shaft or other device to be turned can also measure the absolute angular position after the device has turned through a small angle. In contrast, a conventional optoelectronic incremental-shaft-angle encoder has to be "indexed" (that is, calibrated with respect to the absolute angle) by turning it until the index or starting angle is found; in some cases, this can require nearly a complete revolution. Thus, the new angle encoder helps to save energy and reduce wear in the bearings. Its principle of operation is also applicable to incremental-linear-position encoders.

As in a conventional encoder, the relative angular position is measured with fine resolution by optoelectronically counting finely- and uniformly-spaced light and dark areas on the encoder disk as the disk turns past the position-sensing device (see figure). However, the disk also includes a track containing coarsely- and nonuniformly-spaced light and dark areas, the angular widths of which vary in proportion to the absolute angular position. This second track provides a gating and indexing signal.

The output signals from the position sensor — one for each track — are fed to the counting circuit. The circuit counts the number of fine-increment pulses that occur during each coarse-increment pulse. This count gives a measure of the absolute angle because each coarse interval can be identified by its unique number of fine increments. Thereafter, the angle is determined to a finer resolution by counting the number of fine increments after the start of the gating signal.



The **Number of Fine Increments in Each Coarse Increment** of angle can be counted to determine the absolute angle of the device.

This work was done by Philip R. Christon and Wallace W. Meyer of Ball Corp. for **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13154

Measuring Airflow With Digital Holographic Interferometry

Pressures on surfaces of airfoils are computed from interference fringes.

Ames Research Center, Moffett Field, California

A digital image-processing system assists in the analysis of holographic interferometric images of flow about an airfoil. Operating semiautomatically, the system identifies, counts, and labels interference fringes, then processes the distances between fringes into the distribution of pressure on the surface of the airfoil. The system yields data on pressure faster than do manual image-analyses techniques, and these data compare favorably with those obtained by manual analysis and by probe measurements of pressure.

The equipment is illustrated by the block diagram of Figure 1. A video camera views the interferometric hologram. The video image has a resolution of 512 × 512 picture elements, the intensity of each of which is digitized to 8 bits. The digitized image is stored in two memory planes. Another memory plane stores a graphical and alphanumerical overlay digitized to 4 bits.

The system includes an arithmetic logic unit (ALU), which performs addition, subtraction, or comparison of the data in one or more memory planes in real time. The contents of each memory plane can be routed through lookup tables before entry into the ALU and can be shown on a color display. A joystick control device is used for interactive input. It controls two cursors, which can be used in a number of operating modes. A color printing system augments the color monitor.

The system uses computer programs that evaluate the interferograms along straight or curved lines represented by polygon segments. The user is prompted for such inputs as reference points and fringe numbers. After starting the program, a fringe pattern is digitized and frame-averaged to improve the signal-to-noise ratio. The user enters the location of two reference points to map the image-processor coordinates to the user's coordinate system by directing a cursor to the appropriate locations and entering the corresponding positions in the user's system. The selected reference points are usually the leading and trailing edges of the airfoil.

During numbering, the cursor can be moved along the segmented polygon line, positioning itself along the white segments. A reference fringe, the density along which is known, is selected and assigned the value 0. Subsequent fringes are numbered relative to the reference fringe in increments of 1. The user determines the correct numbers to be assigned to each fringe

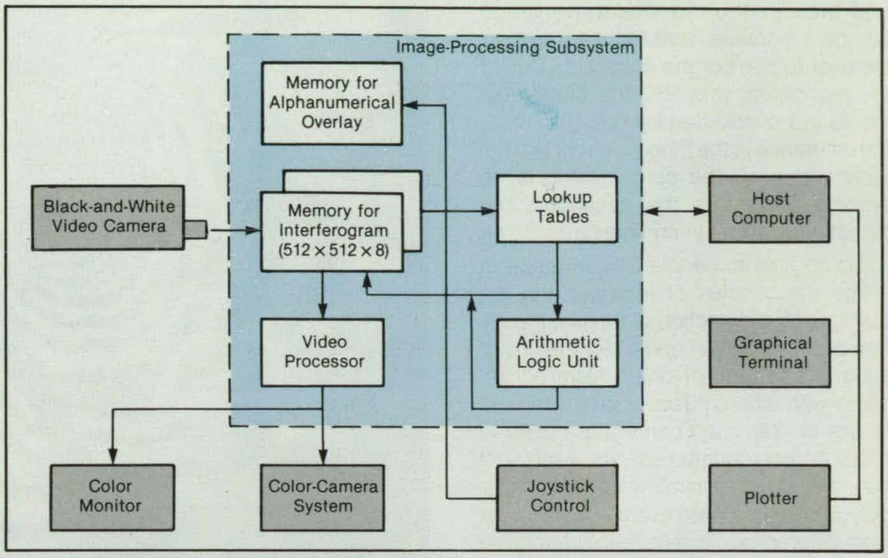


Figure 1. The **Image-Processing System** digitizes holographic interferograms of flow and processes them into data of pressure or other properties of the flow.

by observing the entire flow pattern of the interferogram. If the surface pressure is known to increase to a certain point and then decrease, the user correspondingly assigns fringe numbers that indicate this increase and decrease. Depending on the polygon line being used, some fringes have the same number as the fringe pattern bends in the opposite direction. Two different numbering modules can be used to set the fringe numbers. Only one number and the direction in which the fringe numbers increase have to be entered by the user to number the entire line. During the numbering process, the black segments are overwritten by colors to show the difference in the fringe order of two adjacent fringes. The color coding is an ergonomic feature that facilitates the detection of errors in numbering.

To be able to handle a wide range of fringe frequencies or increase the accuracy of the detection of fringes, the image processor can handle digitizations of several sections of one interferogram taken with different resolutions. Alternate lenses on the video camera are used to focus on appropriate sections. Each section is digitized separately until the entire polygon line has been evaluated. The data from different portions of the interferogram are then merged into one set of data. The output consists of the fringe numbers and location (fringe-order function) along the polygon line being evaluated. The fringe-order function is automatically fed to a file from which it can be converted to the distribution of pressure coefficients by a postprocessing program (see Figure 2).

This work was done by Francisco J. Torres of **Ames Research Center**. *Further information may be found in NASA TM-88358 [N87-24681], "Application of Digital Holographic Interferometry to Pressure Measurements of Symmetric, Supercritical, and Circulation-Control Airfoils in Transonic Flow Fields."*

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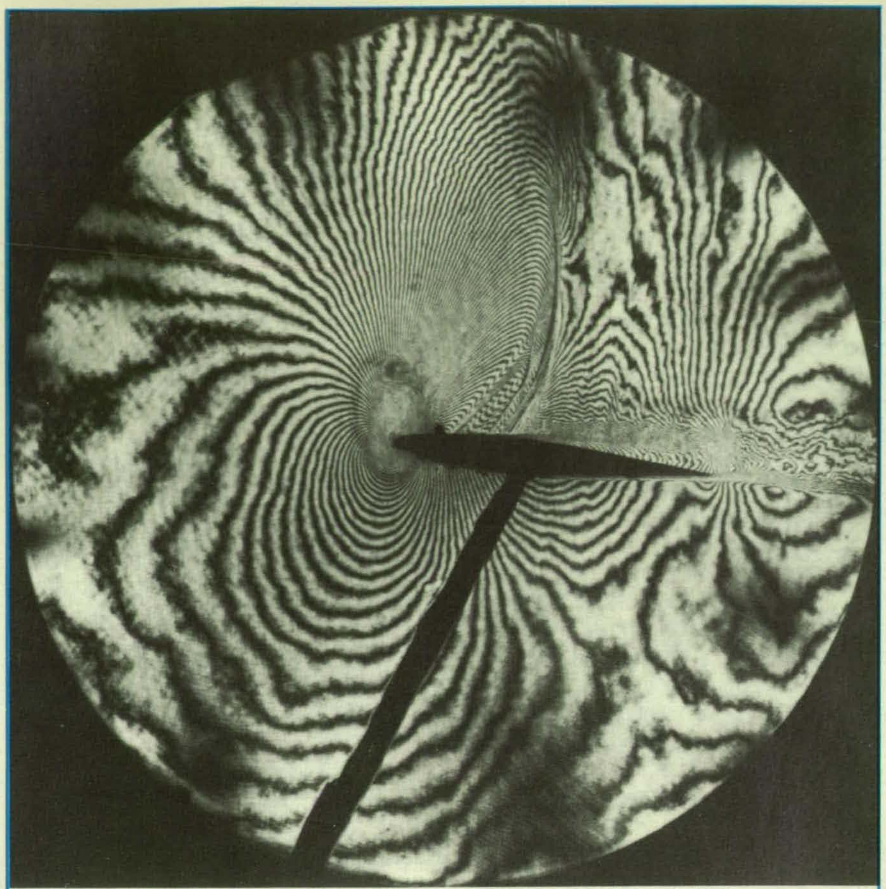
ARC-12131



Interferogram of 64A010 Airfoil at Mach 0.8 and Angle of Attack of 6.5°

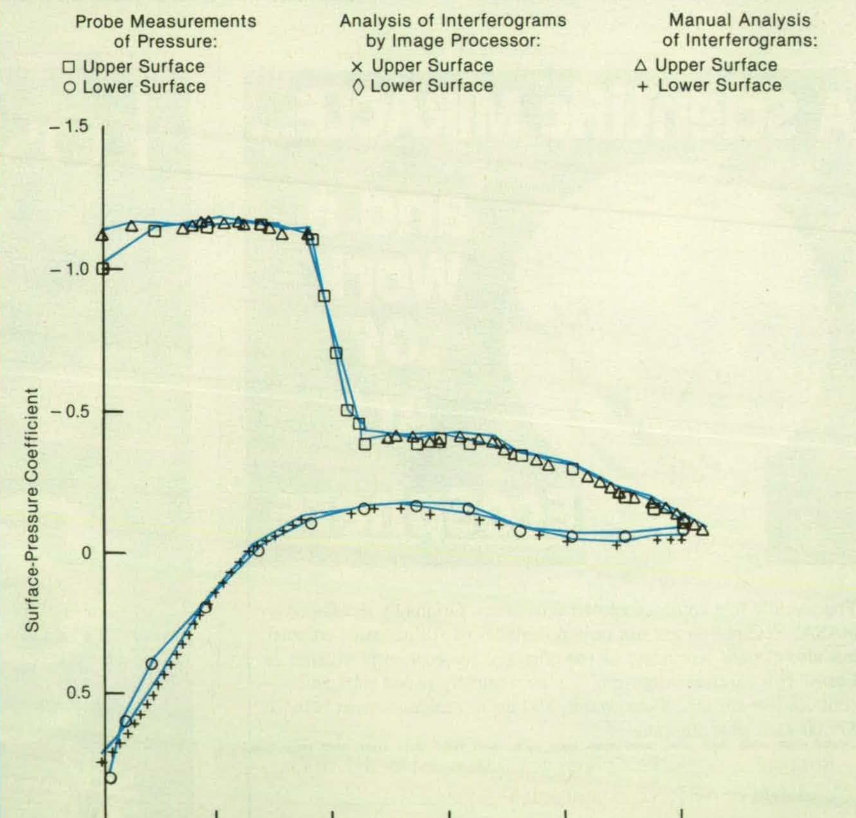


Figure 2. **Analysis of the Interferogram** by the image-processing system produces results in close agreement with those obtained by manual analysis and by direct probe measurements of pressure. In regions along the airfoil where the fringe pattern is clear, the probe measurements and the output of the image-processing system agree within 1 percent.

Optical Processing With Photorefractive Semiconductors

Advantages include high speed and compatibility with other semiconductor devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

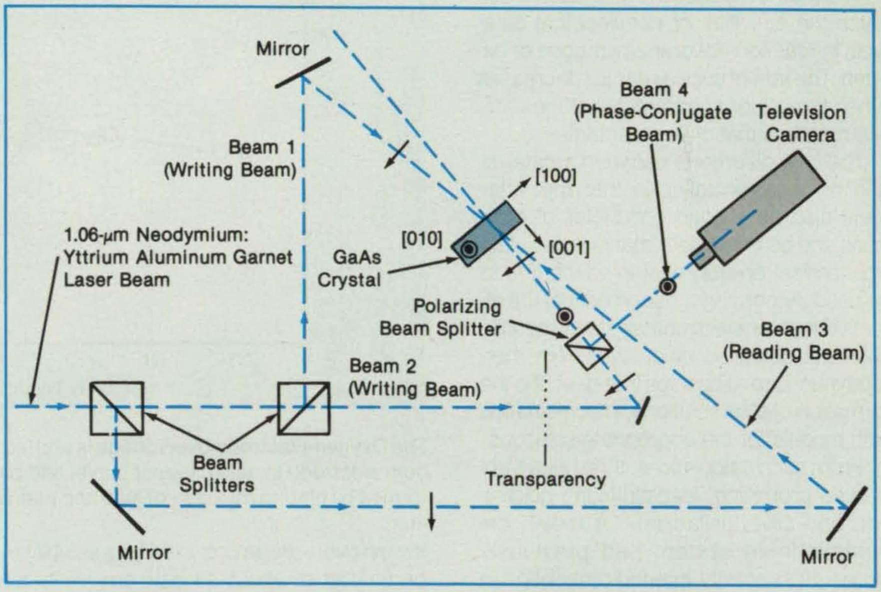
An experimental phase-conjugate four-wave-mixing apparatus has been used to demonstrate the capabilities of GaAs (and potentially of other photorefractive semiconductors like InP and CdTe) for optical processing of information. With modifications, the apparatus performs any of three basic image-processing functions: transfer to a different light beam, enhancement of edges, and autocorrelation.

GaAs offers important advantages over such crystalline oxides as $BaTiO_3$ and $LiNbO_3$. Its photorefractive response occurs within tens of microseconds — about 100 times as fast as that of the oxides. GaAs devices operate in the infrared wavelength range of 0.9 to 1.6 μm and are therefore compatible with semiconductor injection lasers and miniature diode-pumped yttrium aluminum garnet lasers. In contrast, the oxides operate in the visible wavelength range of 0.4 to 0.7 μm and therefore require gas lasers, which are large, expensive, and fragile. Thus, the applications of the oxides are limited, while GaAs is suitable for integration of optical processing with optoelectronic, electro-optical, and electronic systems that are fast, compact, and consume little power.

The apparatus includes a crystal of GaAs of 5 by 9 by 9 mm with its cubic crystalline axes oriented as shown in the figure. The crystal is illuminated from opposite sides by writing laser beams 1 and 2, which are polarized in the plane of the paper. A grating is formed by the photorefractive effect at the intersection of these beams.

The grating is illuminated by reading laser beam 3, which is also polarized in the plane of the illustration. The grating diffracts this beam, producing phase-conjugate beam 4 with polarization perpendicular to the page. Thus, beam 4 can be separated and deflected to a camera by a polarizing beam splitter. The polarizer also reduces the noise caused by randomly scattered background light.

A transparency bearing an image is placed in beam 2 at a distance ℓ from the crystal to modulate the beam spatially with information. Because of the phase-conjugate nature of beam 4, the image appears in beam 4 at distance ℓ from the crystal. Thus, an image has been transferred from one light beam to another.



This **Four-Wave Mixing Apparatus** can be used to transfer an image from one light beam to another, enhance the edges in the transferred image, or autocorrelate an image.

To enhance the edges in an image, another transparency is placed in beam 1, and a lens is placed in front of it at such a distance that its Fourier plane is in the crystal. The intensities of beams 1 and 2 are then adjusted so that the intensities of the portions of the two beams carrying the high spatial frequencies are approximately equal. Under this condition, the hologram formed in the crystal acts as a high-pass filter of the spatial-frequency information. Thus, the eges — which have higher spatial frequencies than the rest of the image does — are enhanced.

To autocorrelate an image, identical transparencies and lenses are placed in both writing beams so that the crystal is illuminated from both sides with Fourier transforms of the image. The hologram in the crystal is read out by beam 3, and beam 4 is inverse Fourier-transformed by a lens. The resulting image is the autocorrelation of the images.

This work was done by Li-Jen Cheng and Gregory Gheen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 82 on the TSP Request Card.*

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

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Pasadena, CA 91125

Refer to NPO-17324, volume and number of this NASA Tech Briefs *issue, and the page number.*

Choosing Compositions of Electrocatalysts

The best alloys for fuel cells and batteries can be determined from thermodynamical considerations.

NASA's Jet Propulsion Laboratory, Pasadena, California

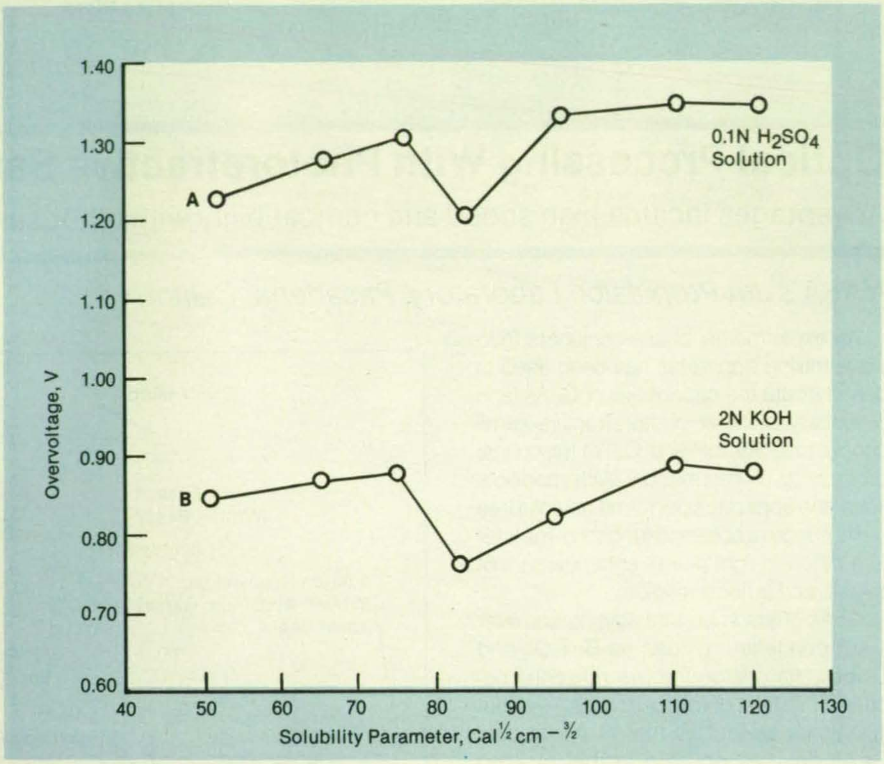
A simple theory predicts the compositions of alloys that exhibit maximum catalytic activities in the presence of certain reactants. The method can be used to select the best catalysts for electrochemical batteries and fuel cells. It predicted, for example, that a platinum/lead electrocatalyst of specified composition would provide the lowest overvoltage of an oxygen electrode in an acidic or basic medium in a lithium battery. This prediction was borne out by experiment.

The method is based on one used to analyze the activities of nonelectrical catalysts in reactions involving hydrogen or oxygen. The rate of such a reaction increases when the solubility parameter of the catalyst matches that of the reactant.

The only difference between a catalyst and an electrocatalyst is that the latter must also be a good conductor of electrons and be chemically stable in the electrochemical environment in which it is to be used. Accordingly, it seemed that the effectiveness of electrocatalysts in metallic solutions could be calculated from thermodynamic relationships that describe the formation of solid solutions, in combination with models for the appropriate solutions.

From such calculations, three alloys appeared promising: lead/platinum, gold/silver, and silver/palladium. Of these, the lead/platinum system had previously shown high activity in anodic oxidation in an ethylene glycol fuel cell.

Accordingly, lead/platinum was selected for experimental evaluation. The electrochemical electrode overvoltage was measured as a function of the solubility parameter (see figure). The lower the overvoltage, the more efficient the electrocatalytic kinetics are. For lead/platinum, the lowest overvoltage occurred for a solubility parameter of about 83 cal$^{1/2}$ cm$^{-3/2}$ — a value close to that of atomic oxygen, as would be expected in nonelectrical catalysis. This solubility parameter represents an electrode composed of about 54 percent lead and 46 percent platinum by volume.



The **Oxygen-Electrode Overvoltage** is plotted against the solubility parameter of a lead/platinum electrode in acidic (upper curve) and basic (lower curve) solutions. The electrode was formed by plating mixtures of lead and platinum, corresponding to various solubility parameters.

This work was done by Daniel D. Lawson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 87 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 14]. Refer to NPO-17167

Algorithm Estimates Microwave Water-Vapor Delay

Accuracy equals or exceeds that of conventional linear algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

The "profile" algorithm is an improved algorithm that uses water-vapor-radiometer data to produce estimates of microwave delays caused by water vapor in the troposphere. Unlike conventional linear algorithms, it does not require site-specific and weather-dependent empirical parameters other than standard meteorological data, latitude, and altitude for use in conjunction with published standard atmospheric data.

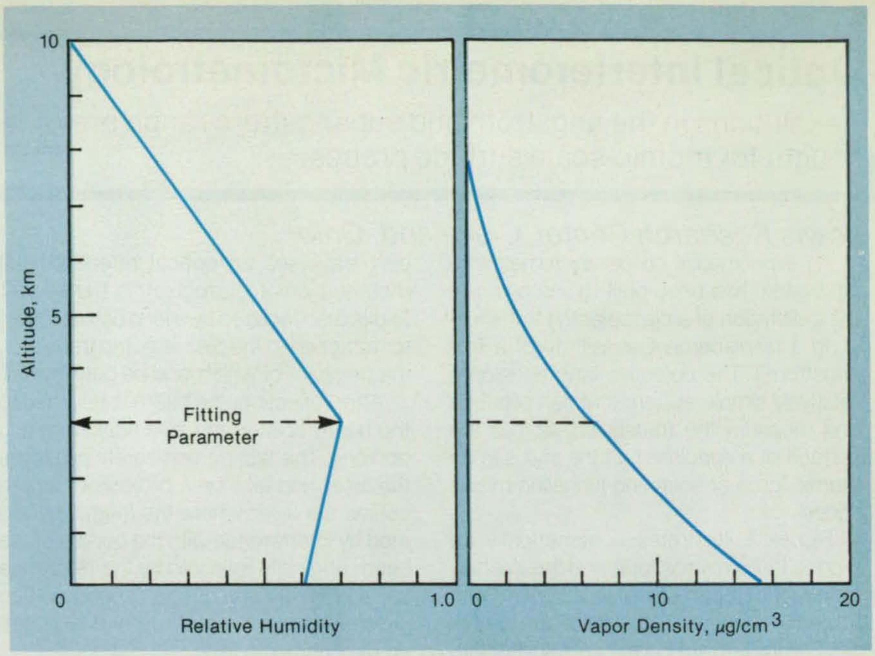
A water-vapor radiometer measures the brightness temperature along a line of sight at frequencies close to the 22.2-GHz resonance of water. These temperatures depend on the distributions of kinetic temperature, pressure, water vapor, and liquid water along this line of sight. The microwave wet-path delay depends on the distributions of water vapor and kinetic temperature along the line of sight. The problem is to estimate the wet-path delay from the brightness temperatures without detailed knowledge of the actual line-of-sight distributions of relevant quantities.

The basic premise of the profile algorithm is that the wet-path delay is approximated closely by the solution to a simplified version of the nonlinear delay problem and can be generated numerically from each radiometer observation and simultaneous meteorological data. The algorithm first chooses various simple vertical distributions of water vapor and liquid and inserts them in a mathematical model of emission by the atmosphere at the radiometric wavelengths. When it finds a distribution for which the output of the model matches the radiometric observations, it uses this distribution in an integration along the desired line of sight to obtain the delay.

It is assumed that the vertical distribution of relative humidity can be represented adequately by the two-piece linear function shown in the figure. At the surface, the relative humidity is measured conventionally. The relative-humidity profile is then approximated by connecting the two endpoints by straight lines to the relative humidity at an altitude of 3 km. This relative humidity is adjusted by the algorithm and used to estimate the trial vapor distributions via standard-atmosphere temperature and pressure profiles calibrated to the temperature and pressure measured at the surface.

The emission model accounts for the continuum emission from droplets of water by assuming that the density of liquid water is proportional to the saturation water-vapor density as set by the temperature and pressure at each point. The algorithm tries different constants of proportionality until it obtains a fit.

The intrinsic accuracy of the profile algorithm, excluding uncertainties in radiometer data and the emission model, has been estimated with the help of archival radiosonde data. The annual root-mean-square errors for a wide range of sites average 1.8 mm in clear weather, 2.2 mm in cloudy weather, and 1.9 mm overall. In clear weather, the accuracy of the profile algorithm is comparable to the best that can be obtained from conventional linear algorithms; in cloudy weather, the profile algorithm offers a 35-percent improvement.



The **Vertical Distribution of Relative Humidity** is represented by a two-piece linear profile with one arbitrary fitting parameter. Once this parameter is chosen, the relative-humidity distribution is used in conjunction with standard temperature and pressure distributions to obtain the water-vapor-density distribution.

This work was done by Steven E. Robinson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 163 on the TSP Request Card.* *NPO-17267*

Optical Interferometric Micrometrology

Resolutions in the angstrom and subangstrom range are sought for atomic-scale surface probes.

Lewis Research Center, Cleveland, Ohio

An experimental optical micrometrological system has been built to demonstrate the calibration of a piezoelectric transducer to a displacement sensitivity of a few angstroms. The objective is to develop a relatively simple system that can produce and measure the translation, across the surface of a specimen, of the stylus in an atomic-force or scanning tunneling microscope.

Figure 1 illustrates schematically an atomic-force microscope and the interferometer that is part of the optical micrometrological system. Light from an He/Ne laser is divided by a cubic beam splitter into two parts. One part falls on a projection screen for visual alignment or on a photocell for stabilization of the laser. The other part traverses an optical reference flat mounted on a piezoelectric transducer and is then focused by a lens onto a reflector attached to the piezoelectric translator, the behavior of which is to be determined.

After reflection, the beam is returned to the beam splitter and split again into two portions. The first portion barely bypasses the laser and falls on a projection screen behind the laser where the fringes generated by interference with the portion of the beam originally reflected by the reference flat can be observed. The second portion passes through an aperture and is detected by a photodiode.

The laser interferometer measures the changes of distance between the optical reference flat and the reflector. Because of the interposed lens, the interference pattern intercepted on the screen behind the laser or on the plane of the aperture consists of Newton's rings. Changes in distance can be determined from changes in the radii of the rings or, more accurately, from changes of the intensity of light in the rings passing by the aperture and detected by the photodiode.

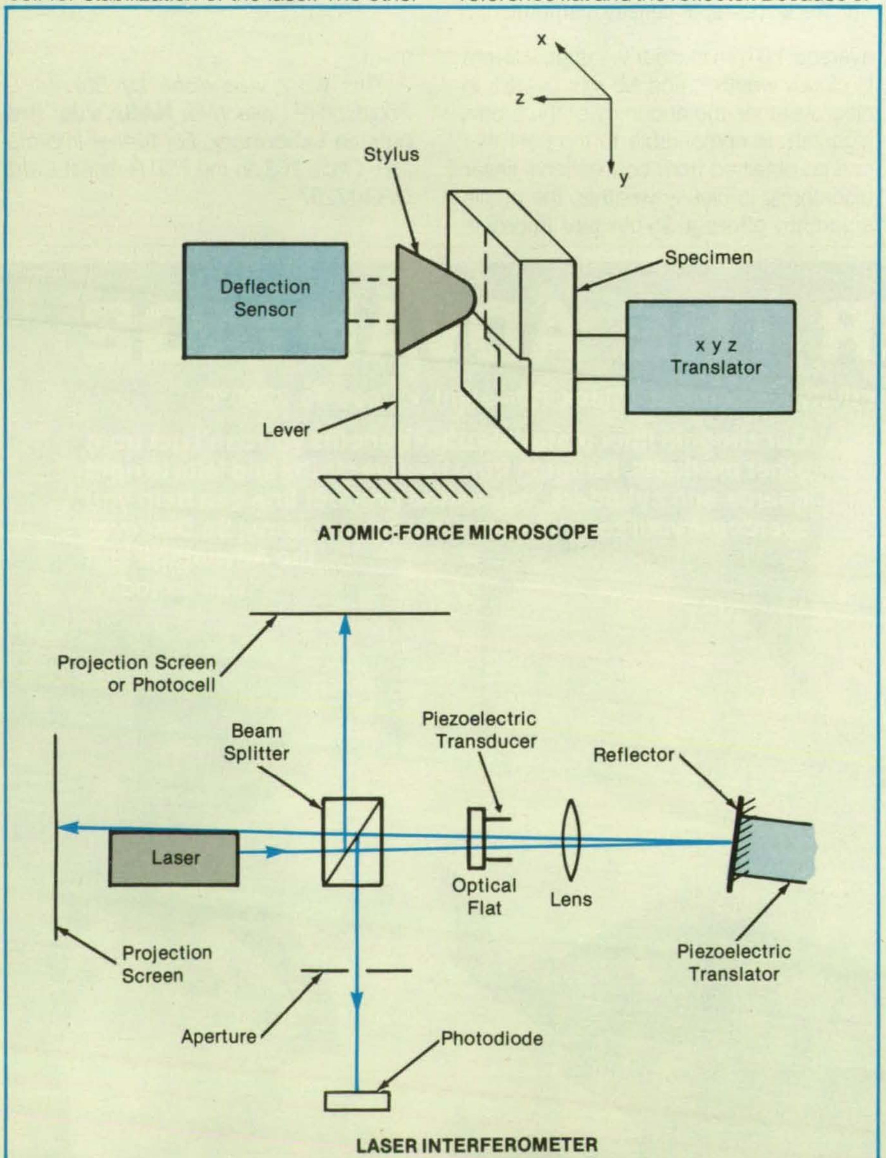


Figure 1. A **Laser Interferometer** is used to calibrate a piezoelectric transducer that would be used in an atomic-force microscope.

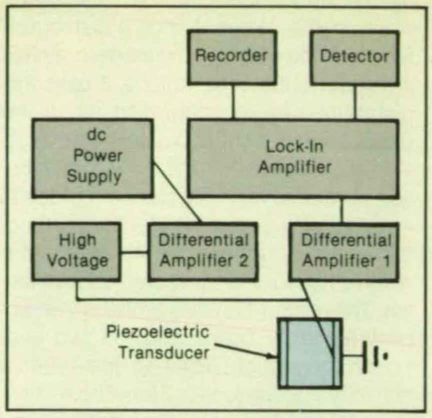


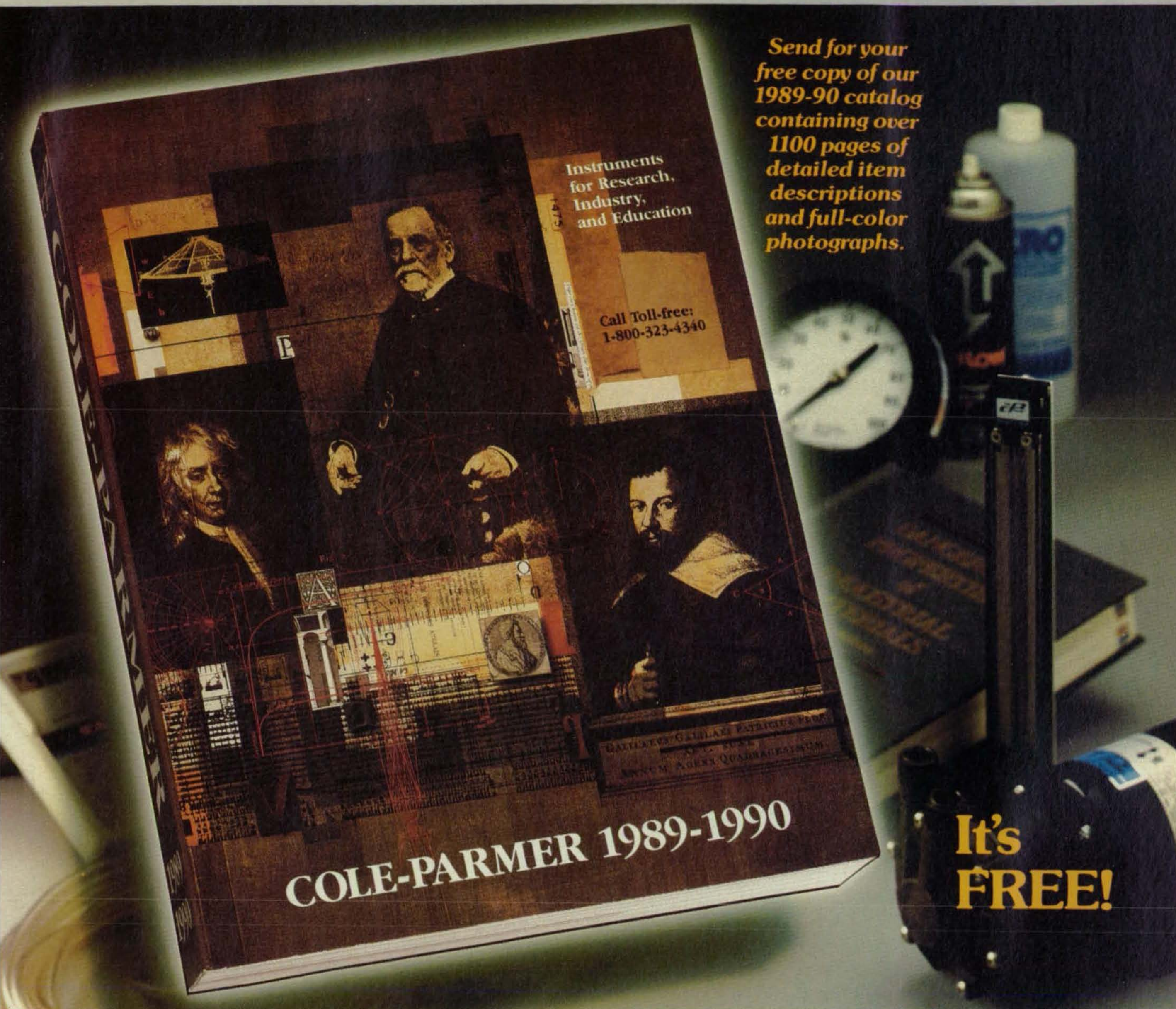
Figure 2. The **Electronic Portion of the Calibration System** is made of commercially available components.

Figure 2 is a block diagram of the electronic portion of the system. In normal operation, the optical-flat piezoelectric transducer is driven by an ac signal at a frequency of 5,000 Hz. The photodiode-output signal from which the displacement is inferred is detected by a lock-in amplifier, which is locked to the same reference oscillator that controls the motion of the transducer. Differential amplifiers isolate the relatively high voltage necessary to drive the piezoelectric transducer from the dc power supply and lock-in amplifier. (A transformer can be substituted for differential amplifier 1 to enhance the signal-to-noise ratio.)

In one test, it was found that the innermost ring of the interference pattern moved by half a fringe when a dc potential of 300 V was applied to the piezoelectric translator. When the time constant of the lock-in amplifier was set at 4 s in the presence of an ac signal, the noise in the output signal corresponded to a signal of about 0.7 V applied to the piezoelectric translator. Since half a fringe represents a displacement of about 1,500 Å, this yields a displacement sensitivity of $1{,}500 \times (0.7/300) = 3.5$ Å.

This work was done by Phillip B. Abel of **Lewis Research Center** *and James R. Lauer of Rensselaer Polytechnic Institute. Further information may be found in NASA TM-100299 [N88-23196], "Development and Applications of Optical Interferometric Micrometrology in the Angstrom and Subangstrom Range."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14837



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Circle Reader Action No. 638

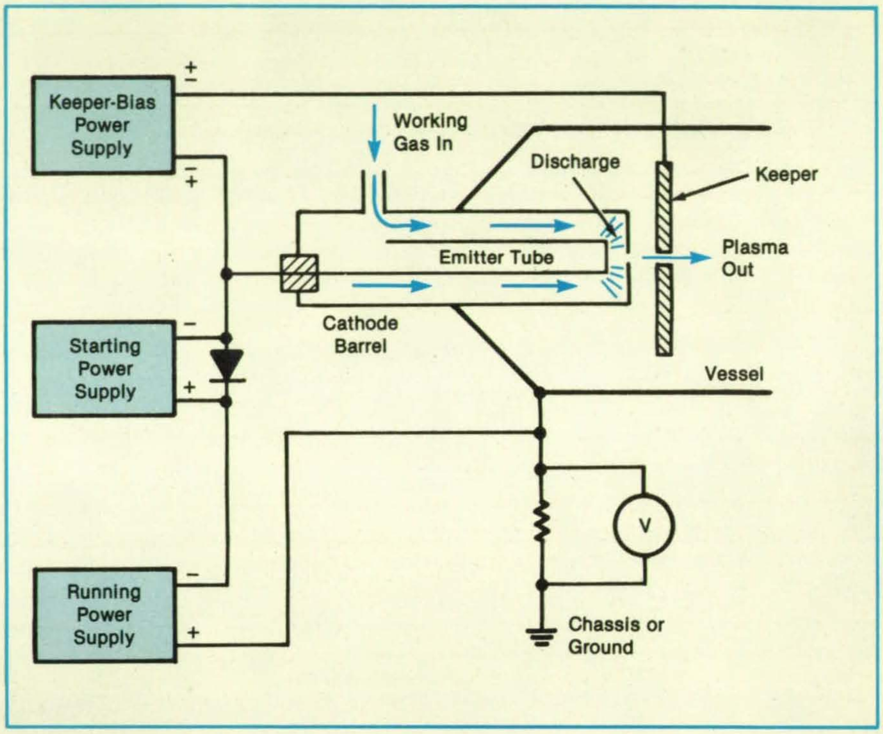
Hollow-Cathode Source Generates Plasma

Exposure to air and moisture does not degrade performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

A device generates an argon, krypton, or xenon plasma via thermionic emission and electrical discharge within a hollow cathode and ejects the plasma into the surrounding vacuum. The device goes from a cold start up to full operation in less than 5 s after the initial application of power. It can be exposed to moist air between operations without significant degradation of its starting and running characteristics. Designed for the neutralization of static electrical charges on spacecraft, the device might be modified for use as a source of plasma in laboratory experiments or industrial processes.

The source includes an emitter tube within the hollow cathode barrel and a keeper electrode just outside the orifice at the end of the barrel (see figure). A flow of the working gas is established within the barrel, and a starting potential of 300 to 400 V is applied, causing the cathode barrel to act as an anode with respect to the emitter tube. Initially, the working gas breaks down electrically in a glow discharge to the end of the emitter tube. Bombardment by ions from the discharge heats the end of the tube to thermionic temperatures within the short starting time. (The much larger heat capacity of the cathode barrel prevents the barrel from heating significantly during the starting process.)



Plasma Is Generated by an electrical discharge in the cathode barrel that sustains and is aided by thermionic emission from the emitter tube. The emitter tube does not depend on rare-earth oxides, which would make it vulnerable to contamination by exposure to the atmosphere.

The emitter tube then begins to emit electrons, and the discharge changes from a glow to an arc. In this condition, the device is considered to be "on" and acts as a stable source of dense plasma. The arc discharge is sustained at the lower barrel/emitter potential of about 55 V. The discharge consumes about 350 W during startup and about 100 W during steady operation.

Flows of plasma containing either predominantly electron or predominantly ion currents are extracted through the orifice in the cathode by applying positive or negative bias, respectively, to the keeper electrode. Electron currents from 20 mA to 6 A and ion currents up to 352 μA have been demonstrated. Ambipolar diffusion ensures that a plasma will be drawn from the cathode at keeper biases up to a few tens of volts.

The tip of the emitter tube is optimized for the minimum heat capacity (for rapid startup and low consumption of power) consistent with adequate mechanical strength. The emitter tube is made of pure tantalum, which can be exposed to humid air, then placed in a vacuum again and restarted with no adverse effects. Because this tube is not impregnated (as many cathode tubes are) with rare-earth oxides to lower its electron work function, there is no need to take the customary precautions to prevent contamination of the oxides by exposure to the atmosphere.

The dimensions (e.g., orifice diameter 1.00 mm) and separation (1.83 mm) of the emitter tube and the cathode barrel are chosen so that the stagnation pressure of the working gas is in the proper range [about 2 torr (270 Pa)] for a minimum-potential glow discharge. The rate of flow of the gas is chosen to yield this pressure.

This work was done by W. D. Deininger, G. Aston, and L. C. Pless of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 67 on the TSP Request Card.*
NPO-16992

Diode-Laser Doppler Velocimeter

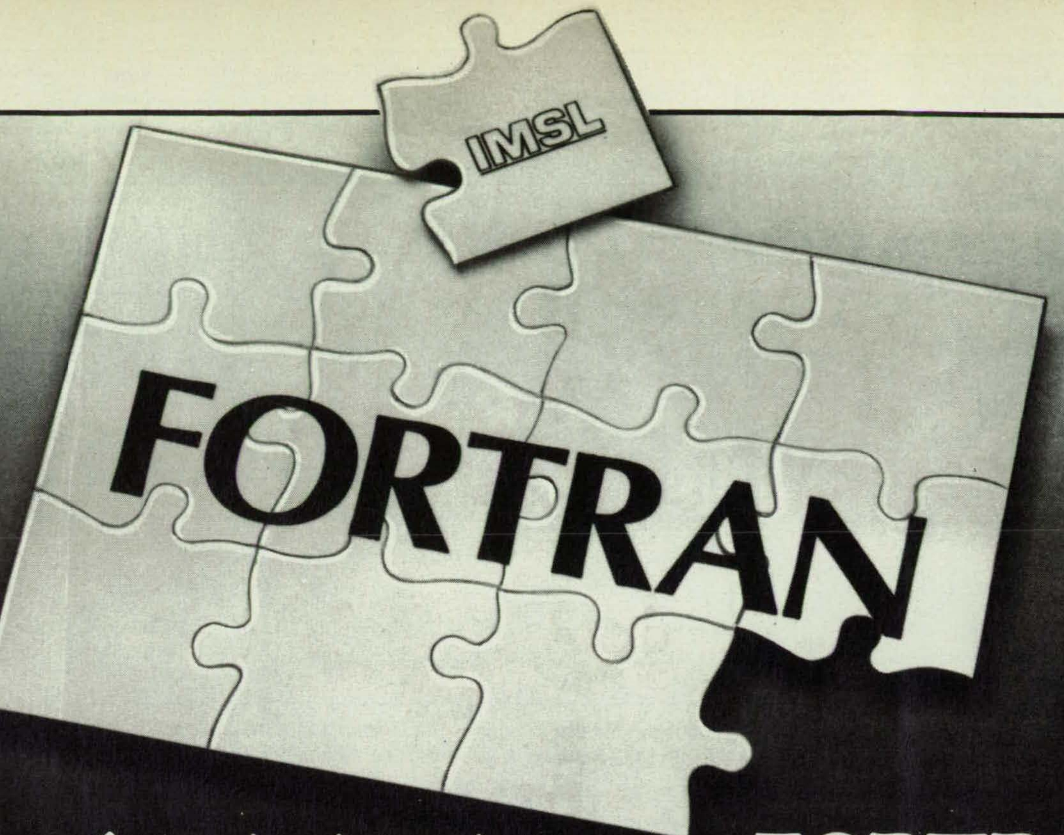
Features include ruggedness and compactness.

Marshall Space Flight Center, Alabama

A diode-laser Doppler velocimeter measures nonintrusively the flow of an incompressible fluid in a narrow tube. In comparison with other flowmeters suitable for this purpose, the new velocimeter is rugged, compact, and competitive in cost.

The velocimeter includes a three-section optical head (see figure) and a separate electronics module. The right section houses a laser diode that operates at a wavelength of ~780 nm. A thermoelectric cooler controls the temperature of the laser diode to keep the wavelength stable. An optical flat splits the output beam from the laser into two beams, which are then focused by a lens.

The middle section of the optical head contains the tube, which is equipped with



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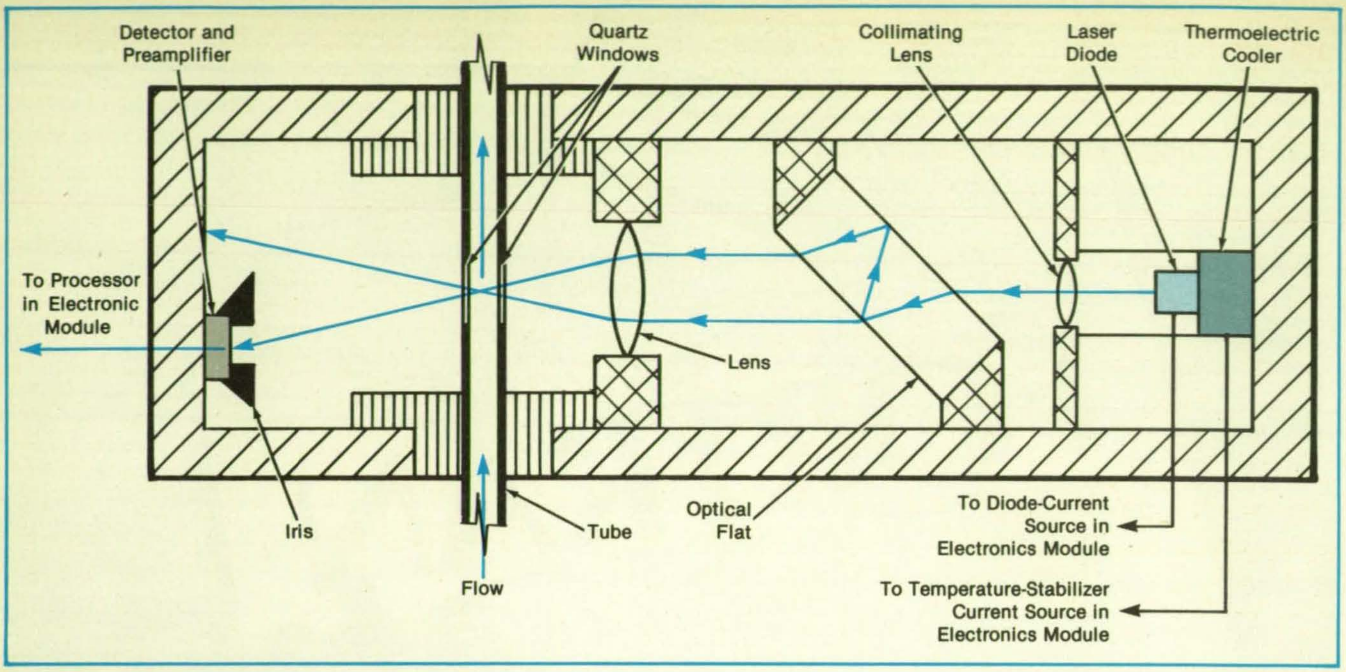


The **Diode-Laser Doppler Velocimeter** includes a compact, rugged three-section optical head that is mounted on the tube containing the flow. In a slightly different version, a beam splitter and mirror would be used to split the laser beam into two beams.

quartz windows for optical access to the flow. The focused beams intersect at the measuring position in the flow. The left section of the optical head contains the heterodyne receiver, which consists of a positive/intrinsic/negative photodiode with an iris aperture and preamplifier.

The electronics module contains current sources that drive the diode and the thermoelectric cooler. It also contains circuits to process the output of the receiver. The output of the processing electronics is fed to display electronics, which are also included in this module.

This work was done by Gregory J. Getzer of OPHIR Corp. 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 [see page 14]. Refer to MFS-26104

Etalons Help Select Modes of Laser Diodes

Stability under changes of temperature and current is increased.

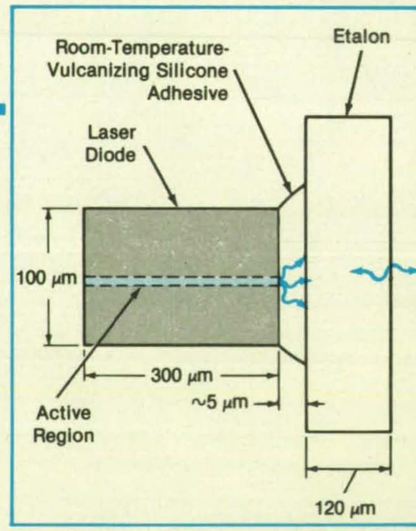
Goddard Space Flight Center, Greenbelt, Maryland

An external etalon aligned with a laser diode can provide optical feedback that enhances the stability of operation in one or a few of the longitudinal laser modes. The selection of longitudinal modes is necessary to keep wavelengths within the required ranges for optical communication systems and other systems that involve the wavelength-dependent combination of laser beams. The mode-selection problem arises because the output of a typical laser diode contains multiple longitudinal modes and/or hops from one mode to another as the temperature or the diode current changes.

The etalon provides an amount of feedback that varies periodically with wavelength. The superposition of this feedback on the gain versus wavelength of the laser diode reduces the threshold loss(es) of the mode(s) near the peak(s) of the feedback vs. wavelength more than it reduces the threshold loss(es) of other modes. Consequently, lasing in the mode(s) near the feedback peak(s) is favored over lasing in other modes. The etalon also helps to increase stability by reducing the sensitivity to minor feedback from external objects other than the etalon itself.

The figure illustrates an experimental configuration used to test the etalon-feedback concept with two types of AlGaAs laser diodes. The cover glass of each diode was removed. The clear room-temperature-vulcanizing silicone-rubber adhesive provided a good match between the indices of refraction of the diode and of the uncoated, fused-silica etalon. The thickness of the etalon was chosen to obtain feedback with intensity peaks 1.9 nm (5 to 6 longitudinal modes) apart in wavelength.

Measurements were performed on three types of commercial AlGaAs laser diodes. Two of these were tested both without and with the external etalon. The third, of a type called "thin, tapered thickness" (TTT), was tested without the external etalon, in its original package. Without the external etalon, the first two diodes exhibited hops to longitudinal modes two to three modes away, consistent with etalon feedback from their cover glasses. The mode hops of the TTT diode were larger because of what amounts to in effect an etalon within the diode structure. That is why the external etalon was not used with this diode.



The **External Fabry-Perot Etalon** provides feedback that helps to stabilize the operation of the laser diode in a single longitudinal mode. In some laser diodes, some etalon feedback is provided by reflections from cover glasses and/or from internal diode structures.

With the external etalon, the first three laser diodes put out single modes, without hops, over temperature ranges of 8 °C in continuous-wave operation and 4 °C in

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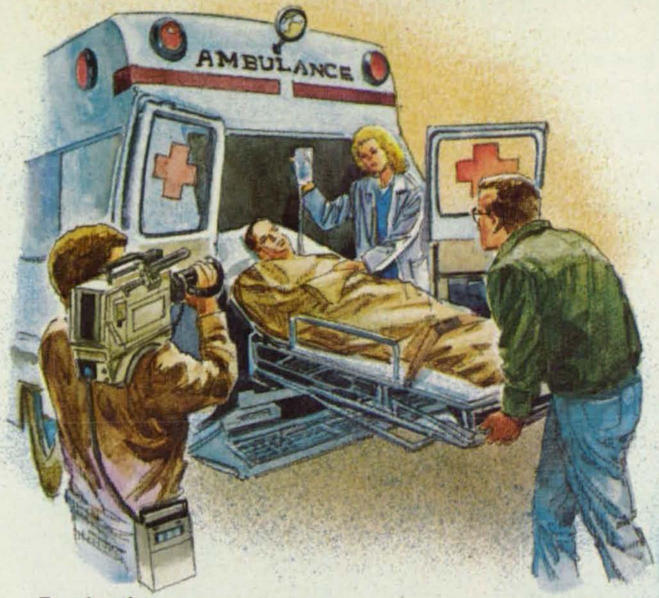

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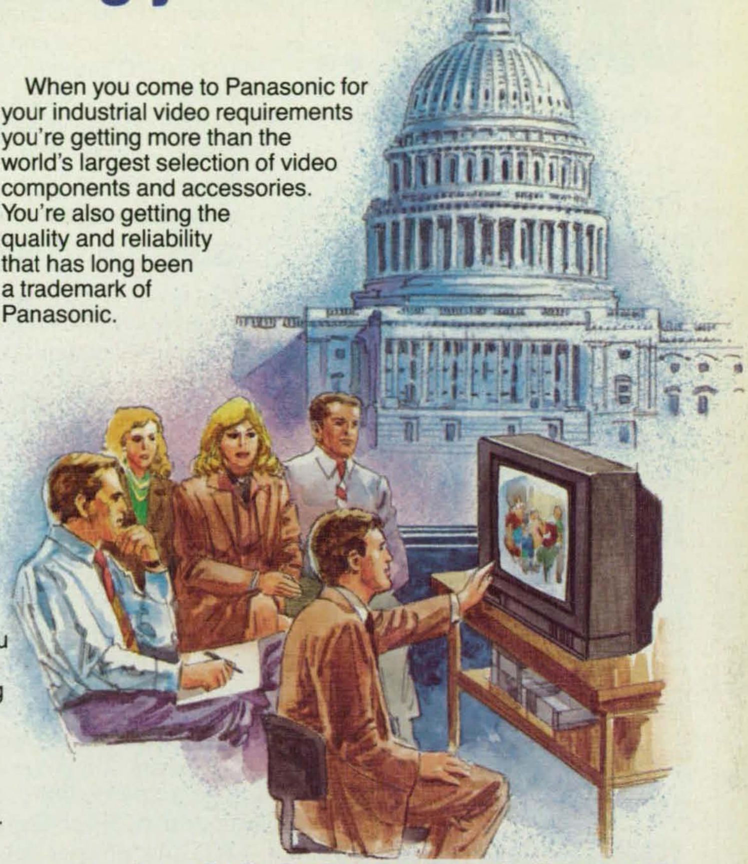

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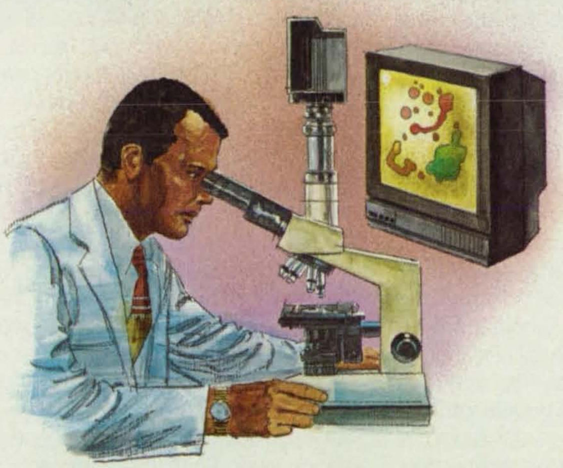

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pulsed operation, with 0.07 nm/°C tuning. The unmodified TTT diode put out a single mode over temperature ranges of 10 °C (continuous-wave) and 2 °C (pulsed), with 0.08 nm/°C tuning. The time-resolved behavior of both types of laser diodes showed single-mode lasing within the proper temperature ranges, with minor modes present only early in the pulse if at all. Preliminary aging tests indicate stability to within one longitudinal mode after a few hundred hours of operation, and expected lifetimes of at least several thousand hours.

This work was done by William L. Maynard of **Goddard Space Flight Center**. *For further information, Circle 69 on the TSP Request Card.*
GSC-13235

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Laser Rayleigh-Scattering During Space Shuttle Entry

The density of the atmosphere around the flightpath would be measured.

A report presents a detailed study of the capabilities and the requirements for the equipment of a proposed ultraviolet Rayleigh-scattering instrument to be carried aboard the Space Shuttle. Using a pulsed ArF excimer laser operating at a wavelength of 193 nm, the instrument would measure the density of the upper atmosphere in the vicinity of the flightpath, with an uncertainty of less than 1 percent and a spatial resolution of 1 km, over the range of altitudes from 50 to 90 km. With this accuracy and resolution, the measurements should be adequate for the detection of small-scale meteorological structure that can affect the analysis of flight dynamic data of reentering spacecraft.

Rayleigh scattering is attractive because it is the simplest of all radiative interactions with gases. In essence, it can be described as the nonresonant elastic scattering of light by molecules. The scattered light is at nearly the same wavelength and bandwidth as those of the source, and its intensity is proportional to the number density of the particles. The cross section for Rayleigh scattering increases sharply with decreasing wavelength, but in the absence of resonance-enhancement effects, it has no sensitivity to any resonant transitions in the gas and is therefore insensitive to the temperature.

In the case of backward scattering from gases, the intensity of the scattered light is also independent of the polarization of the incident light. Furthermore, in air at ambient temperatures, the yield of photons from Rayleigh scattering is greater than that from any other radiative interaction. Hence, the restrictions on the energy and spectral qualities of the laser are minimal. The ArF laser and its wavelength of 193 nm were chosen to take maximum advantage of the large Rayleigh signal and the low solar background at that wavelength.

In the proposed instrument, the laser beam would emerge from the window in the middeck crew hatch and propagate perpendicularly to the longitudinal axis of the vehicle. The light scattered backward by the ambient air would be collected during each pulse by optics attached to the inside of the window. For this application, the collection optics would be arranged so that only light scattered from the length of the beam beyond the shock layer would be detected. The intensity of the scattered light would be integrated over a selected period following each pulse, then divided by the laser-pulse energy to obtain a signal proportional to the ambient density in the observed length of the beam.

For this kind of measurement, the performance of the laser is characterized primarily in terms of its average power, which should be at least 0.6 W to yield an adequate signal-to-noise ratio. In practice, one would most likely use a commercial laser of about 5 W. Extrapolating from tests on a commercial laser, it appears that the laser and its power and gas supplies would have a total mass up to 300 kg and would require 1 to 2.5 kW of electric power and 1 gpm (0.06 L/s) of liquid coolant.

The authors also discuss extensions of the concept to measurements of the location of, and the density as a function of position in, the shock wave of the Space Shuttle. The same ultraviolet system would be used to take time- and space-resolved Rayleigh-scattering measurements of the shock layer. Such measurements would provide baseline data for verification of computer models of high-enthalpy hypersonic, nonequilibrium, and viscous conditions.

This work was done by Robert L. McKenzie of **Ames Research Center**. *Further information may be found in AIAA paper A87-43052, "A Method of Atmospheric Density Measurements During Shuttle Entry Using UV Laser Rayleigh Scattering."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.
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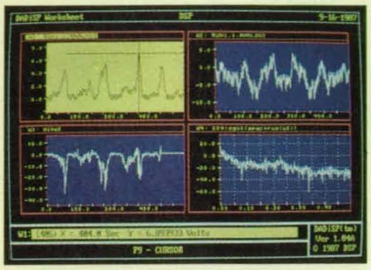
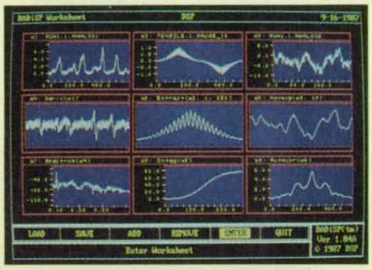




Silver Ink for Jet Printing

There are no silver particles to foul the printing head.

NASA's Jet Propulsion Laboratory, Pasadena, California

A metallo-organic ink containing silver (with some bismuth as an adhesion agent) is applied to printed-circuit boards and pyrolized in air to form electrically conductive patterns. The ink contains no particles of silver, does not have to be mixed during use to maintain homogeneity, and can be applied to the boards by ink-jet printing heads.

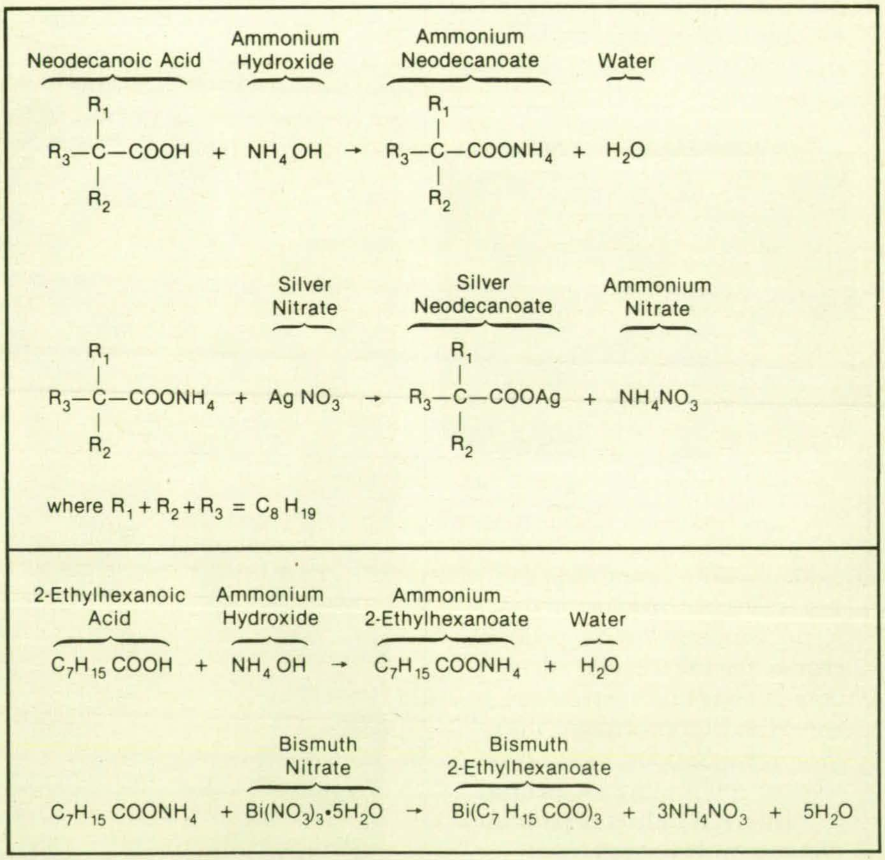
The ink consists of silver neodecanoate and bismuth 2-ethylhexanoate dissolved in xylene and/or toluene. In an experimental synthesis, ammonium neodecanoate soap was prepared by reacting neodecanoic acid with ammonium hydroxide; this soap was then reacted with silver nitrate, producing impure silver neodecanoate and ammonium nitrate (see figure). The silver neodecanoate was washed and dried, forming a white, powdery solid that was stored in dark bottles.

Similarly, ammonium 2-ethylhexanoate soap was prepared from 2-ethylhexanoic acid and ammonium hydroxide. The soap was reacted with a clear solution of bismuth nitrate in nitric acid. The resulting white oil of bismuth 2-ethylhexanoate was extracted in toluene or xylene and dried over molecular sieves.

To prepare the ink, the silver neodecanoate was dissolved in xylene or toluene, and the solution was assayed by thermogravimetric analysis to determine the fractional weight of silver. The bismuth 2-ethylhexanoate was analyzed similarly to determine the fractional weight of bismuth oxide produced on thermal decomposition. The two solutions were then mixed to obtain an ink that, upon thermal decomposition in air, would leave a residue of 99 weight percent silver and 1 weight percent bismuth oxide. Three drops of neodecanoic acid per 100 mL of ink were added as a stabilizer.

The viscosity of the ink was measured and adjusted to bring it into the range of 3 to 10 mPa•s. The viscosity was decreased by adding toluene or xylene, then increased by bubbling dry nitrogen through the ink to evaporate the toluene or xylene. The ink was stored in a tightly-covered amber bottle until needed.

This work was done by R. W. Vest and Saraswathi Singaram of Purdue University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 38 on the TSP Request Card. NPO-17153*



These **Two Sequences of Reactions** are used to prepare the main ingredients of the ink.

Making MgO/SiO_2 Glasses by the Sol-Gel Process

Melting to form glasses having liquid-liquid immiscibility is not necessary.

Lewis Research Center, Cleveland, Ohio

Silicon dioxide glasses containing as much as 15 mole percent magnesium oxide have been prepared by a sol-gel process. Such glasses cannot be made by conventional melting because the ingredients are immiscible liquids.

The sol-gel process involves the hydrolysis and polycondensation of silicon tetraethoxide [$Si(OC_2H_5)_4$] and magnesium nitrate hexahydrate to form a clear gel (see figure). Because the free energy of a gel is higher than that of a glass of the same composition, the gel can be converted into glass at temperatures far below the liquidus temperature. Besides producing glasses of new composition at lower processing temperatures, the sol-gel method leads to improved homogeneity and higher purity.

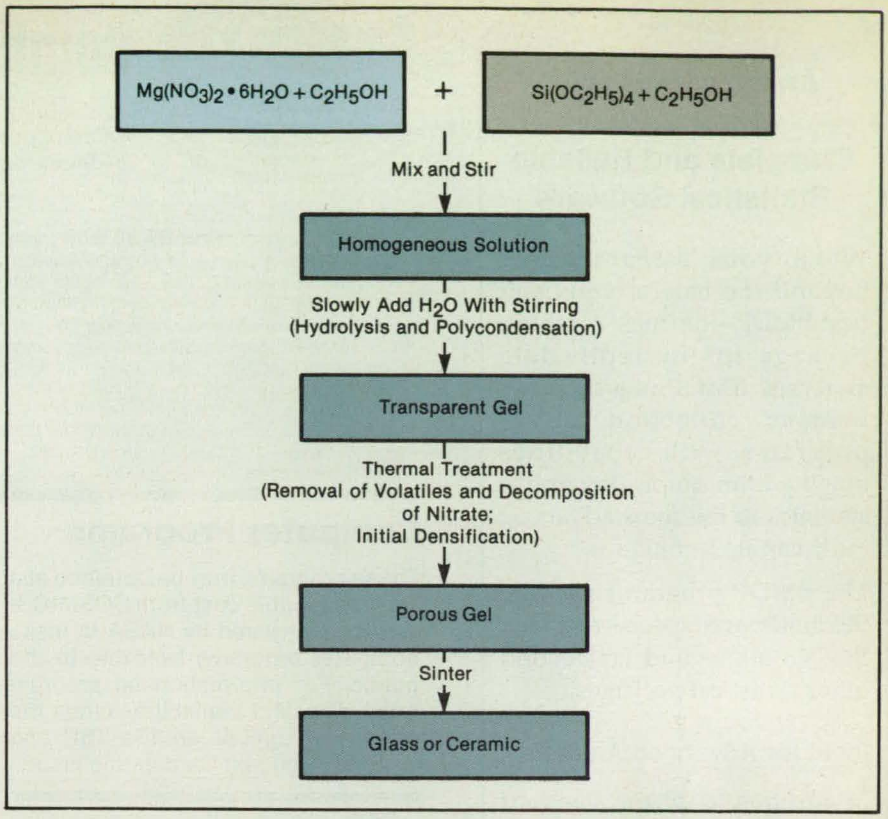
In experiments, magnesium nitrate hexahydrate was dissolved in alcohol and stirred with $Si(OC_2H_5)_4$ that had been diluted in alcohol. Water was added, drop by drop, and stirred in vigorously. The alcohol acted as a mutual solvent for $Si(OC_2H_5)_4$ and water, which are immiscible with each other. A clear, homogeneous solution resulted.

The solution was allowed to stand for gelling, in some cases at room temperature and in other cases in a warm, constant-temperature bath. Gelation took several hours to many days, depending on the ratio of water to $Si(OC_2H_5)_4$, the concentration of magnesium, and the temperature. The gels were clear and monolithic and cracked into smaller pieces when dried for several days at room temperature. The dried gels were then sintered into glasses at temperatures up to 1,200 °C.

No organic groups were detected in glasses heated to 800 °C, but infrared spectroscopy showed trace amounts of hydroxyl groups even in specimens heated to 890 °C. No crystalline phase was found in x-ray diffraction of samples heated to 890 °C. Alpha quartz was identified as the crystalline phase in gels heated to 950 °C.

This work was done by Narottam P. Bansal of ***Lewis Research Center****. Further information may be found in NASA TM-89905 [N87-23750], "Sol-Gel Synthesis of MgO-SiO$_2$ Glass Compositions Having Stable Liquid-Liquid Immiscibility."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14714



The **Synthesis of MgO/SiO$_2$ Glass** starts with the mixing of magnesium nitrate hexahydrate with silicon tetraethoxide, both in alcohol. Water is added, and a transparent gel forms. Subsequent processing converts the gel into a glass.

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the 1988 *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Mechanics

Simulating the Gamma-Ray Observatory Spacecraft

Positions, orientations, torques, sensor data, and actuator commands are generated as required by the user.

The Gamma-Ray Observatory (GRO) spacecraft will constitute a major advance in γ-ray astronomy by offering the first opportunity for comprehensive observations in the range of 0.1 to 30,000 MeV. The Gamma Ray Observatory Attitude Dynamics Simulator (GROSS) computer program is designed to simulate this mission.

GROSS consists of three separate programs: the stand-alone profile program; the simulator program, which contains the simulation control input/output (SCIO) subsystem, the truth model (TM) subsystem, and the on-board computer (OBC) subsystem; and the postprocessor program. The stand-alone profile program mathematically models the environment of the spacecraft and generates a set of profile data for use by the simulator. This set contains such items as individual external torques; ephemerides of the GRO spacecraft, of the Tracking and Data Relay Satellite (TDRS), and of the Sun and Moon; and data on stars. The stand-alone profile program is run before a simulation.

The SCIO subsystem is the executive driver for the simulator. It accepts input from the user, initializes parameters, controls simulation, and generates output files of data and a display of the status of the simulation. The TM subsystem models the sensors, actuators, and dynamics of the spacecraft. It accepts ephemerides, data on stars, and environmental torques from the stand-alone profile program. With these and actuator commands from the OBC subsystem, the TM subsystem propagates the current state of the spacecraft and generates sensor data for use by the OBC and SCIO subsystems.

The OBC subsystem uses sensor data from the TM subsystem, a Kalman filter (to determine the attitude), and control laws to compute actuator commands to the TM subsystem. The OBC subsystem also provides output data to the SCIO subsystem for output to the analysts.

The postprocessor program is run after simulation is completed. It generates printer and cathode-ray-tube plots and tabular reports of the simulated data at the direction of the user.

GROSS is written in FORTRAN 77 and assembler and has been implemented on a VAX 11/780 computer under VMS 4.5. It requires a virtual memory of 255K. GROSS was developed in 1986.

This program was written by J. Garrick of **Goddard Space Flight Center**. *For further information, Circle 26 on the TSP Request Card.*
GSC-13147

Computing Stress, Stability, and Vibration of Shells

Complicated, branched shells of revolution are analyzed by a finite-difference energy method.

The BOSOR4 computer program was developed as a comprehensive program for the analysis of stress, stability, and vibration of complex, branched shells of revolution made of elastic materials. It can be

used to analyze prismatic shells and panels. BOSOR4 performs large-deflection axisymmetric stress analysis, small-deflection nonsymmetric stress analysis, modal vibration analysis with axisymmetric nonlinear prestress included, and buckling analysis with axisymmetric or nonsymmetric prestress. One of the main advantages of the BOSOR4 code is the provision for such realistic engineering details as eccentric load paths, internal supports, arbitrary branching conditions, and a "library" of wall constructions.

The program is based on the finite-difference energy method and offers very rapid convergence with increasing numbers of mesh points. The BOSOR4 analyses are based on minimization of energy with constraint conditions. The total energy of the system is taken to include the strain energy of the segments of the shell, the strain energy of the discrete rings, the potential energy of applied line loads and pressures, the kinetic energy of the shell segments, and the kinetic energy of the discrete rings.

The constraint conditions arise from displacement conditions imposed anywhere in the composite shell and from conditions of compatibility between segments and branches of the composite shell. These components of energy and the constraint conditions are expressed in differential form in terms of the components of displacement of the reference surface of the shell at the finite-difference mesh points and in terms of the Lagrange multipliers. The integration is performed numerically by means of the trapezoidal rule. Now in algebraic form, the energy is minimized with respect to the discrete dependent variables.

The BOSOR4 program is written in FORTRAN 77 for interactive execution. It was developed on a DEC VAX 11/780 computer under VMS 4.0. It has a central-memory requirement of approximately 984K. With use of the DI-3000 plot library (available from Precision Visuals), the program plots the shape of the prebuckling state, buckling, or vibration mode. The BOSOR4 program was developed in 1986.

This program was written by David Bushnell of Lockheed Palo Alto Research Laboratory for **Langley Research Center**. *For further information, Circle 64 on the TSP Request Card.* *LAR-13940*

Computing Optimal Multiarc Trajectories

Impulsive changes of velocity and finite burns are options.

The Optimal Multi-Arc Trajectories (OMAT) computer program is designed to calculate a solution to the optimal-trajectory problem in cases of low thrust-to-weight ratios. This formulation is logical and concise, making maximum use of vector•matrix algebra. It is also "error-free" and attempts to anticipate unexpected errors and situations that would hinder the continuity of the solution.

The OMAT program is developed for a two-body exoatmospheric problem with three degrees of freedom in an inverse-square force field. The program offers two different options: impulsive changes in velocity and finite burns with low thrust-to-weight ratios. Therefore, two distinct solutions are available from the program — the optimal multi-impulse (OMI) solution and the optimal multiburn (OMB) solution.

The two solutions can be obtained separately, or the results of the OMI solution can be used to guess the unknown parameters of the OMB solution. This capability allows for nearly automatic design of missions without the requirement to guess controls. The state, costate, and variational equations are propagated numerically on the burn arcs with a unique Runge-Kutta-Nystrom integrator and analytically on the coast arcs. A combined gradient/Newton-Raphson iterator adapts readily to any reasonable guess of the unknown elements in the parameter vector.

This program is written for the DEC VAX-series computer. It is written completely in FORTRAN 77 and has a central-memory requirement of 232,000 8-bit bytes. The program was made available in 1987.

This program was written by Donald J. Jezewski of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information, Circle 6 on the TSP Request Card.* *MSC-21112*

Mechanics

Multiple-Boundary-Condition Vibration Tests

Experiments build confidence in this emerging technique.

NASA's Jet Propulsion Laboratory, Pasadena, California

The multiple-boundary-condition testing method is gaining acceptance as a technique to improve the analysis of vibrations in large structures. The method was conceived for the vibrational testing, in a terrestrial environment, of large, complicated three-dimensional structures intended for use in outer space. The objective of such testing is to identify the parameters (e.g., nodal masses, stiffnesses of elements, and other quantities related to the shapes, sizes, and frequencies of vibrational modes) of mathematical models used to predict the vibrations of such structures in the absence of gravitation and air. The technique has potential terrestrial uses in the testing and evaluation of the dynamics of towers and offshore structures and of the safety of large buildings in Earthquakes.

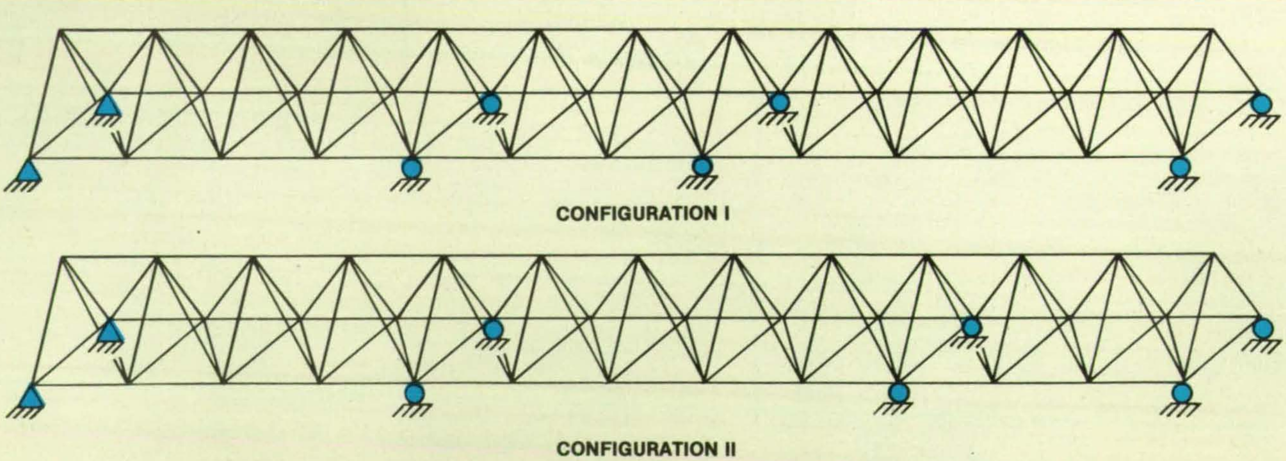
The multiple-boundary-condition test method can help in overcoming the distorting effects of the atmosphere and mechanical supports, which can overwhelm the effects that one seeks to measure. In this method, the structure is supported and/or restrained at several positions; the structure is excited at the desired vibrational frequencies, and the vibrations are measured to determine the characteristics of the vibrational modes. The supports and/or restraints are then moved to different positions and the tests conducted anew to measure the resulting new vibrational modes. This procedure may be repeated several times under different support/restraint (boundary) conditions.

No single test of this type yields data on all the parameters of the structure, and, in particular, a test yields no data on the parameters of the parts located at the restraints. However, each test under different boundary conditions excites different portions of the structure and can be related to a small subset of the total mathematical formulation; this facilitates the modification or verification of the affected parts of the mathematical model, and recent theoretical developments make it possible to determine quantitatively the sensitivities of the parameters to the results of a given test. In addition, many different combinations and positions of the mechanical constraints can be used to obtain many different estimates of any desired parameter. Statistical theory suggests that the data from many different boundary conditions can increase the accuracy of the mathematical model.

Experiments were performed on an aluminum beam of uniform cross section, an aluminum beam of two different cross sections alternating along the length, and a 12-bay truss structure. These structures were simply supported at their ends and at various intermediate positions (see figure). Each beam was tested in four and the truss in two different configurations of supports. In each case, the vibrational data were used to update a mathematical model of the affected structure containing deliberately and grossly erroneous parameters of the beams and cross-sectional areas of the truss members (areal moments of inertia of which the true values were known), to test the corrective power of the multiple-boundary-condition approach. In all cases, the test data led to updated parameters within a few percent of the true values.

This work was done by Chin-Po Kuo and Ben K. Wada of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 125 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA's Jet Propulsion Laboratory [see page 14]. Refer to NPO-17351.



This **Truss Was Tested** by measuring its vibrations in different configurations of supports. Test data obtained from multiple configurations are more useful than are data from one configuration, in which the supports could mask important effects.

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Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Chaotic Motion of a Two-Link Planar Mechanism

Even a simple dynamical system exhibits instability.

A report discusses global instability in the orbital motion of a two-link planar mechanism. A principal objective of this and related studies is to contribute to the understanding of chaotic motions in robot manipulators and other deterministic mechanical systems. In this context, "chaotic" and "unstable" are not restricted to their customary meanings but are also used to characterize motions that are deterministic and may even remain finite but are unpredictable over long times.

The discussion begins with a brief review of previous studies of chaotic motion and introduces the notion of orbital instability in nonlinear systems. The authors introduce a geometric approach that is useful in the representation of orbital instability. If the equations of a conservative, frictionless dynamical system can be put in the form of the equations of a point mass moving on a smooth nonplanar surface in the absence of external forces, then, analogously to the motion of the point mass, the evolution of the system can be represented as a motion along a geodesic line on the surface.

A measure of the chaos in the motion is provided by the distance $d(t)$ between two systems that started moving on two geodesics a small distance d_0 apart at $t = 0$ (where t = time or other parameter that characterizes the motion along the trajectory). From differential geometry

$$d(t) = d_0 \exp(t\sqrt{-G})$$

where G = the Gaussian curvature. Thus, if the curvature is negative, the separation increases exponentially with time; i.e., the system is unstable or chaotic. If the curvature is positive, the separation oscillates, bounded by its initial value. (This is a necessary but not a sufficient condition for stability.)

The geometric approach is applicable to the two-link planar mechanism. The kinetic energy, E, of this system is given by the nonlinear equation

$$E = a_{11}\dot{f}_1^2 + a_{12}(f_1, f_2)\dot{f}_1\dot{f}_2 + a_{22}\dot{f}_2^2$$

where a_{11} and a_{22} are moments of inertia; a_{12} is a coordinate-dependent product of inertia; f_1 and f_2 are the angles between the first and second links, respectively, and an inertial coordinate axis; and the overdots represent derivatives with respect to time. This equation is equivalent to that of a point mass moving on a two-dimensional surface characterized by coordinates f_1, f_2 and a curvature G that can be calculated as a function of f_1 and f_2.

It turns out that the sign of G depends only on $\cos(f_2 - f_1)$. Therefore, the system is orbitally stable in some regions of the f_1, f_2 plane but not in others. In particular, folded-arm configurations tend to be orbitally unstable (as one might expect intuitively), while extended-arm configurations tend to be orbitally stable. Furthermore, the orbit of the system can pass through both stable and unstable regions.

Because the instability causes the arms to unfold eventually, it is apparent that no trajectory can remain in the unstable region indefinitely. Though it is not obvious whether one can find a trajectory that remains in the stable region, the authors may have found one. In one of their numerical simulations of this system, the arms were stretched out at the start and continued to rotate around the origin almost as a single rigid rod.

This work was done by Anatoly Lokshin and Michail A. Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Chaotic Motion in Robot Manipulators," Circle 39 on the TSP Request Card.*
NPO-17387

Vibrating Beam With Spatially Periodic Stiffness

Vibrational modes are analyzed via a perturbation expansion.

A report presents a theoretical analysis of the vibrations of a simply supported beam, the bending stiffness of which varies about a steady value, sinusoidally with position along its length. This is a problem of practical importance because it is related to the vibrations of twisted-pair electric-power transmission lines. The twists are meant to promote the nonuniform shedding of vortexes and to prevent the resonant accumulation of vibrational energy from wind.

The beam is assumed to be long in comparison with its width and thickness, to have negligible rotary inertia about its centerline, and to undergo negligible dynamic shear distortions. Hooke's law is assumed to hold. The equation of motion for vibrations of the beam is written in the normal-mode form. The equation is put in a dimensionless form in which the sinusoidal variation of stiffness is represented as a fraction, ε, of the steady value.

The exact equation is a nonlinear fourth-order differential equation with variable coefficients. Because an exact analytic solution in closed form is not available, the author solves the equation approximately in closed form by expressing the eigenfunctions and eigenvalues as perturbation expansions to first or second order in ε.

The perturbation solutions are characterized in terms of the ratio P/n, where P is the number of half periods of the stiffness function in the length of the beam and n is the number of the vibration mode. These solutions exhibit two distinct ranges in which the effects of the perturbations are the strongest: $P/n < 1$ and P/n near 2. The results of the perturbation analysis are confirmed by a finite-element numerical simulation and by measurements of vibrations in a twisted-pair cable.

At $P/n = 1$, the maximum and minimum stiffnesses occur at the vibrational nodes in alternating sequence along the beam. An anomaly occurs at $P/n = 2$, when the lengths of the vibration loops match the period of the stiffness function, the nodes are at the points of maximum stiffness, and the antinodes are at the points of minimum stiffness. Furthermore, at the anomaly, the stiffnesses of the vibration loops vary most sharply with P/n, there is a jump in the natural frequency of vibration, and the perturbation solution loses some accuracy (though it is still adequate to describe the qualitative characteristics of the vibrations).

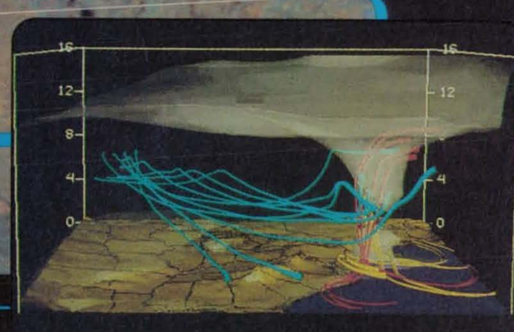
The changes in the shapes of the vibrational modes with changes in P/n can be explained in terms of energy principles. Apparently, there is a tendency toward minimization of the elastic strain energy stored in the dynamic span via adjustment of the lengths of the vibrating loops until the same average bending stiffness exists across each loop. Equalization of loop stiffnesses may require the loops to have different lengths depending on the vibrational mode. Because longer loops have greater masses, the equal distribution of potential (and, therefore, kinetic) energy among the loops requires that longer loops vibrate at smaller amplitudes.

This work was done by John S. Townsend of **Marshall Space Flight Center**. *Further information may be found in NASA TP-2697 [N88-23988], "Dynamic Characteristics of a Vibrating Beam With Periodic Variation in Bending Stiffness."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *MFS-27202*

Wisconsin

High Technology in the Heartland



Produced by NASA Tech Briefs in cooperation with Wisconsin Department of Development and Forward Wisconsin

Greetings:

For decades, Wisconsin built its reputation on its manufacturing prowess. Wisconsin still is a leading manufacturing state; in fact, in the last two years, Wisconsin manufacturers created one out of every ten new jobs generated in the entire country.

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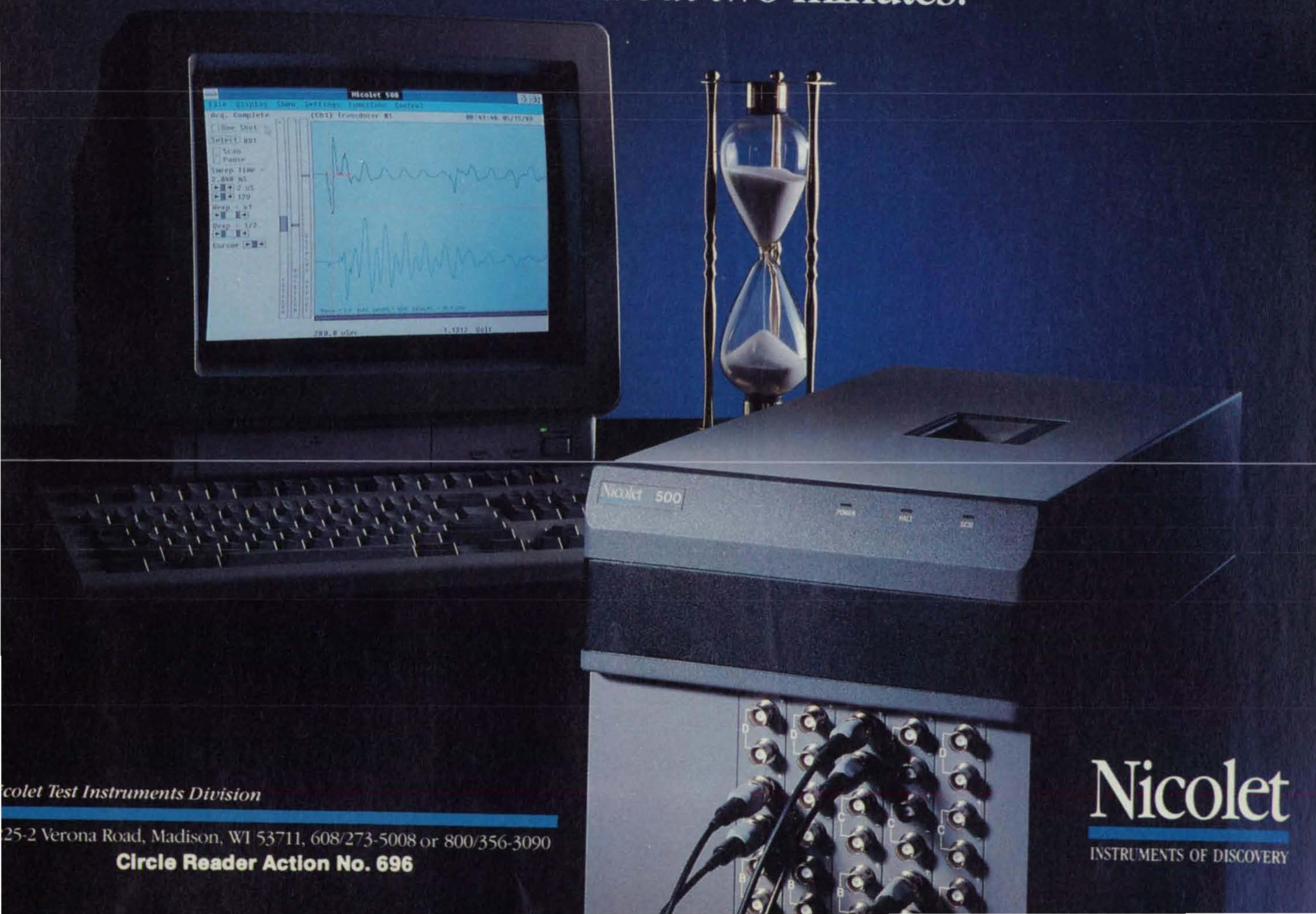

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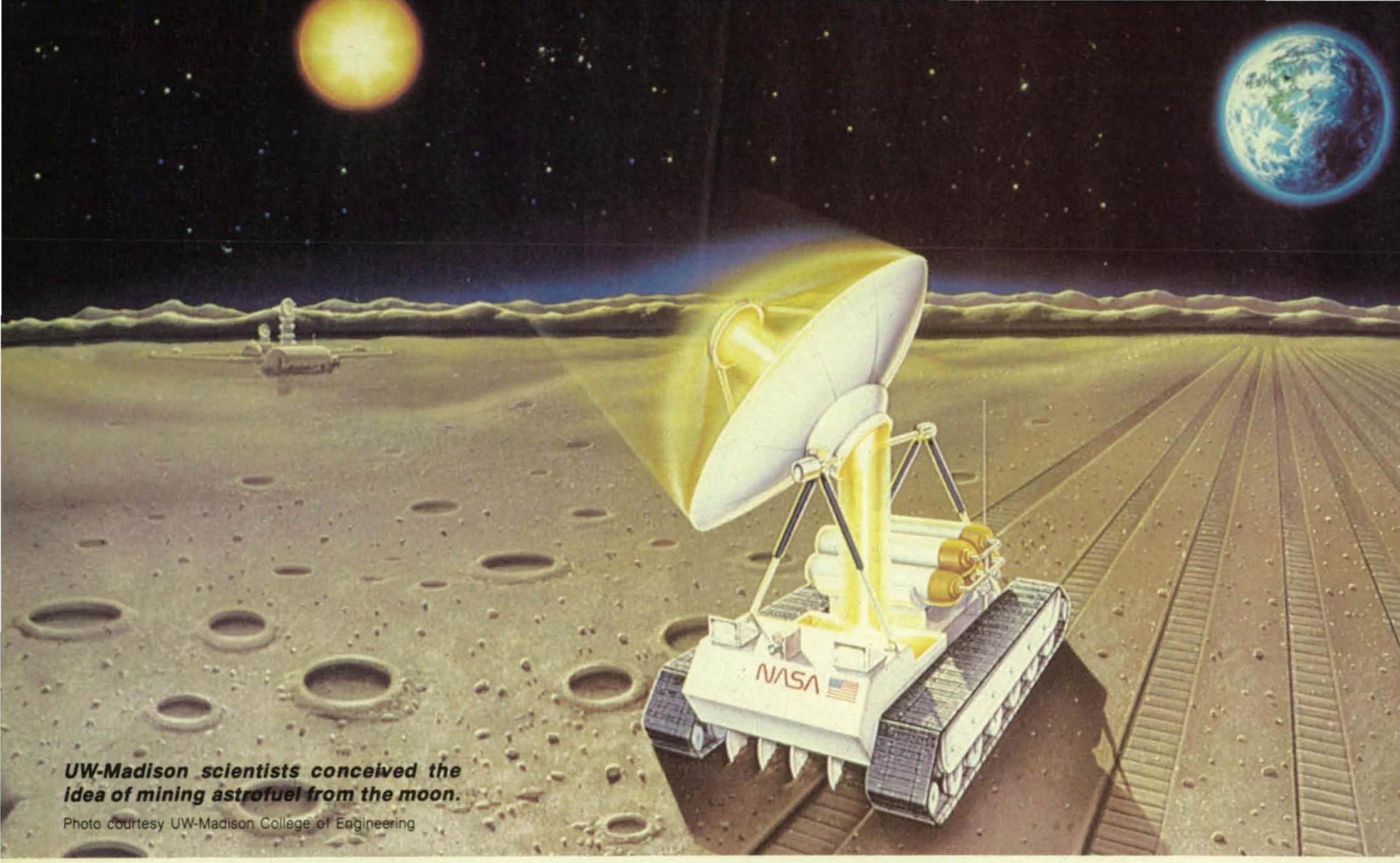


UW-Madison scientists conceived the idea of mining astrofuel from the moon.

Photo courtesy UW-Madison College of Engineering

From Vitamins To The First Eye In the Sky:

Space Science

Over the course of its 140-year history, the University of Wisconsin has forged an international reputation as a center of learning, discovery, and innovation. UW-Madison research has brought the world vitamins, photoelectric astronomy, the eradication of infantile rickets, hybrid corn, bone marrow transplants, the world's first orbiting observatory, digital subtraction angiography, and synthetic genes.

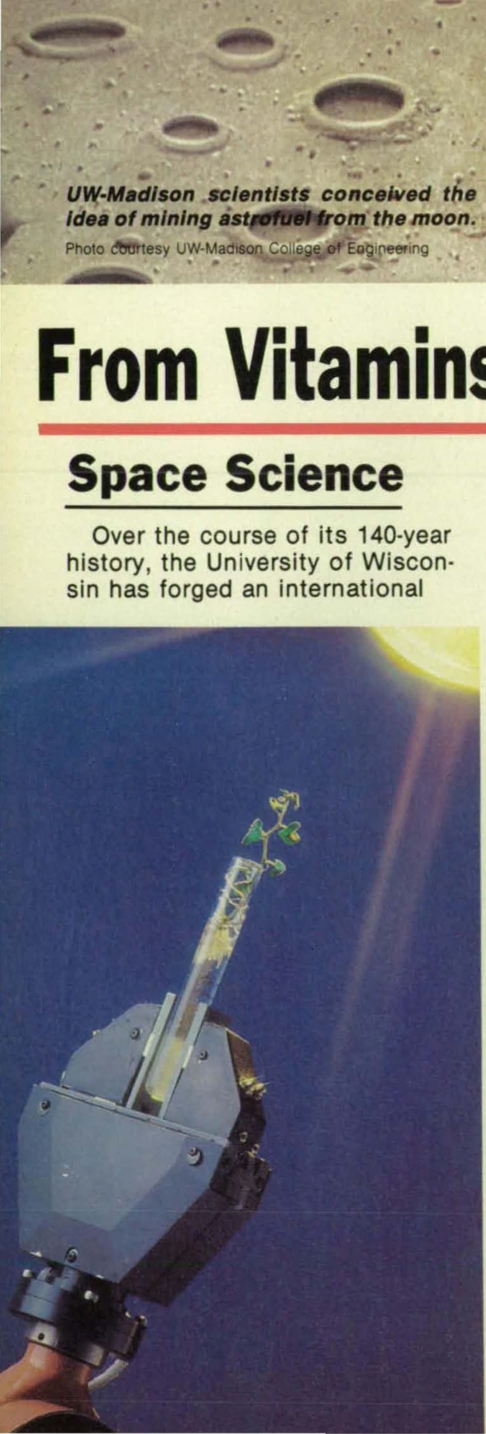


Photo courtesy UW-Madison College of Engineering

Researchers from the Wisconsin Center for Space Automation and Robotics plan to use robots in orbit and on the moon for plant growth and harvesting.

In the space sciences and astronomy, UW-Madison has few peers. NASA alone spends almost \$9 million annually to support Wisconsin research, and sustains projects ranging from studies of the effects of microgravity on living creatures to the development of a global interactive computer network to instantly track world precipitation.

The university houses the Wisconsin Center for Space Automation and Robotics (WCSAR), one of NASA's Centers for the Commercial Development of Space. WCSAR features three thrusts: astrobotics, astroculture, and astrofuel.

Astrobotics is geared to the creation of technologies that allow robots to perform routine and complicated tasks in space. By developing modular, add-on systems to enhance dexterity, sensory perception, performance, and telepresence in robots, humans will be able to safely extend their reach beyond the confines of spacecraft or space stations.

Astroculture focuses on the development of automated plant growth facilities for space. These "galactic gardens" promise to enhance life in space by providing a plentiful source of oxygen and food, and by removing carbon dioxide from the air and purifying water for long-duration space flights and permanently manned space stations.

The third research thrust, astrofuel, aims to design and develop equipment to mine the moon for helium-3, rare on Earth but abundant on the moon. Conservative estimates put the moon's helium-3 supply at one million metric tons. A spacecraft the size of the shuttle could bring back a liquified load of 20 tons, enough helium-3 to power the United States for a year.

Helium-3 would be the best possible fuel for nuclear fusion reactors because it would produce far less radiation than other potential fuels, said Gerald R. Kulcinski, a UW-Madison professor of nuclear engineering and the director of the astrofuel project.

The roots of space-based astronomy — the placing of telescopes and other astronomical instruments above the haze of the Earth's atmosphere — lie in UW-Madison's Space Astronomy Laboratory. When the rocket-powered X-15, considered to be the first true spacecraft, coursed above the atmosphere to begin the U.S. push into space, it carried with it four UW-Madison-built ultraviolet photometers.

UW-Madison astronomers next developed a payload of seven telescopes which were placed in Earth orbit in 1968 aboard the world's first space observatory, the Orbiting Astronomical Observatory (OAO), which resulted in the discovery of the hydrogen envelopes that surround comets and provided the first real evidence that stars are still being born throughout the galaxies.

The evolution of space astronomy continues at UW-Madison today as scientists prepare instruments to be launched aboard the giant Hubble Space Telescope (HST). Wisconsin astronomers built one of HST's five scientific instruments and helped in the development of two others. UW-Madison is the only university to have contractor status for an HST instrument, the High-Speed Photometer.

The photometer will act as a sophisticated light meter to measure the quick changes in a star's brightness, which could help astronomers locate black holes, objects so massive and compact that even light cannot escape their gravitational pull. The instrument may detect the variability of light produced by blobs of material as they make their last few orbits around the hole before being sucked in.

Much of the spaceflight hardware built on the UW-Madison campus emanates from the Space Science and Engineering Center (SSEC). Founded in 1965 by Verner Suomi, the pioneering scientist and meteorologist, SSEC specializes in studies of the planetary atmospheres, the construction of satellite hardware, and the development of powerful computing and imaging tools for meteorologists and space scientists.

Among SSEC planetary instruments is the Net Flux Radiometer, now aboard the Galileo planetary probe awaiting an October launch to Jupiter. After a six year voyage with its companion orbiter, the probe will descend below Jupiter's cloud tops and make the first direct measurements of the planet's atmosphere. The Net Flux Radiometer will measure solar and thermal energy fluxes which drive atmospheric motions on Jupiter.

Although putting hardware in space is the prime mission of SSEC, it is also a world center for the development of interactive computing systems capable of processing, organizing and displaying satellite images and other weather data in real time.

McIDAS, or Man Computer Interactive Data Access System, is the gold standard for such systems. Conceived and developed at SSEC, McIDAS uses three- and four-dimensional computer displays to home in on and provide a satellite's eye view of everything from severe storms to exploding volcanoes as they occur. With McIDAS, meteorologists can analyze the weather at varying scales — 10 to 100 miles — every minute.

The computerized weather system is used by the National Hurricane Center, the Air Force Geophysics Laboratory, the National Weather Service at its Centralized Storm Information Center in Kansas City, the Australian Bureau of Meteorology, and by NASA's Johnson Space Center to support shuttle flights.

To keep a close eye on weather systems that could disrupt their package delivery system, Federal Express in 1986 became one of the first commercial users of McIDAS. With McIDAS, Federal Express meteorologists can quickly alert pilots to changes in the weather that may affect flight operations.

In one example, a Federal Express flight to Salt Lake City had been deflected to Boise, Idaho, because of fog. Using McIDAS, company meteorologists noticed on a satellite image a downslope wind that was clearing the Salt Lake airport of fog. The plane was quickly rerouted, a trucking expedition to relieve the stranded jet of its cargo was cancelled, and the aircraft landed back at Salt Lake City within minutes of a predicted windshift that refogged the airport.

The imaging side of McIDAS is finding application at Madison-based Colorgraphics as a high-tech paintbrush for commercial and video artists. Computer hardware and software spawned from the McIDAS testbed underlie Colorgraphics' Artstar 3D Plus. "That machine is to commercial artists what the word processor is to writers," said Richard Daly, a Colorgraphics founder and former SSEC staffer.

Its principal applications, Daly said, lie in news and weather graphics, computer animation, and advertising. Colorgraphics customers include television stations in virtually every major market in the United States and an increasing number of foreign companies.

Scientists at the Astronautics Advanced Technology Center near Madison are working on a variety of space transportation and life-support systems, including this tactile spacesuit glove for astronauts.

Photo courtesy Astronautics Corp. of America

Wisconsin Research May Mean Longer Life For Industrial Tools

John Conrad and his colleagues are helping industry to get more punch from their punches.

Conrad, a University of Wisconsin-Madison professor of nuclear engineering and engineering physics, is researching ways to improve ion implantation, a technique that has been used for more than a decade to increase the life of surgical equipment, industrial tools, plastics, and ceramics. The process involves implanting a target, such as a steel punch or drill bit, with a thin layer of ions of a different substance, such as nitrogen. Ions are atoms with the electrons stripped off, leaving just the electrically charged nuclei.

Ion implantation may mean a tool such as a punch will last 80 times longer, Conrad said. Also, the cost of punches to produce 100,000 holes in a manufacturing process could drop from more than $1000 to under $40.

The conventional ion implantation method requires complicated equipment to scan the beam across targets and wastes many of the ion particles. In Conrad's technique, called Plasma Source Ion Implantation, or PSII, the target is placed directly into a vacuum chamber. The chamber is then filled with plasma ions, and pulsed high voltage is applied to the target to attract ions to it.

The simplicity and economy of PSII means corporations now forced to send materials away for ion implantation may be able to treat materials in-house. It also allows ion implantation of a variety of large, small, and odd-shaped industrial tools that cannot be economically implanted by conventional methods. Field tests of the new process are being run at several Wisconsin companies. □

Computers

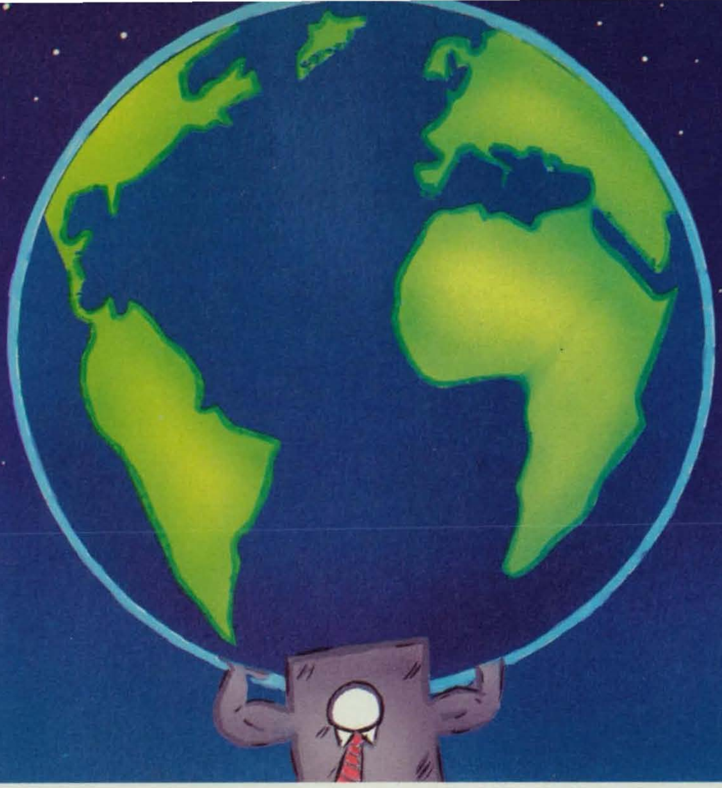
In 1972, Seymour Cray left Control Data Corp. — a company he helped establish 15 years earlier—and moved to his hometown of Chippewa Falls, in northwestern Wisconsin. There he started another company that would build supercomputers. He called it Cray Research Corp.

Seventeen years later, Cray supercomputers have revolutionized science and engineering while making the United States the world leader in a new billion-dollar industry.

Today, Cray Research is a Fortune 500 company with 5200 employees worldwide; 1988 sales were $756 million. Cray Research has designed, built and installed 240 of its systems, which represents approximately two-thirds of the world total.

Cray now has 15 complexes in Chippewa Falls, including a newly added machine shop and printed circuit board facility. In addition to building the supercomputers, Cray employees in Wisconsin produce circuit boards for the CRAY Y-MP and the CRAY-3 prototype. The Y-MP system, introduced in 1988, is regarded as the most powerful general-purpose computer available.

Cray Research continues to push the leading edge of technology in both hardware and software. Last year it introduced a new feature of its Fortran compiler called autotasking, which lets Cray users reap the benefits of parallel processing — the simultaneous application of two or more central processing units to a single problem. On a four-processor system, autotasking can result in performance improvements of up to 3.9



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- **The Janus/Ada Newsletter:** Our quarterly newsletter is mailed to all of our registered users, complete with up-to-date bug listings, programming hints, and articles of interest to the Ada programmer.
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times that of single-processor execution. On an eight-processor system, performance improves up to 7.8 times.

Steven Chen, a Cray Research alumnus, is heading a team of scientists and engineers who are designing a competing supercomputer with a parallel processor design. Chen's company, Supercomputer Systems Inc., has received substantial funding from IBM Corp. The first product rollout is not scheduled for several years.

In southern Wisconsin, Astronautics Corp. of America entered the mini-supercomputer market last year when it introduced the ZS-1, a high-speed, 64-bit central processor system for general scientific and engineering applications. Thus far, Astronautics has installed four of the systems — at the University of Wisconsin, the University of Michigan, New York University, and NASA's John C. Stennis Space Center in Mississippi.

Astronautics also designs and builds CRT displays and control consoles, flight instruments, guidance and navigation systems, computer systems and communications terminals, high-resolution monitors, and tank weapon fire-control systems.

At its Advanced Technology Center near Madison, Astronautics is developing a variety of space transportation, robotics, and life-support systems. The company is working with other industries, universities, and government institutions on solutions to weather, space, agricultural, and industrial problems.

Elsewhere in Madison, Heurikon Corp. designs and manufactures microcomputer boards and systems for such applications as medical and scientific image processing, flight simulation, automatic testing systems, securities trading, and gateway controls for computer communications.

Heurikon's image-processing equipment helped locate the sunken Titanic off the Newfoundland coast in 1985, and its processors currently are helping the National Archives in Washington, D.C., to record its holdings.

In the early 1980s, Heurikon moved into developing microcomputer boards for original equipment manufacturers when it introduced a line of 8-bit Multibus boards. Subsequently it brought out its 16-bit and 32-bit VME, as well as Multibus 1 and 2 microcomputers incorporating the powerful Motorola 68000 family of microprocessors based on chip architecture. Continuing to press for higher performance, Heurikon recently announced real-time RISC products incorporating state-of-the-art processors from Intel and National Semiconductor.

Heurikon has been ranked six times among *Inc. Magazine's* list of the top 500 fastest-growing privately-held U.S. companies. The company projects sales of more than $20 million this year.

Among producers of digital computers worldwide, no one can top the output of the Milwaukee operations of Delco Electronics Corp., based in suburban Oak Creek. It produces 20,000 computers a day for General Motors vehicles.

Delco also builds inertial navigation systems for military and commercial aircraft at the sprawling complex south of Milwaukee's Mitchell International Airport, which it shares with AC Rochester, a manufacturer of catalytic converters.

Automation

Robots are rapidly becoming a fixture in many American industries as more companies turn to automation. An estimated 35,000 robots are at work in U.S. factories, performing such tasks as painting, welding and handling hazardous materials — all with tireless precision.

One of the leading players in this field is ABB Robotics, a Swedish company with U.S. headquarters in the Milwaukee suburb of New Berlin. The company is ranked number one in the world, with more than 16,000 units installed worldwide, or more than twice as many as its nearest competitor. Since it entered the U.S. market a decade ago, ABB has installed nearly 3000 robots in this country. American orders last year reached $45 million, representing 300 units.

In 1974, ABB developed the world's first all-electric robot, the IRB 6, at a time when everyone else in the business was building only hydraulic robots. New this year is a family of gantry robots and an electric painting robot (most painting robots are still hydraulic, not electric). Another recent advance is the LaserTrak, which can instantly define the position, shape, and gap of a welding seam in three dimensions. The data is then transmitted from the on-board LaserTrak computer to the welding equipment to assure welding precision, thereby eliminating the need for an additional robot axis.

Recently, ABB and Deneb Robotics of Troy, MI, jointly developed a 3D graphics-based robot simulation and off-line programming software package. The software works with the entire ABB product line and can use virtually all commercially available CAD data to reduce simulation programming. The package would enable an auto maker, for example, to simulate a robot installing a windshield and see the results on a computer screen.

ABB has also entered into an agreement with Ford Motor Co. to design, engineer, and install a system for fixed glass automation in light truck assembly.

The corporate mission of Gilman Engineering & Manufacturing of Janesville, in south-central Wisconsin, is making automatic assembly systems — integrated systems that let industrial customers piece together products automatically.

Gilman, which started in Janesville in 1936, pioneered the assembly machine business, building its first system in the early 1950s. At the time, the company was owned by Parker Pen, and one of its first assembly machines was designed to put caps on ballpoint pens.

Gilman can tackle a variety of production challenges to help manufacturers assemble their products more efficiently using human hands, robots, or automated operating stations — or a combination of the three.

This engineer uses expert system software developed by Milwaukee-based Eaton Corp. to monitor, evaluate, and calibrate the operation of a plastics molding machine in real time.

Photo courtesy Eaton Corp.

Cost Effective Contract Manufacturing

The View From Here

An Open Letter from Roger R. Mayer, President, MANU-TRONICS, Inc.

Dear Manufacturer:

I believe that if you think about full service contract electronic manufacturing like MANU-TRONICS, Inc. offers, then you know that cost effectiveness is the bottom line.

I believe that cost effectiveness depends on employee involvement, and that starts with me. When you think of MANU-TRONICS, I want you to know what type of CEO I am.

My style of management is based simply on "old fashioned work ethics." I just enjoy work. Every new order — no matter how small or large — gives me an exciting high.

My pride in America is very strong. I believe in full out competition, and may the best products win. Protectionism is a sin. I know we can compete successfully. That's why I have invested 2½ million dollars in a new 74,000 sq. ft. production facility.

We have designed in 3,000 sq. ft. for ongoing training and motivational programs. We emphasize quality. We have found what I believe our customers most respect. It's a very high energy level. It's this feeling we're creating — "mystique," "ambiance," "camaraderie," "team spirit." Call it whatever you want. Once you've put it together it's terrific!

And cost effective? You bet! Touring our new facility customers are always impressed with the rapid pace, the optimism of manner, the quickstepping tempo, outspoken and interactive employees, and a contagious sense of enthusiasm.

I believe that we are right in emphasizing cost effectiveness, quality, and personal growth. The result is a team of superior performers with the drive, the vision, and the sense of urgency to be your first choice.

Judge for yourself. Call me now. Toll free 1-800-451-6661 outside Wisconsin, or 1-414-947-7700 within Wisconsin. We can discuss arranging a convenient time for you to inspect our new facility.

Yours truly,

Roger R. Mayer
President

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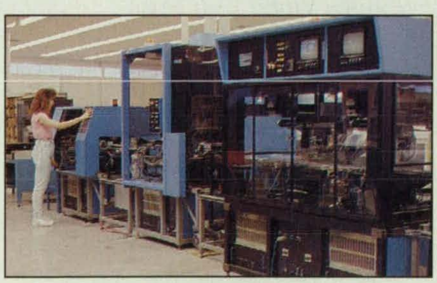

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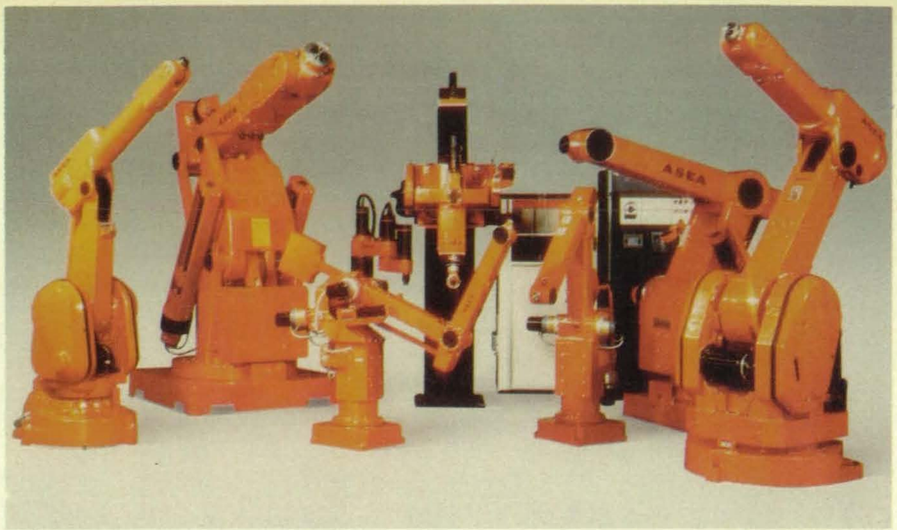


Photo courtesy ABB Robotics Inc.

Many of the all-electric robot systems produced by ABB Robotics can be adapted for welding or a wide range of flexible automation applications.

More than 1000 Gilman systems are operating in a variety of manufacturing plants around the world, including the Soviet Union, where Gilman shipped a system that makes flywheels for automobiles out of raw bar stock for a company called Stankoimport. The system is operating in the Soviet city of Ufa, in the foothills of the Ural Mountains.

Gilman sells predominantly to Fortune 500 customers — including General Motors, Ford, General Electric, Whirlpool, Bendix, and Caterpillar. A Gilman system, for example, put together the milling and drilling equipment that helped assemble the body of the Pontiac Fiero. Besides the automotive market — a major customer — Gilman systems are used to assemble such products as automatic dishwashers, telephones, and instruments and dashboards for automobiles.

Inside the world headquarters of Allen-Bradley Co. near downtown Milwaukee is a factory which has been called "the world's most advanced assembly line."

Here, visitors to the Bud Whitney World Contactor Automated Assembly Facility watch in amazement as relays and contactors are made at the rate of 600 units an hour in more than 1000 variations — and in lot sizes as small as one.

What they don't see are many human operators. Only about a dozen workers are needed to keep the computer integrated manufacturing (CIM) operation humming. A series of lights or alarms signals attendants when there's trouble on the line. A blue light means a parts feeder is running low on supplies, yellow indicates a parts jam, and red is for a machine malfunction.

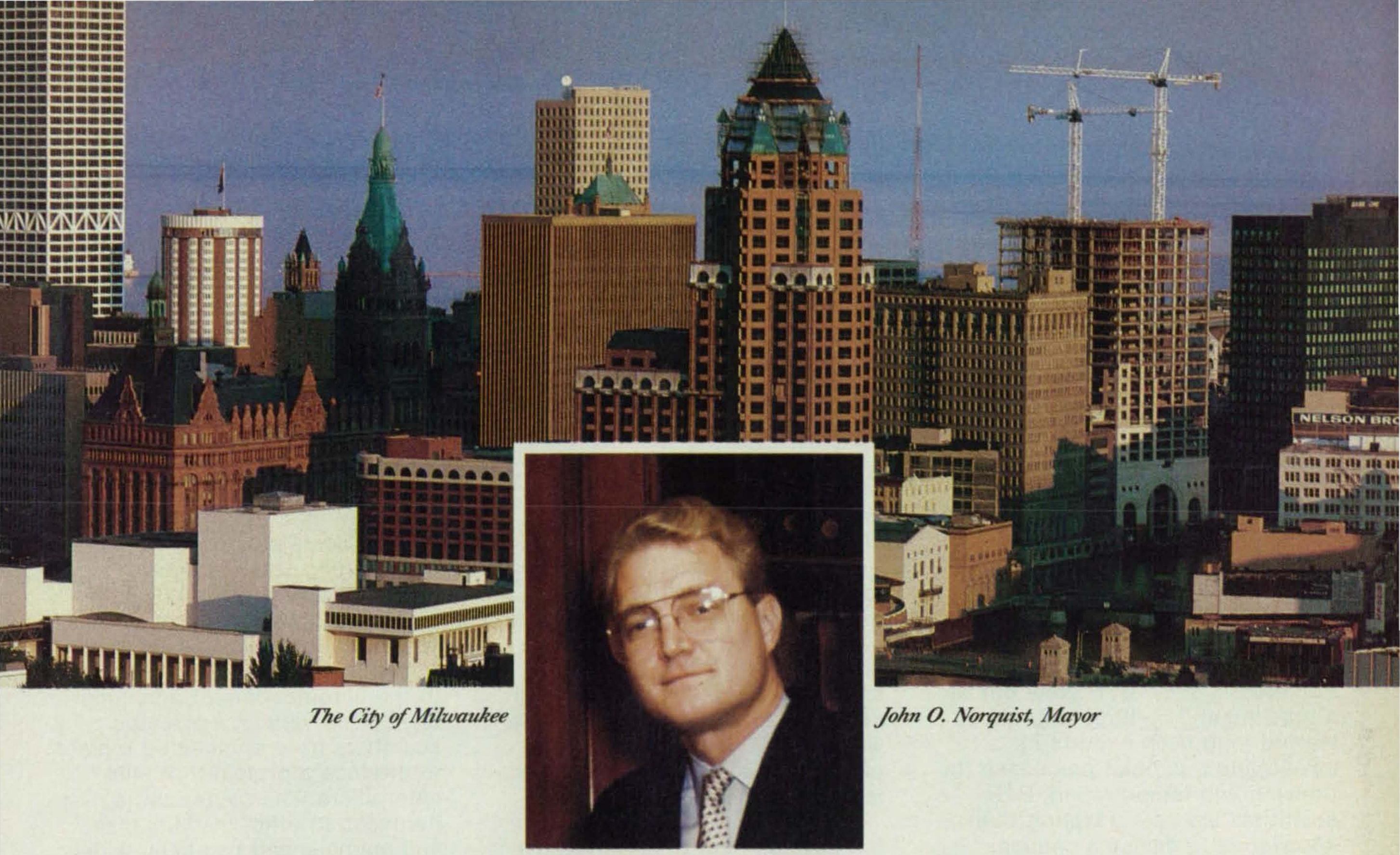
It's a virtually zero-defect operation inside this 45,000-square-foot, $15-million factory-within-a-factory. At some 3500 points on the line, production is monitored via automatic inspection.

Visitors watch as orders sent the previous day to Allen-Bradley's mainframe computer are processed in the CIM facility control room. Orders are translated into specific production language, then transmitted to a programmable logic controller (PLC). Finally, the PLC controller communicates with 26 smaller controllers on the hardwood factory floor via two Allen-Bradley Data Highways.

A strong competitor for the growing factory automation market is the Automation Products Division of Square D Company, headquartered in Milwaukee.

In addition to programmable controllers, the business unit provides welder controls that work with robots, press controls for metal stamping operations, and cell controllers — industrial computers that control an entire production process or network of machines on the factory floor.

Square D automation products help a variety of industries boost productivity. For example, they aid a New England baking company in producing one million English muffins and hamburger buns of uniform quality every day for McDonald's restaurants in the region. They let a Louisiana oil company monitor offshore drilling 35 miles away. And they make sure an Iowa rubber manufacturer's "recipe" is cooking at the proper heat from the first batch onward.



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"I invite you to discover how well Milwaukee really works. I'm sure you'll find it interesting, perhaps even surprising. And you might well discover a new business opportunity."

John O. Norquist
Mayor

City of Milwaukee, Department of City Development, Economic Development Division.

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Circle Reader Action No. 513

Biotechnology

Biotechnology is generally defined as the use of living organisms to make commercial products. Wisconsin's food manufacturers have traditionally used biotechnology to produce foods such as yogurt, soy sauce, and beer by harnessing microorganisms such as yeast and bacteria. Recent advances in genetics and cell biology, however, have resulted in the development of powerful new tools and methods, collectively known as the new biotechnology, that have significantly broadened our capabilities to develop and improve products and processes.

One Wisconsin company that has made the transition from the old to the new biotechnology is Bio-Technical Resources (BTR). Founded in 1962, BTR grew out of a brewing and malting laboratory. Having long been experts in developing microbial processes for brewing and fermentation, BTR scientists are now adapting their knowledge to devise a cheaper and more efficient method for producing a chemical compound important to the aerospace industry — meta-hydroxy phenylacetylene. This compound is a key intermediate in the production of acetylene-terminated (AT) resins, which are considered the leading candidate materials for advanced aerospace structural composites and adhesives.

AT resins offer good thermooxidative stability, mechanical properties, and processability, as well as low moisture pick-up. They may, for example, replace steel as a structural component in airplanes and have the added defense-related benefit of helping to make jet fighters "invisible" to radar detection. The resins' temperature-resistant quality might also prove useful in making computer circuit boards that tend to get hot.

Perhaps the greatest impact of the new biotechnology will be in agriculture, and Middleton's agricultural biotech firm, Agracetus, is leading the way in bringing genetically engineered crops closer to the marketplace. Agracetus was the first in the U.S. to conduct a field test of a genetically engineered plant. Last summer it tied Monsanto in producing the first genetically engineered soybeans. And in April of this year, Agracetus began the world's first field test of cotton plants that are genetically modified to resist insect attack.

Part of their success is due to the development of an innovative technology, called electric discharge particle acceleration, that gives scientists a more efficient way to introduce foreign genes into plant cells. The "particle gun" method fires DNA-coated gold particles directly into the meristem of the soybean embryo (the part of the seed that normally develops into a plant). By allowing the "transformed" cells to grow directly into plants, the method bypasses the tissue culture step required in other plant transformation systems. This in turn reduces product development time by up to 2.5 years and decreases the incidence of mutation that is frequently introduced during tissue culture. More importantly, it extends scientists' capabilities by transforming important crops that were previously not amenable to tissue culture.

What is the significance of these events? Consider that U.S. cotton growers spend $150-200 million annually to control damaging caterpillar infestation with chemical insecticides. Also consider the environmental and health hazards that a farmer is exposed to during the course of the multiple chemical sprayings that are necessary to control these pests. As chemicals are coming under close public scrutiny, alternatives such as those provided by biotechnology are greatly needed. For example, by adding the gene from a common soil bacterium into the chromosome of a commercial cotton variety, Agracetus scientists have engineered a plant to produce a protein that kills caterpillars. The bacterium is harmless to other insects, man, and animals, and has been widely used in biological pest control since the early 1960s.

Biotechnology is also creating new opportunities in the computer software business — opportunities that the Genetics Computer Group (GCG) is taking full advantage of. The genetic code is made up of four nucleic acid bases, where each gene is composed of hundreds of these bases in a unique sequence. The business of understanding and manipulating genes requires that the gene's sequence of nucleic acids is known and can be compared to other known sequences.

GCG distributes a software package that includes over 100 programs and utilities for the analysis of DNA and protein sequences. Five sequence databases are also distributed with the software, which is used by over 12,000 scientists at hospitals, universities, and government research facilities in 27 countries.

Currently, there are approximately 30,000 DNA sequences and 9000 protein sequences in the database. It is estimated that these numbers are doubling every year. In addition, the Department of Energy and the National Institutes of Health will be coordinating a major effort to sequence the entire human genome. Software such as the GCG Package will figure prominently in completing this task and analyzing the data.

Photo courtesy Agracetus

An Agracetus researcher hand-pollinates soybeans as part of a project to develop hybrid soybean plants.

Medical Technology

Waukesha-based General Electric (GE) Medical Systems is the only American manufacturer that still builds and sells all five of the so-called diagnostic imaging modalities — x-ray, CT (computerized tomography) scanners, ultrasound, nuclear medicine, and MR — or magnetic resonance — scanners.

GE leads the world market in MR technology. Images produced by MR are exquisitely detailed. Unlike x-ray or CT scanners, which use ionizing radiation, MR scanners employ a strong magnetic field and radio frequency signals to produce images of organs and soft tissue. GE has sold hundreds of its Signa MR models.

A Signa system, which can cost more than $2 million, is noted for the high magnetic-field strength of its superconducting magnet. Last year, GE also introduced a mid-strength, lower priced model, the MR Max, which it produces through a joint venture with Yokogawa Medical Systems in Tokyo.

Metriflow, a small Milwaukee entrepreneurial company, is using magnetic resonance imaging to build dedicated MR scanners that measure blood flow in patients' arms and legs. Just as the arteries that carry blood from the heart can become blocked, so can blood vessels in the limbs. If flow cannot be restored, the tissue dies and the limb must be amputated.

As with heart disease, vascular surgeons sometimes treat a blockage of blood vessels in the legs with bypass surgery. But one of the more exciting and fast-moving developments is a treatment called laser angioplasty. Using an argon laser, the surgeon can insert a catheter precisely at the point of blockage and reopen the blood vessel.

Before surgery, Metriflow's AFM-100 scanner can diagnose the problem and help determine the severity of circulatory impairment. After the laser procedure, it can measure the patient's blood flow and quickly produce a printout that determines whether the procedure has worked.

Last year Metriflow took a leap forward by developing software that makes a scan simpler and quicker for both patient and operator. After the patient is positioned on a table, a series of message prompts indicate where the table should be stopped and data acquired. Altogether, the system measures blood flow at six positions along the limb; no other equipment on the market can measure blood flow volume on an entire limb.

The entire scan takes just a few minutes. Afterwards, the system produces a printout of blood flow quantities at various points along the limb. Or, pre- and post-operative studies can be combined on a single printout, which allows the physician to quickly measure flow improvement after the procedure. Before the new software

Metriflow scanners use magnetic resonance imaging technology to measure patient blood flow before and after surgery. Photo courtesy Metriflow Inc.

development, the same information required two hours to gather and 24 pages to display.

In Madison, Nicolet Instrument Corp. has created BEAM (Brain Electrical Activity Mapping), which makes possible noninvasive inspection of the brain's reaction to certain stimuli. Useful as a diagnostic tool in psychiatry, BEAM provides color images of the brain's electrical activity and compares the patient's reactions to a ten-year database of benchmark reactions. The device assists in the diagnosis of such conditions as dyslexia, epilepsy, and head trauma. □

Wisconsin's Technology Transfer Team

Wisconsin has a wealth of resources for technology assistance available from organizations and educational institutions in the state.

University Technology Transfer Offices

Technology transfer offices serve as the starting point for businesses seeking access to university facilities and faculty expertise. These offices also sponsor special university-industry research programs, seminars, and consortia.

- **University-Industry Research Program (UIR), UW-Madison —** UIR provides industry referrals to faculty, sponsors briefings and seminars on current industry-related research, and encourages formation of new university-industry consortia.
  Contact: Director, UIR
  (608) 263-2840
- **Office of Industrial Research and Technology Transfer, UW-Milwaukee —** The office serves businesses interested in collaborative research and development programs, technology transfer activities, and/or consulting agreements, and licenses patentable technology to qualified manufacturers for development and marketing.
  Contact: Irving D. Ross Jr.
  (414) 229-5000
- **Biotechnology Center, UW-Madison —** Can provide expertise or resources for genetic engineering, DNA sequencing, protein purification, tissue culture, embryo transplants, biopulping, and use of monoclonal antibodies.
  Contact: Richard R. Burgess, Director
  (608) 262-8606
- **Medical College of Wisconsin Research Foundation —** Facilitates the commercial development of technology originating at the college. Technology development can take place through existing firms or through new business start-ups.
  Contact: Donald H. Westermann, Executive Vice President
  (414) 257-8219
- **Milwaukee School of Engineering — Applied Technology Center —** The center aids companies by arranging faculty consulting, student internships, faculty summer employment, and referrals.
  Contact: Thomas Davis, Dean of Faculty
  (414) 277-7300

Cover Photos

Top: A University of Wisconsin-Madison electrical and computer engineering graduate student (left) works with a technician at Silicon Sensors Inc., to insert wafers into a vacuum chamber for thin-film metal application.

Middle: UW-Madison graduate student uses the ESCA (electron spectroscopy for chemical analysis) system to study polymer materials.

Bottom: Model simulation of a storm showing a potential vorticity surface and trajectories over a topographical map.

Background: Satellite image of Wisconsin was processed digitally from data acquired by the Advanced Very High Resolution Radiometer (AVHRR) onboard a research meteorological satellite operated by the National Oceanic and Atmospheric Administration.

- **Wisconsin Center for Manufacturing and Productivity** — WCMP is dedicated to fostering industry-university partnerships to help transfer the latest in manufacturing and engineering technology to business.
  Contact: Director
  Manufacturing Systems Engineering
  (608) 262-0921

Patents and Product Licensing

New products or processes developed in Wisconsin universities are usually licensed for production or application in the private sector through specialized offices. Several organizations also provide assistance in patenting and licensing technology that has been developed in the private sector.

- **Wisconsin Alumni Research Foundation (WARF), UW-Madison** — WARF handles patent and licensing services for UW-Madison inventors. Net income generated from these services provides part of an annual grant to support university research.
  Contact: John Pike, Managing Director
  (608) 263-2500
- **Research and Resources Inc.** — A subsidiary of Medical College of Wisconsin formed to help develop new technologies originating outside MCW, Research and Resources offers industry the use of equipment and information, evaluates new products, and assists in obtaining patent protection.
  Contact: Donald H. Westermann,
  Executive Vice President
  (414) 257-8219
- **Center for Innovation and Development** — Provides technical evaluation of inventions and new products.
  Contact: John Entorf, Director
  (715) 232-1252
- **Technology Transfer Program** — Assists entrepreneurs and inventors with new business and product development, and links commercially viable new products with existing manufacturers.
  Contact: Randall Olson, Director
  (414) 472-1600

Technology Development Funding Assistance

The Department of Development has established two programs to assist companies in obtaining research funds:

- **SBIR Support Program** — This program helps small technology-based firms in Wisconsin secure federal research contracts under the Small Business Innovation Research Program. The program sponsors conferences and workshops, provides editorial review services, and assists in identifying appropriate university resources to aid in proposal preparation.
  Contact: Caroline Garber, SBIR Director
  (608) 267-9383
- **Technology Development Fund** — The fund provides competitively awarded R&D grants to Wisconsin businesses.
  Contact: Philip Albert,
  Director of Development Finance
  (608) 266-2766

Machinery

Transpiration and Regenerative Cooling of Rocket Engine

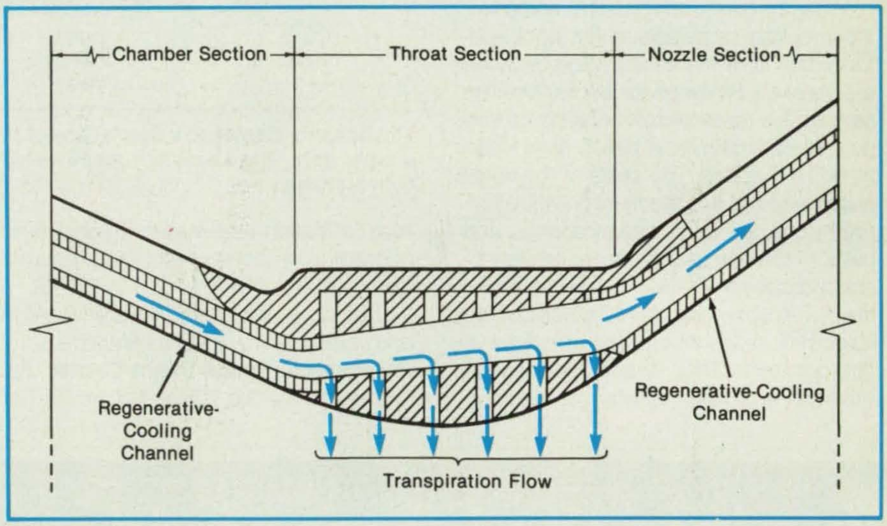
Transpiration cooling extends the limits of performance.

Marshall Space Flight Center, Alabama

The addition of transpiration cooling to a regeneratively-cooled rocket-engine combustion chamber has been proposed. This modification would improve the performance of the engine by allowing the use of higher chamber pressure. The concept may also be applicable to advanced, high-performance terrestrial engines or some kinds of industrial combustion chambers.

Heretofore, a typical liquid-fueled rocket engine has used regenerative cooling, in which fuel or oxidant is pumped along channels in the wall of the combustion chamber. The pumped propellant absorbs heat from the wall, and the heat aids in the vaporization of the fluid upon subsequent injection into the chamber. An attempt to improve performance by increasing pressure in the chamber requires a higher coolant-pump discharge pressure and a higher pressure drop in the coolant. The latter two effects impose a limit beyond which the engine cannot be regeneratively cooled with propellant and/or the power or other measure of overall performance of the engine cannot be increased.

The combination of transpiration and regenerative cooling should make it possible to exceed this limit. In the new cooling scheme (see figure), the chamber and nozzle sections of the wall of the combustion chamber would be cooled regeneratively while the throat section would be cooled by transpiration. The fuel would diffuse into the chamber through small holes in the throat section of the wall from bypass channels that connect the chamber and nozzle sections. The transpiration and regenerative flows can be apportioned with metering channels, manifolds, and compartments. The bypass of the coolant around the throat section (as opposed to pumping it through regenerative-cooling channels in the throat section) should reduce significantly the pressure drop in the coolant circuit, thereby reducing the required pumping power and discharge pressure.



The **Throat Section** of the combustion-chamber wall would be cooled by transpiration, while the chamber and nozzle sections would be cooled by fluid flowing in closed channels.

Transpiration cooling degrades the performance of the engine somewhat by disturbing the fuel/oxidant mixture. The magnitude of this effect depends on the coolant fluid. However, the new cooling scheme should increase the net output power. A transpiration-cooled throat should be more reliable than a regeneratively cooled throat is when designed near its state-of-the-art limit. With proper design, the new cooling scheme should make it possible to achieve higher chamber pressure and higher overall performance in a smaller engine.

This work was done by Charles J. O'Brien of Aerojet TechSystems Co. for **Marshall Space Flight Center**. *For further information, Circle 154 on the TSP Request Card.*

MFS-28251

Three-Position Cryogenic Actuator

The position is selected by selecting the applied pressure.

Marshall Space Flight Center, Alabama

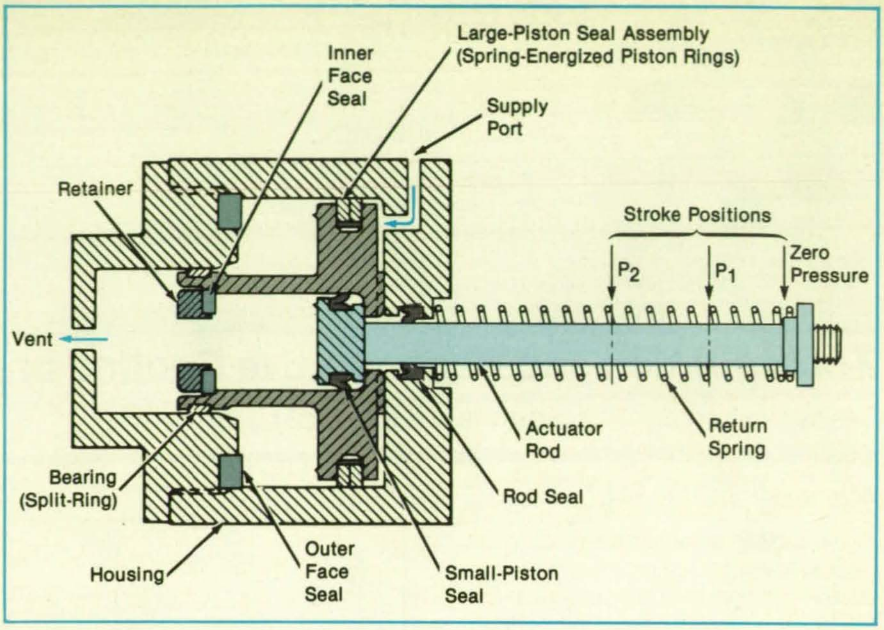
A linear actuator is set at one of three positions by supplying gas to it at a suitable pressure. The actuator is designed for use as part of a relief valve in a system that stores liquid oxygen.

The actuator rod is connected to a small piston that slides inside a large piston. The large piston slides in the bore of a housing, supported at one end by a spring-energized two-piston-ring seal and at the other end by a split ring (see figure). A return spring pushes the rod away from the housing (to the right in the figure).

When no pressure is applied to the pistons through the supply port, the actuator rod remains at its outermost (rightmost) position. When the applied pressure is increased to P_1, the large piston moves to the left, pulling the small piston and the rod with it, until it comes to a stop against the outer face seal in the bore. This stop establishes the intermediate position of the actuator rod.

When the pressure is increased from P_1 to P_2, the small piston is driven to the left inside the large piston until it comes to a stop against the inner face seal in the large piston. This establishes the innermost (leftmost) position of the actuator rod. When the pressure is decreased, the return spring moves the actuator rod back to the right, in the reverse of the preceding sequence.

When the pressure is cycled up and down, there is little hysteresis in the back-and-forth motion of the actuator rod because the seals are designed for low friction. The seal of the large piston consists of two polytetrafluoroethylene piston rings energized by a spring. The seals of the small piston and rod are made of polytetrafluoroethylene, are energized by springs, and have pressure-assisted, approximately-C-shaped cross sections. The face seals and the split-ring bearing on the left end of the large piston are also made of polytetrafluoroethylene. The use of polytetrafluoroethylene and large clearances helps to reduce friction and makes it possible to operate over the range of temperatures from −420 to 250 °F (−251 to 121 °C).



The **Actuator Comes to a Stop** at any of three positions, depending on the pressure at the supply port. The seals are made of polytetrafluoroethylene for low friction at low temperatures.

This work was done by Peter B. Allen and James White of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 115 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 [see page 14]. Refer to MFS-28265

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Survey of Wind Tunnels at Langley Research Center

Capabilities and recent and planned improvements are described.

A report was presented at the AIAA 14th Aerodynamic Testing Conference on current capabilities and planned improvements at NASA Langley Research Center's major wind tunnels. Langley Research Center has nearly 40 wind tunnels varying in size and complexity from small, inexpensive research tunnels to the new, $85-million National Transonic Facility. The estimated replacement cost of Langley's wind tunnels approaches $1 billion. The report focuses on 14 major tunnels, 8 of which are unique in the world and 3 of which are unique in this country.

Some of Langley's wind tunnels are over 50 years old. During the past decade, more than $100 million has been spent in upgrading the major existing tunnels, and approximately another $100 million on new construction. In addition to routine repair, refurbishment, and modernization, emphasis has been placed on increased capability. Flow quality has been improved across the speed regime. Cryogenic technology has been used to achieve full-scale Reynolds-number capability and increased flexibility. Advances in instrumentation, particularly nonintrusive techniques, have been exploited. Two new supersonic tunnels are being added to increase Langley's capability for supersonic tests. The hypersonic complexes are being upgraded and expanded in both propulsion and aerothermal capabilities.

The report covers the Langley Spin Tunnel, which is uniquely designed to free-spin test dynamically scaled models to determine-spin and recovery characteristics of aircraft. Despite the age of this facility (45 years), it is serviceable and is in continuous two-shift operation.

The report includes the new National Transonic Facility (NTF), a cryogenic, fan-driven wind tunnel designed to provide full-scale Reynolds-number capability in the critical flight regimes of most current and planned aircraft. It can operate at mach numbers from 0.2 to 1.2.

This report also surveys the Langley Unitary Plan Wind Tunnel (UPWT), a closed-circuit, variable-pressure facility with a mach-number range of 1.47 to 4.6. Virtually every supersonic airplane, missile, and spacecraft in the United States inventory has undergone extensive tests in this facility since it began operating in 1955.

The report addresses the resurgence of the inexpensive (less than $100 thousand), simple-to-operate research tunnels. Several of these tunnels exist at Langley to perform fundamental research that is not appropriate for the larger, more expensive tunnels.

The report predicts that there will be no shortage of tools for the aerospace researcher and engineer in the next decade or two. There will be new major wind tunnels and many research tunnels. New advances will provide unparalleled diagnostic tools.

This work was done by Robert E. Bower of **Langley Research Center**. *Further information may be found in AIAA paper 86A-37087, "Current Wind Tunnel Capability and Planned Improvements at Langley Research Center."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.
LAR-14037

Fabrication Technology

Hardware Techniques, and Processes

Baffles Promote Wider, Thinner Silicon Ribbons

A smoother temperature profile reduces the tendency toward buckling.

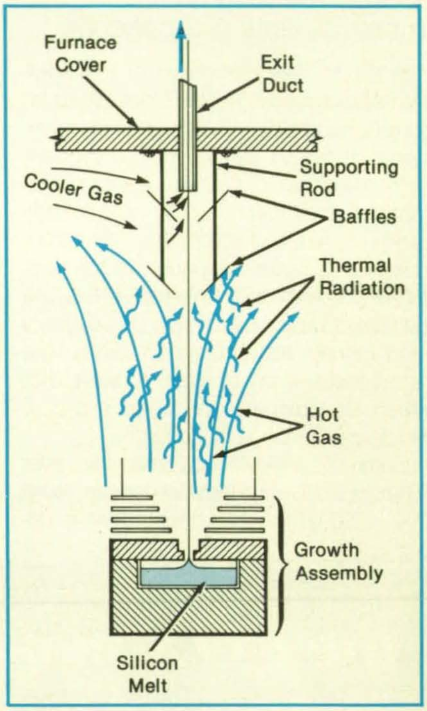
NASA's Jet Propulsion Laboratory, Pasadena, California

A set of baffles just below the exit duct of a silicon-ribbon-growing furnace reduces thermal stresses in the ribbons so that wider ribbons can be grown. The productivity of the furnace is thus increased.

The baffles divert the plume of hot gas from the ribbon and allow cooler gas from the top of the furnace to flow around it. The baffles also shield the ribbon from thermal radiation from the hot growth assembly (see figure). The ribbon is therefore cooled to a lower temperature before it reaches the cooler exit duct, avoiding an abrupt drop in temperature as it enters the duct.

Abrupt temperature drops induce stress, and stress makes the ribbon buckle and break. The tendency to buckle increases with the fourth power of the ribbon width. Before the baffles were installed, a 113-μm-thick ribbon could be grown no wider than 38 mm. With the baffles, the ribbon width can be increased to 42 mm and its thickness decreased to 100 μm.

This work was done by Raymond G. Seidensticker, James P. McHugh, Rolv Hundal, and Richard P. Sprecace of Westinghouse Electric Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 149 on the TSP Request Card.*
NPO-17168



Baffles Like Venetian Blinds, reduce the effects of two heating mechanisms: radiation from the growth assembly and convected hot gas. The silicon ribbon cools without a sharp dip in its temperature profile as it proceeds into the exit duct of the furnace.

Calculating Obscuration Ratios of Contaminated Surfaces

Equations for the calculation of an index of cleanliness are derived.

NASA's Jet Propulsion Laboratory, Pasadena, California

Equations have been derived to estimate the obscuration ratios of surfaces contaminated by particles. The obscuration ratio is the fraction of surface area covered by the particles. It is useful as an index of cleanliness in clean-room operations in the manufacture of semiconductor devices, magnetic recording media, optical devices, and pharmaceutical and biotechnological products.

The complete description of the cleanliness of a surface requires the areal density of particles as a function of their sizes. In many cases, the data available are too limited to provide this distribution. Limitations include the granularity of the particle-size intervals and the statistics of the particle counts. In addition, the complete distributions for two surfaces do not, in general, permit the comparison of their cleanliness. Only in the special case in which the distribution for one surface is bounded by the distribution of another for all particle sizes may one state that the first surface is cleaner than the second. Nevertheless, the obscuration ratio is a convenient measure of contamination with respect to effects that are proportional to the squares of the sizes of particles.

For the purpose of this estimation, it is assumed that the available measurements and counts of particles can be fitted to a continuous areal-density distribution. To accommodate fibers, particles of roughly spherical shape, and various size-dependent quantities, the cross-sectional area of a particle in the distribution is considered to be proportional to an arbitrary power of the size of the particle (e.g., diameter^2 for a sphere or length^1 for a fiber).

The assumed distribution is a generalized form of the one in MIL-STD-1246A:

$$\log n(>d) = \log n_o + s \log^2 d$$

where $n(>d)$ = the number of particles per unit area of size greater than d, n_o = the number of particles per unit area of size greater than 1 μm, s = the slope (s is negative), and d = the particle size in micrometers (d greater than or equal to 1). Using this distribution, the obscuration ratio R for spherical particles is given by

$$R = (\pi/4)n_o\{1 + 2\ln 10\,[10^{-1/s}\left(\frac{\pi}{-s\ln(10)}\right)^{1/2} P_n(w_1, \infty)]\}$$

where n_o = the areal density [in units of $(\mu m)^{-2}$] of particles larger than 1 μm, $P_n(w, \infty)$ = the normal-probability integral from w to ∞, and $w_1 = (-2s \ln 10)^{1/2}/s$.

For a collection of particles that are spherical for $d<d_o$ and fibers of diameter d_o at larger sizes, the obscuration ratio is

given by

$$R = (\pi/4)n_o\{1 - d_o^2 10^{s \log^2 d_o} + 2\ln 10$$

$$[10^{-1/s}\left(\frac{\pi}{-s\ln(10)}\right)^{1/2} P_n(w_1, w_2)]\}$$

$$+ n_o d_o\{10^{s\log^2 d_o} - \ln 10$$

$$[10^{-1/4s}\left(\frac{\pi}{-s\ln(10)}\right)^{1/2} P_n(w_3, \infty)]\}$$

where $w_2 = (-2s\ln 10)^{1/2}(\log d_o + 1/s)$ and $w_3 = (-2s\ln 10)^{1/2}(\log d_o + 1/2s)$. A typical value of d_o is 100 μm.

For a distribution that has discrete size intervals, one can calculate the obscuration ratio without assumptions:

$$R = (\pi/4)\sum_i n_i d_i d_{i+1}$$

where the measured distribution consists of n_i particles per unit area in each (ith) size interval from d_i to d_{i+1}.

This work was done by Jack B. Barengoltz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 2 on the TSP Request Card.*
NPO-17376

Forging Long Shafts on Disks

A removable punch halves the required stroke.

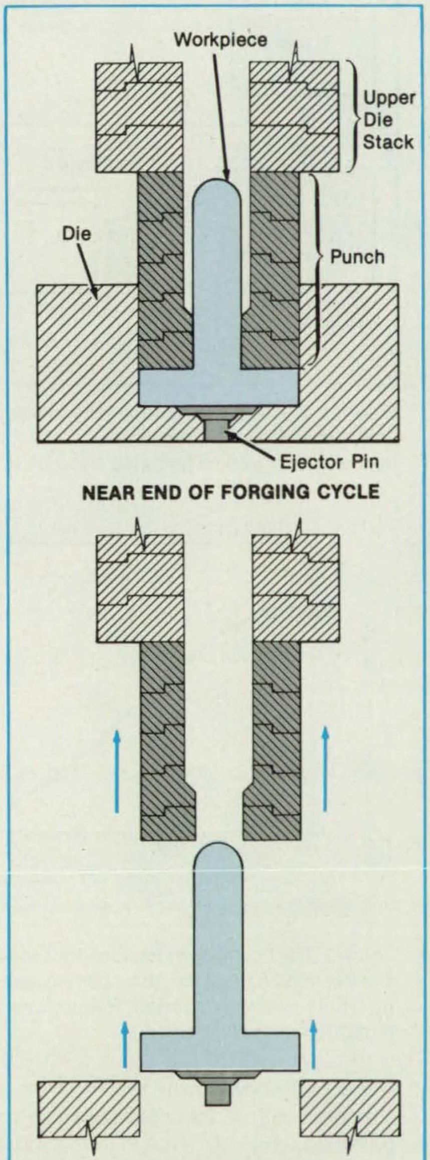
Marshall Space Flight Center, Alabama

A proposed isothermal-forging apparatus could produce long shafts integral with disks. In conventional isothermal-forging equipment, the forging stroke must be at least twice as long as the shaft being forged to enable the loading and unloading of the workpiece. In the proposed equipment, which is based on the modification of conventional isothermal-forging equipment, the required stroke could be cut by more than half. This would enable the forging of shafts as long as 48 in. (122 cm) on a typical modified conventional forging press, which would otherwise be limited to making shafts no longer than 18 in. (46 cm).

The principal feature of the modified apparatus would be a removable punch (upper die) (see figure). The upper die would be part of a stack that would include spacers. Some of the spacers could be removed to enable the workpiece and punch to be loaded into the forging chamber. After completion of a forging cycle, the workpiece and punch would be removed from the forging chamber together and disassembled outside the press.

Only the region of the workpiece at the junction of the disk and shaft undergoes significant plastic deformation; therefore, the existing heating elements on a conventional isothermal-forging press would be adequate for use in the modified version. The workpiece would not remain isothermal during the forging process in the modified apparatus. Once the material extruded past the orifice in the punch, it would move out of the heat zone and shrink away from the punch.

The process and equipment are suited to the forging of alloys that exhibit superplasticity at some range of temperature and strain rate. A workpiece of an alloy otherwise difficult to process could be preformed by end upset, and a shaft could be isothermally forged into it, producing a high-integrity disk/shaft component that would have radial flow of grain in the disk and axial flow of grain in the shaft. This



The **Removable Punch**, in which the forged material would cool after plastic deformation, is the essential novel feature of the proposed forging apparatus.

technology could be used to improve such products as components of gas turbines and turbopumps and of other shaft/disk parts for powerplants, drive trains, or static structures.

This work was done by Chris Tilghman, William Askey, and Steven Hopkins of United Technologies Corp. for **Marshall Space Flight Center**. *For further information, Circle 97 on the TSP Request Card. MFS-28288*

Determining Equilibrium Position for Acoustical Levitation

The sample does not have to be levitated during the measurement.

NASA's Jet Propulsion Laboratory, Pasadena, California

The equilibrium position and orientation of an acoustically-levitated weightless object can be determined by a calibration technique on Earth. From the calibration data, it is also possible, in principle, to calculate the equilibrium position and orientation in the presence of Earth gravitation. The sample is not levitated acoustically during the calibration.

The technique relies on the Boltzmann-Ehrenfest adiabatic-invariance principle, one consequence of which is that the effective potential energy of an object in an isolated acoustic mode of a cavity is proportional to the resonant frequency of that mode. The factor of proportionality depends on the properties of the mode. Such equilibrium levitation properties as the position and orientation of the object are determined by measuring the conditions under which the total energy of the object/cavity system is minimized. Thus, by measuring the resonant frequency as the orientation or position (or both) of the object is varied, one can find the equilibrium orientation or position (or both) as that which minimizes the measured resonant frequency.

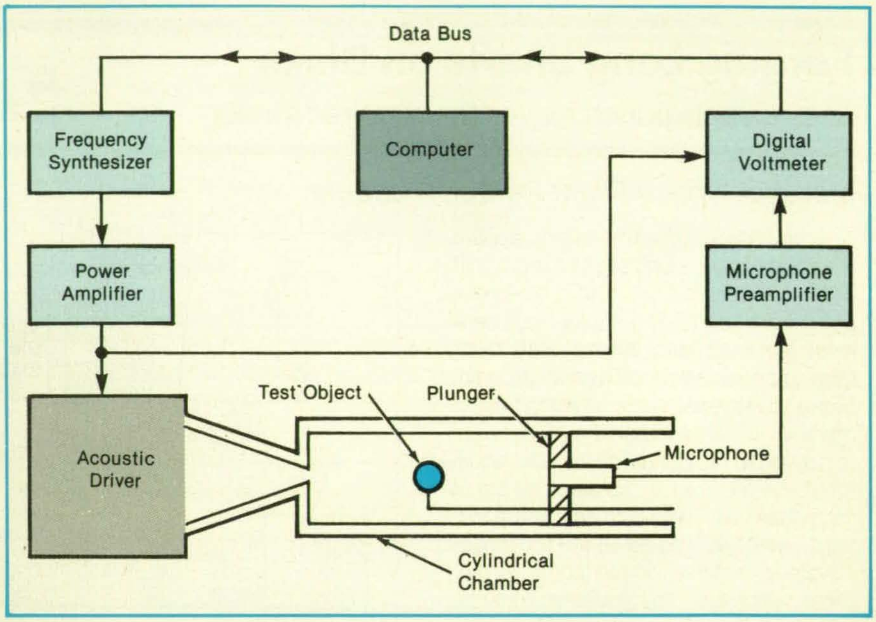


Figure 1. The **Resonant Frequency of the Chamber** is measured as a function of the position and/or orientation of the sample. The point of minimum resonant frequency is that at which the sample would be levitated acoustically if it were weightless.

Figure 1 illustrates the use of this technique in a round cylindrical levitation chamber. (However, the technique is applicable to objects and chambers of arbitrary shape.) The object is rigidly supported at a selected position and orientation, and the frequency of the acoustic driver is adjusted to resonance, as indicated by maximum sound-pressure amplitude detected by the microphone. The process is repeated for other positions and/or orientations to find the minimum resonant frequency and to obtain plots of the relative shifts in the resonant frequency as functions of position and/or orientation. The process can be automated and controlled by a computer.

By use of the Boltzmann-Ehrenfest principle, one can convert the resonant-frequency-shift data into data on the normalized acoustical potential energy. Of course, the minimum of this energy occurs at the equilibrium point. From the gradients of the acoustical potential energy, one can calculate the acoustical restoring force or torque on the object as a function of the deviation from the equilibrium position or orientation.

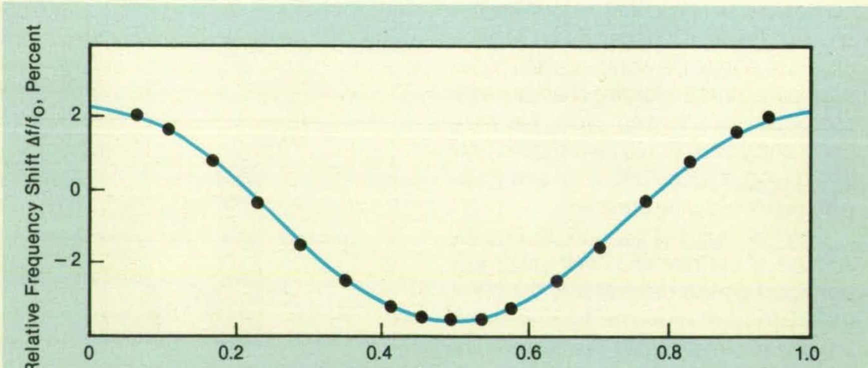


Figure 2. The **Equilibrium Position for Levitation** of the spherical sample illustrated in Figure 1 is at the midlength of the chamber, where the resonant frequency is at its minimum. Here f_o = the empty-chamber resonant frequency and $\Delta f = f - f_o$, where f = the resonant frequency as a function of axial position z.

Figure 2 shows some results of measurements with a spherical object in the cylindrical chamber excited in the fundamental z-plane-wave mode. As one might expect intuitively, the equilibrium (minimum-resonant-frequency) position in this mode is at the midlength of the chamber.

This work was done by M. B. Barmatz and G. Aveni of Caltech and S. Putterman and J. Rudnick of UCLA for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 77 on the TSP Request Card. NPO-17511*

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Vacuum Head Checks Foam/Substrate Bonds

Inspections are performed quickly and nondestructively.

Marshall Space Flight Center, Alabama

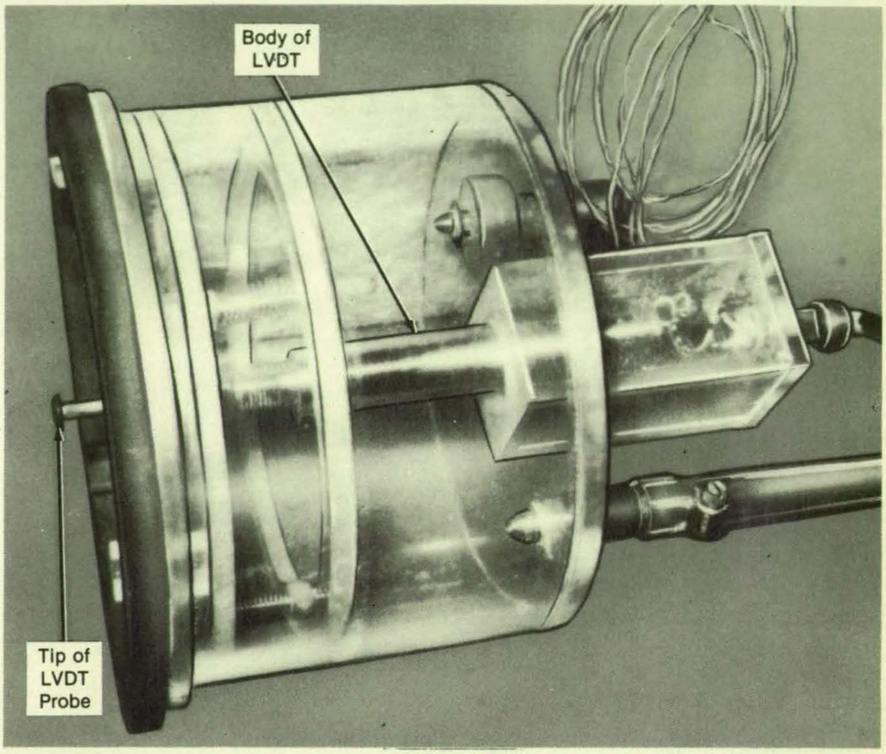
An electromechanical inspection system quickly gives measurements that indicate the adhesion, or the lack thereof, between rigid polyurethane foam and an aluminum substrate. The system does not damage the inspected article, is easy to operate, and can be used to perform "go/no-go" evaluations or as a supplement to conventional destructive pull-plug testing.

The system applies a vacuum to a small area of the foam panel and measures the distance through which the foam is pulled into the vacuum. (The rest of the panel remains at atmospheric pressure.) The measurable deflection is greater in an unbonded than in a bonded area, and the magnitude of deflection that signifies a failure of adhesion can be determined on specimens of known condition for subsequent use as a "go/no-go" criterion.

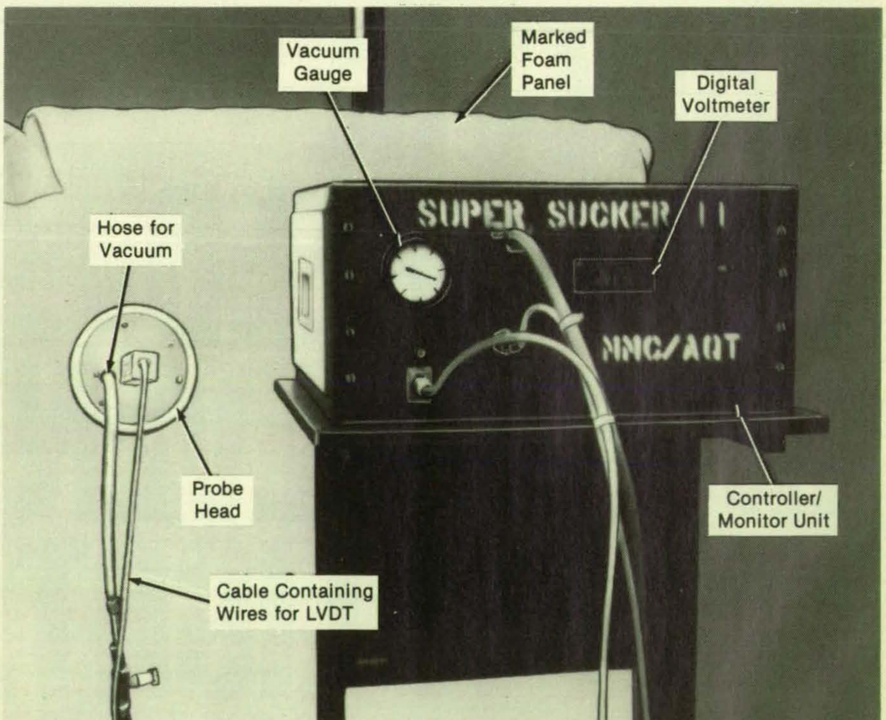
The system consists primarily of a probe head connected through wires and a hose to a controller/monitor unit (see figure). The probe head is a transparent cylindrical chamber 8¼ in. (21.0 cm) long and 6 in. (15.2 cm) in diameter that applies the vacuum to the area of foam to be tested. A soft rubber seal bonded to the rim of the chamber helps to maintain the vacuum. A spring-mounted linear variable-differential transformer (LVDT) on the axis of the chamber measures the deflection of the foam during a test. The controller/monitor unit contains a mechanical pump that evacuates the probe head through the hose and a digital voltmeter that indicates the displacement of the LVDT.

The testing procedure is simple. The probe head is positioned on the specimen and pumped to a low vacuum. After waiting about 15 s for the specimen to stabilize, the displacement of the LVDT is recorded. The probe head is then pumped to a high vacuum, and again the specimen is allowed to stabilize for 15 s before a reading is taken with the LVDT. The difference between the LVDT readings is the measured deflection to be compared with the "standard" value. The ability to detect flaws via this measurement decreases with the thickness of the foam.

This work was done by James F. Lloyd of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 117 on the TSP Request Card.*
MFS-28301



PROBE HEAD



SYSTEM IN USE ON FOAM PANEL

The **Probe Head Is Applied to the Specimen** and evacuated through the hose to the controller/monitor unit. The digital voltmeter in the controller/monitor unit reads the deflection of the LVDT in the probe head.

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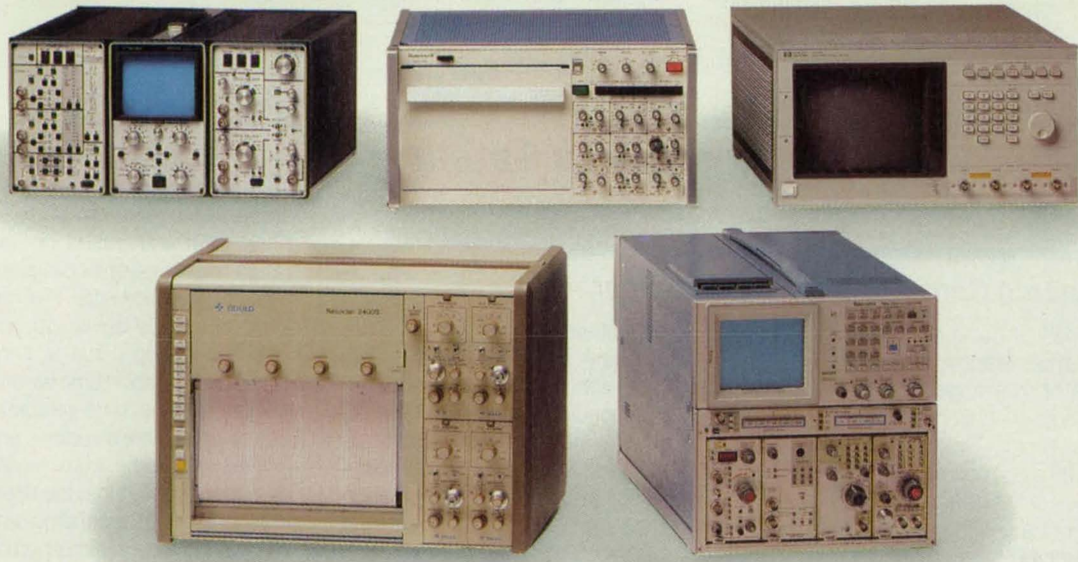
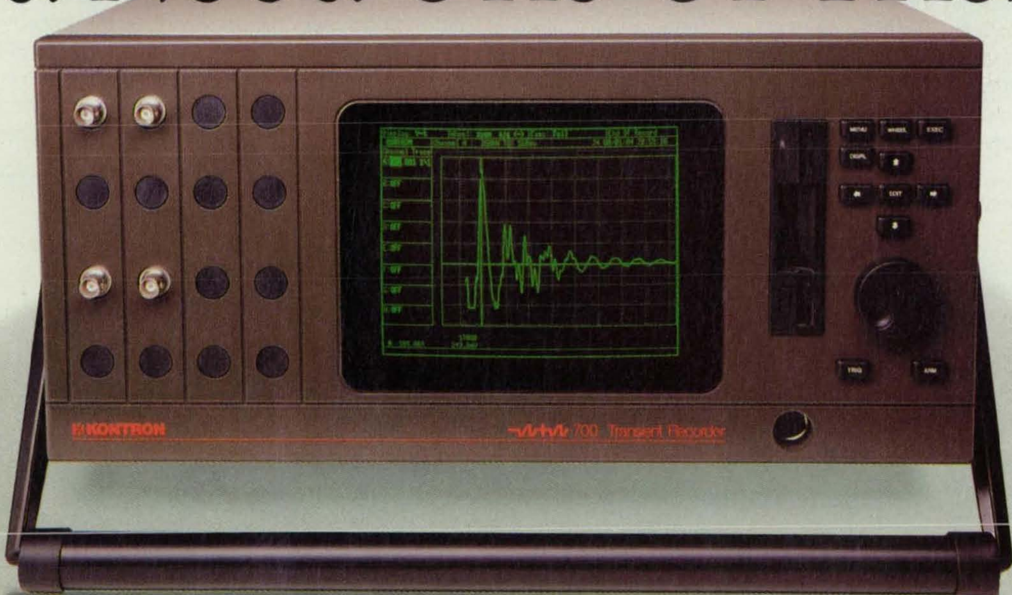


You Need One Of These:



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Circle Reader Action No. 640

Range Filtering for Navigation by Satellite

Less processing and storage of data are needed.

Ames Research Center, Moffett Field, California

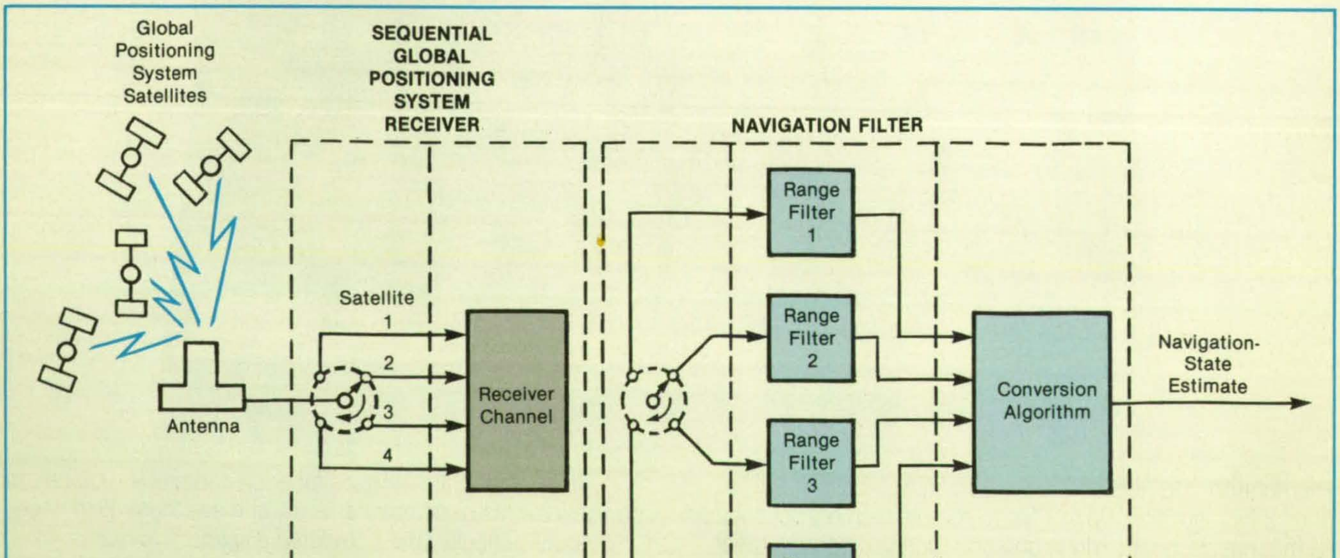
The mathematical basis has been developed for Kalman filtering of sequential measurements of the range (that is, the distance) from a single-channel receiver in the Global Positioning System (GPS) to each of several navigation satellites. The main advantages of the new range-filtering technique, in contrast with the more-conventional navigation-filtering technique, are simplification of tuning and decreases in the required amounts of storage and processing of data for navigation in ships, airplanes, and ground vehicles.

Range filtering involves the separate application of a kinematic Kalman tracking filter to the measurements of the signal from each satellite in use (see figure). The state vector consists of the pseudorange and its time derivatives. Typically, the first one or two derivatives are used, giving two or three state variables, respectively. The filtered range-domain quantities are then combined for the navigation solution.

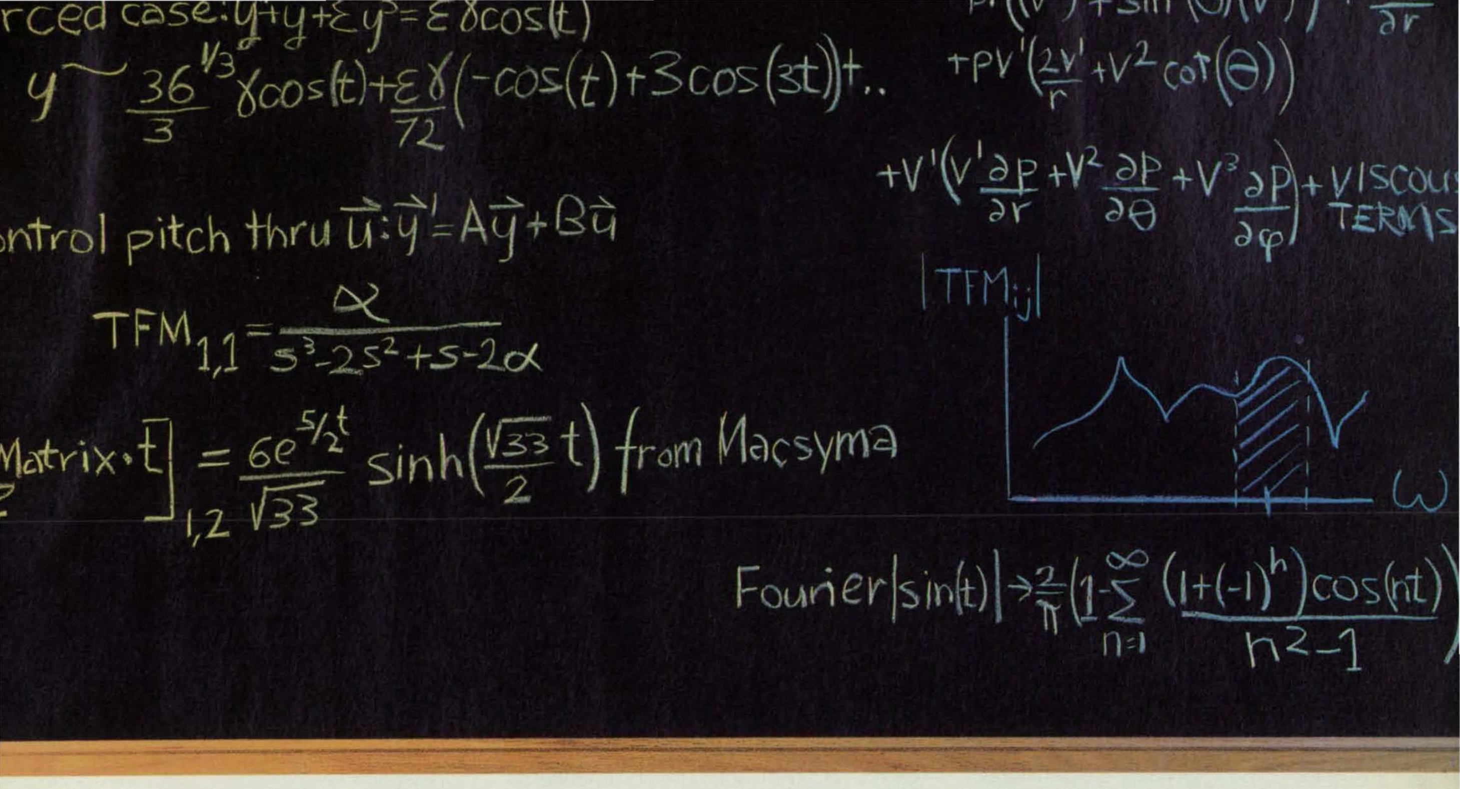
The range filters may be thought of as navigation filters that have been transformed to a nonorthogonal coordinate frame corresponding to the satellite directions, then separated into decoupled filters corresponding to each satellite, with simple neglect of the state-error-covariance cross-correlation elements. Although the loss of the cross-correlation information makes this a suboptimal approach, the sacrifice in optimality may not be substantial in comparison with the prior error caused by the erroneous assumption of white noise in the Kalman-filter equations.

The new technique for conversion of the range-domain state estimates to the navigation-state estimate involves the "conversion" algorithm, which enables the filtered range-domain state estimates from each satellite to be incorporated sequentially into the navigation-state estimate as they become available. The conversion algorithm consists basically of a conventional navigation filter but without the recursive state-error-covariance computations. Instead, an equivalent state-error-covariance matrix is based on the individual range-filter state-error covariances and on the satellite geometry. The conversion algorithm can be set up to operate under "clock coasting"; that is, navigation can continue for a short time when the accessible satellites become insufficiently numerous to determine the clock error.

Measurements from auxiliary sensors can be integrated into the filtering scheme in several ways, depending on the type. For example, by use of a mathematical "virtual satellite," altimeter measurements can be treated equivalently to satellite range measurements. Inertial measurements can be used as a navigation-domain process driver in the conversion filter, and the predicted navigation-domain state estimate can then be used to compute the predicted range-domain state estimates, thus enabling the use of narrower range-filter bandwidths for improved rejection of noise. Measurements of the altitude of an aircraft can be used to infer the predicted flightpath if a coordinated-turn assumption is reasonable; alternatively, direct meas-



In the new **Range-Filtering Technique**, a kinematic Kalman tracking filter is applied separately to the measurements of the signal from each satellite.



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urements of control inputs can be fed into an aircraft-dynamics state estimator to predict the flightpath.

This work was done by Russell Paielli of **Ames Research Center**. *Further information may be found in NASA TM-89418 [N87-20057], "Range Filtering for Sequential GPS Receivers with External Sensor Augmentation."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12106

Generalized Multiple-Trellis-Coded Modulation

Performance exceeds that of conventional trellis-coded modulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A generalized multiple-trellis-coded modulation technique combines multiple trellis coding (in which more than one channel symbol per trellis branch is transmitted) with symmetrical M-ary phase-shift keying. This technique performs better than the conventional trellis-coded modulation technique does, with no increase in complexity (as measured in the number of states in the trellis diagram of the code).

Figure 1 illustrates the encoding-and-modulation scheme. During each transmission interval, the encoder maps *b* binary input information bits into *s* binary code symbols. These *s* symbols are partitioned into *k* groups of $m = \log_2(M)$ symbols each. Each of these groups results in an M-ary modulator-output symbol. The only constraint on these parameters is that *s* must equal *mk*; *b* is not required to be an integral multiple of the multiplicity *k*, the trellis-code rate *b/s* need not be a ratio of adjacent integers, and the throughput *b/k* is not constrained to be an integer, as in conventional trellis-coded modulation.

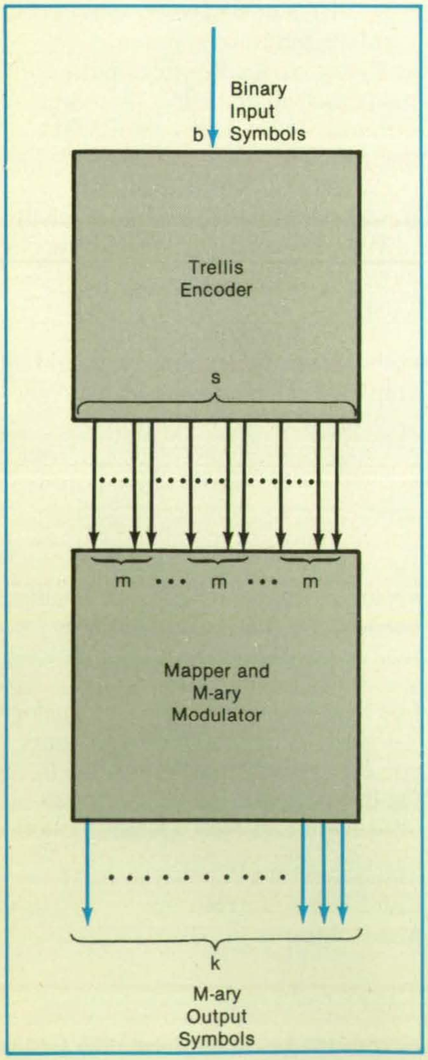

Figure 1. The **Generalized Multiple-Trellis-Coded Modulation** transmitter puts out *k* M-ary code symbols for every *b* input binary symbols.

The performance of a coding-and-modulation scheme of the new type is characterized by comparing its throughput performance, *b/k*, with the computational cutoff rate, R_o, of the transmission channel as functions of the ratio E_s/N_o or E_b/N_o required to obtain an arbitrary small bit-error rate. Here E_s is the symbol energy, N_o is the noise energy received during one symbol period, E_b is the bit energy, and $E_s = (b/k) E_b$. Such a comparison was done by a computer simulation for binary-, quadrature-, and 8-phase-shift keying (BPSK, QPSK, and 8PSK) channels with various values of *b* and *k*. Figure 2 shows that at a given level of performance, these multiple-trellis-coded modulation schemes all require lower signal-to-noise ratios E_s/N_o than do the corresponding uncoded modulation schemes.

This work was done by D. Divsalar and M. K. Simon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 130 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

Edward Ansell
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Pasadena, CA 91125

Refer to NPO-17321, volume and number of this NASA Tech Briefs *issue, and the page number.*

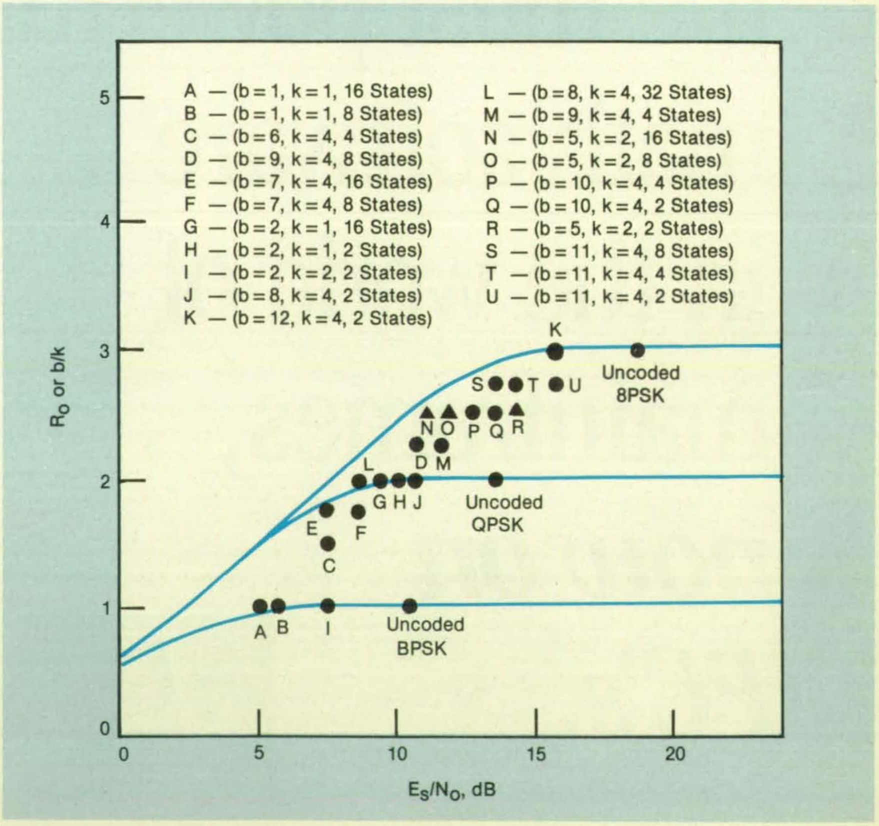

Figure 2. The **Throughput Performances**, *b/k*, of trellis-coded multiple-phase-shift-keying channels are compared with the computational cutoff rates, R_o, of multiple-phase-shift keying. The numbers of states noted above are those of the code trellises.


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Life Sciences

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Depth Perception in Remote Stereoscopic Viewing Systems

A viewing strategy accommodates the competing requirements of low distortion and high resolution.

A report describes theoretical and experimental studies of the perception of depth by human operators through stereoscopic video systems. The purpose of such studies is to optimize dual-camera configurations used to view the workspaces of remote manipulators at distances of 1 to 3 m from the cameras. On the basis of their findings, the authors propose a strategy that minimizes the stereoscopic depth distortion without sacrificing stereoscopic depth resolution.

To provide high depth resolution with adequate overlap of the stereo image pairs, the viewing axes of the cameras are made to converge on the point of interest. As the intercamera distance increases, the depth resolution increases, but so does the depth distortion. Conversely, the depth distortion can be reduced by decreasing the distance between cameras, but depth resolution is decreased. Heretofore, some researchers have advocated orthostereoscopic camera alignments (those that imitate natural human viewing conditions), while others have advocated hyperstereoscopic alignments (those with unnaturally-large camera separations).

The authors note that the small-angle approximations used in most previous analyses obscured the relationship between the stereoscopic distortion and the major parameters of the camera configurations. To explore this relationship more fully, they present a rigorous geometric analysis without small-angle approximations. They also ask whether human observers' responses follow the predictions of the geometric analysis despite internal human perceptual corrections and distortions.

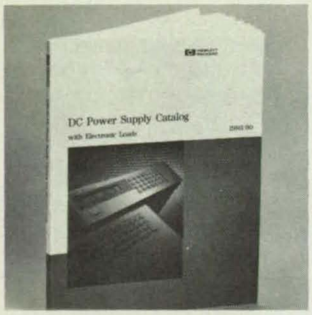
Experiments were performed to answer the latter question. Human observers used a Honeywell (or equivalent) field-sequential stereoscopic viewing system and viewed two vertical rods through two television cameras. One rod was placed at a distance of 1.3 m from the line between the cameras; the other was placed at various distances a few centimeters closer or farther than 1.3 m. In one set of experiments, the cameras were translated to different distances along the line between them. In another set of experiments, the cameras were rotated about a point between them. In all the experiments, the observers were asked to report their perceptions of which of the two rods appeared closer to the viewer.

The experimental results show that although uncertainties in depth perception vary among observers, the perceived depth distortions follow the predictions of the geometric analysis. Thus, the observers' internal corrections and distortions do not invalidate the usefulness of the geometric analysis in the prediction of optimal camera configurations.

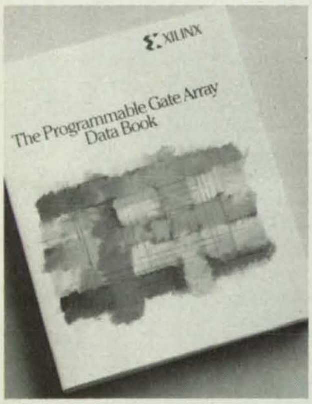
According to this analysis, the static stereoscopic depth distortion can be decreased, without decreasing the stereoscopic depth resolution, by increasing the camera-to-object and intercamera distances and the camera focal length. The analysis further predicts that the dynamic stereoscopic depth distortion can be reduced by rotating the cameras around the center of the circle (the Vieth-Mueller circle) that passes through the point of convergence of the viewing axes and the first nodal points of the two camera lenses.

This work was done by Daniel B. Diner and Marika von Sydow of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Stereo Depth Distortions in Teleoperation," Circle 59 on the TSP Request Card.* NPO-17118

New Literature



Manual and computer-controlled **DC power supplies and electronic loads** are featured in a new catalog from the Hewlett-Packard Company, Palo Alto, CA. A system-power-supply section includes single- and multiple-output models offering up to 200 volts, or up to 120 amps output and 1000 watts, on the HP-IB (IEEE-488) interface. Another section describes electronic loads for power-supply, battery, and power-component testing, including HP-IB and manually controlled models with ratings from 300 to 1600 watts.
Circle Reader Action Number 708.

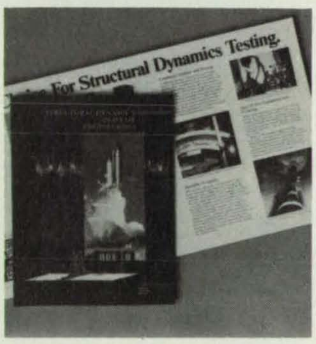


The updated Programmable Gate Array Data Book from Xilinx Inc., San Jose, CA, explains where **programmable gate arrays** fit, compared to TTL, PLDs or conventional gate arrays. The free 320-page book includes detailed data sheets, diagrams, product briefs, and article reprints.
Circle Reader Action Number 702.

The technologies employed in **semi wafer processing** are described in a free brochure from MKS Instruments Inc., Andover, MA. Included are such processes as silicon crystal growth, epitaxial layer deposition, dopant ion implantation, trench etch by sputtering, trench filling by atmospheric pressure CVD, oxide or nitride plasma deposition, metal or silicide etch, sputter deposition, and interconnect layer etch. Typical system configurations and instrumentation/component selections are provided for each process.
Circle Reader Action Number 712.

A new product catalog from Spectrum Signal Processing Inc., Burnaby, British Columbia, lists a wide range of **digital signal processing (DSP) development tools** and OEM systems for the IBM PC/XT/AT and Sun 386i. The products can be used for DSP algorithm development, proof-of-concept demonstrations, and system prototyping. The DSP-Link system expansion interface, which provides for a variety of analog and digital interfaces, enables users to closely match their development environment with their target hardware, or to rapidly create an end-user application.
Circle Reader Action Number 704.

A directory of more than 160 **manufacturing research centers** nationwide is now available from MTIAC, Chicago, IL. Each entry includes a description of the center's technical expertise, facilities, and publications; additional information is offered on funding, staff, and affiliates. The 108-page publication is indexed by state, center name, affiliation, and keyword. It is also available as an ASCII file on 5-¼ and 3-½ inch disks.
Circle Reader Action Number 706.

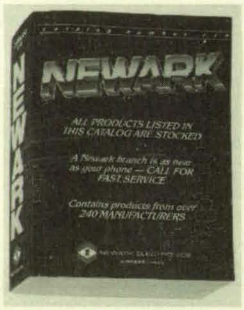


A new brochure describes National Technical Systems' recently expanded **structural dynamics services,** including modal testing, digital signal analysis, signature analysis, finite element and dynamic response analysis, dynamic characteristics prediction, and acoustic intensity studies. Also spotlighted are test facilities for a variety of hazardous products, high pressure/high temperature gases, liquids, cryogenics, EMI/EMC/EMP, and PCB/PWBs.
Circle Reader Action Number 710.

A free booklet from Electronics Corporation, San Jose, CA, addresses problems frequently encountered by **IEEE 488 Bus** users, and describes mix and match solutions for expansion, extension and control. Heavily illustrated with charts and diagrams, the publication provides information for enhancing 488 Bus configurations.
Circle Reader Action Number 714.

New Literature

A free **aviation poster** is available from the Aircraft Wheel and Brake Division of Parker Hannifin Corp., Avon, OH. The 24" by 30" poster depicts a variety of general aviation aircraft in full color, and is printed on heavy stock, suitable for framing.
Circle Reader Action Number 718.



More than 100,000 **electronic components** from 240 manufacturers are described in the new catalog from Newark Electronics, Chicago, IL. The 1100-page publication includes dimensions, specifications, and descriptions of semiconductors, computer supplies, capacitors, surface mount devices, switches, test equipment, and much more. The 1989 catalog features 7900 new products and 13 new product lines.
Circle Reader Action Number 724.

"Technology Alliances for Competitiveness" provides an overview of various **public-private sector collaborations** in the technology industries, such as strategic alliances, joint ventures, research agreements, R&D consortia, incubators, and government funding programs. Issued three times a year, the free booklet is published by the IC² Institute, a research center affiliated with the University of Texas at Austin, and KPMG Technology Development Services. The latest edition includes information on MIT's management in the 1990's program, as well as a new consortium formed by US automakers, a planned DARPA engineering research center, and the first major joint venture between American and Japanese semiconductor companies.
Circle Reader Action Number 726.

A new brochure from Wayne Kerr Inc., Woburn, MA, introduces the 900 series for **printed circuit board (PCB) testing**. Comprised of three test systems that can stand alone or be used in a network configuration, the 900 series supports a wide range of test modules for shorts/opens, functional, and in-circuit testing. The systems incorporate standard IBM hardware and the Wayne Kerr test bus architecture. A full range of digital testing capabilities are available, from sequential logic tests to real-time, bus-structured tests.
Circle Reader Action Number 716.

A full line of **vacuum valves and valve control systems** for applications from coarse vacuum to extreme UHV is described in a catalog published by VAT Inc., Woburn, MA. Available free of charge, the 225-page publication describes a wide range of gate valves, rectangular slit valves, all-metal bakeable gate valves, angle valves, closed-loop control valves for downstream pressure control, and fast closing systems for beam lines. Full technical data, drawings, and specifications are included.
Circle Reader Action Number 720.

A four-page brochure from OrCAD Systems Corp., Hillsboro, OR, introduces **software to help engineers generate complex designs on PCs**. The software, called OrCAD/SDT III, provides simple pop-up menus; offers special design management features to simplify complex designs, such as heirarchical layers and powerful macros; and includes utility programs, once the user has entered the design, so the schematic data can be used in a variety of environments. A free demonstration disk that walks the user through the basic steps of the software is also available.
Circle Reader Action Number 722.

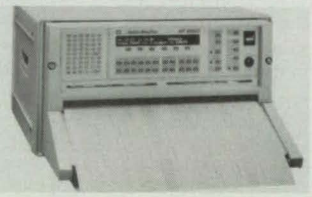
New on the Market

CSD International Inc., Shelburne Falls, MA, is marketing CSD-Vision™, a hardware and menu-driven **software package** for automatic manufacturing and quality control inspections. It includes a solid state camera with a 35mm lens, a frame grabber and VGA display adapter, I/O modules for production/product control, vision inspection software, picture scanning and enhancement software, and all the necessary cables and documentation needed for on-line quality inspections. Unique to the CSD-Vision package is the ability to store captured images in TIFF, IFF, EPS, or PCX file formats. These common image files are compatible with most popular desktop publishing software. CSD-Vision works with IBM-compatible computers, and sells for $4995.
Circle Reader Action Number 776.

PPG Industries, Pittsburgh, PA, has developed a **liner for polycarbonate windshield transparencies** that in flight tests has shown an ability to "heal" surface damage such as abrasion from foreign-object impact. The liner, which bonds directly to the substrate, is also resistant to ultraviolet radiation, chemicals, and stress, and is lighter than acrylic, currently the most popular protective ply for polycarbonate transparencies. In one example, a weight reduction of nearly one pound per square foot resulted when an acrylic outboard ply and an interlayer used to bond the acrylic to the polycarbonate were replaced with the PPG material. In addition to outboard shielding applications, the liner may provide inboard protection, be photochromic to reduce light transmission as needed, and have antistatic and laser defeat capability.
Circle Reader Action Number 772.

Xtra™, an **integrated programming environment** for the development of parallel and multiprocess applications, has been introduced by BBN Advanced Computers Inc., Cambridge, MA. Available on the Butterfly® GP1000 system, the Xtra tool set employs Window System™ multiple windows, mouse-driven inputs, and pop-up menus. Through its use of automatic multiple window displays, Xtra tools enables users to see a full picture of the program and thereby quickly grasp the nature of specific problems. In addition, context-sensitive on-line help automatically gives the user information about specific operations being attempted. The TotalView™ source-level multiprocess debugger, part of the tool set, allows programmers to observe the effects of many processes running simultaneously.
Circle Reader Action Number 774.

With a resolution of 1000 point per inch, GTCO Corporation's new SketchMaster "sees" up to five times more detail than other low-cost digitizers. Sketchmaster also consumes less power. While other **digitizers** require a dedicated internal or external power supply, SketchMaster can be powered by the RS232C port of the host computer. The new digitizer works with most popular digitizing software and includes a tablet, four-button cursor, interface cable, adaptor, and manual.
Circle Reader Action Number 770.



A high-resolution **recorder** that writes with laser printer resolution has been introduced by Astro-Med Inc., West Warwick, RI. The Model MT-95000 recorder features a resolution of 300 dpi on the amplitude axis and more than 300 dpi on the time axis. All-electronic and operating without pens, styli, or other moving parts, the MT-95000 records 8, 12, or 16 separate or overlapping channels and features real-time frequency response of 20 kHz as well as automatic self-calibration. With its high frequency response, the recorder can be used in applications formerly reserved for light beam oscillographs.
Circle Reader Action Number 766.

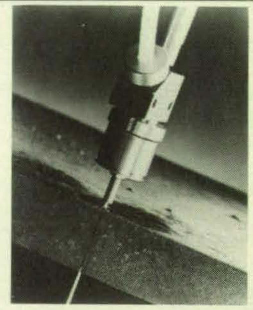
New on the Market

Spectraguard C-608, a silver-filled, **conductive coating material** that provides electromagnetic and radio frequency interference (EMI/RFI) shielding in demanding environments is now available from Carroll Coatings Company, Providence, RI. Formulated for use as a finish on surfaces exposed to water, solvent, chemical, and salt- spray environments, Spectraguard C-608 has a surface resistance of .02 ohms/square at 1.5 to 2.0 mil dry film thickness. It provides EMI/RFI protection up to 83dB 1MHz to 3GHz, and offers a service temperature range of -60° to +400° F. Available in sample kits, the two-part epoxy coating can be applied with standard spray devices to various plastics, composites, and primed or unprimed metals.
Circle Reader Action Number 790

Teledyne Semiconductor, Mountain View, CA, has introduced a **measurement system on-a-chip** which will enable designers to create a single instrument that can measure voltage, current, resistance, frequency, and logic levels. The chip's main components are an analog-to-digital converter, a logic probe, a frequency counter, and a liquid crystal display (LCD) driver. Designated the TSC820, the device also includes normally external functions such as decimal point drivers, a low-battery detector, and peak reading hold. With a resolution of 3-¾ digits, the TSC820 doubles the dynamic range of current A/D converters and, in the 200 to 400 mV range, delivers ten times the resolution, according to the manufacturer.
Circle Reader Action Number 792.

A programmable vision-based system that **measures and inspects the lead dimensions and coplanarity** of a variety of surface mount packages has been introduced by VIEW Engineering Inc., Simi Valley, CA. The automated system provides accurate and repeatable measurements for such dimensional features as seating plane coplanarity, shoulder or elbow width/spacing, tweezing, lead angle and lead pitch, footprint, and package size. Designed to accomodate a variety of package styles, the inspection system uses five CCD cameras to create a composite view of the entire device. Its measurements are in full compliance with JEDEC and ANSI Y14.5 standards.
Circle Reader Action Number 796.

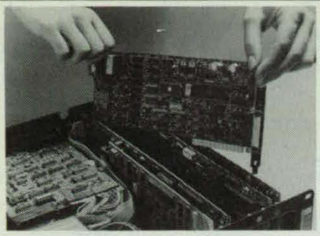
Piezo Systems Inc., Cambridge, MA, is offering a kit to help engineers get both instruction and hands-on experience in **designing piezoelectric devices**. Equivalent to a classroom and lab course, the kit also permits fast verification of design feasibility. It consists of a tutorial and design calculator on floppy disk for IBM-compatible computers; a manual containing practical techniques developed by Piezo Systems engineers; and a motor/actuator kit with laminated piezoceramic stock, solder, flux, and a motor/actuator manual. Applications for piezoelectric actuators and sensors include: solid state actuators for rocket valves, hydraulic and pneumatic controls, laser-optic positioners, machine vision systems, miniature pumps and fans for fluid delivery systems, and ultrasonic devices.
Circle Reader Action Number 794.



An advanced **waterjet cutting system** from Hydrojet Services Inc., Reading, PA, quickly and cleanly cuts both hard and soft materials by pressurizing water and focusing it into a jet stream as small as .003". Traveling at up to three times the speed of sound, the jet stream cuts without distorting or degrading the material, and eliminates the need for secondary finishing. The computer-controlled, omnidirectional system can net-cut complex shapes and contours.
Circle Reader Action Number 798.

Precision Visuals Inc., Boulder, CO, has released PV-WAVE, a new **software package for exploring, analyzing, and displaying scientific data interactively**. Within one integrated environment, scientists can navigate through large datasets, selecting and analyzing key features and trends, and translating results into graphs, contour maps, surface plots, and images. Uses can combine computational analysis and graphics with image processing techniques to look at their data in unconventional ways, for example, combining 3D shaded surfaces with contour maps and pixel images, all in one graphics window. PV-WAVE is tailored for Sun and DEC workstations and VAX/VMS environments, with direct end-user access to windows, mouse input, and menus.
Circle Reader Action Number 800.

New on the Market



A **PC-to-PC transfer card** that allows business users to send and receive data and documents automatically, without PC power, is offered by Face Technologies Inc., Ann Arbor, MI. Designed to fit in an open slot on any IBM PC/XT/AT or compatible computer, the FaceCard™ communications board enables scheduling information transfer for a designated time of day, such as the evening when telephone rates are lowest. It works up to six times faster than standard FAX machines and transfers true files—not just pictorial copies. This allows the receiver to modify the document on-line, thereby eliminating tedious pencil-and-paper editing. Unlike many other data transfer devices, FaceCard™ does not permit open access; it protects against unauthorized access to data on the PC even if it is part of a network.

Circle Reader Action Number 786.

Versacad Corp., Huntington Beach, CA, has introduced a high-performance **CAD system** for 80386 computers. Called VersaCAD/386, the software features 2D production and 3D modeling capabilities, as well as a Bill of Materials report generator and universal CAD communications utilizing IGES, DXF, VLINK, PostScript, HPGL, and DMPL. A QuickRender 3D model viewer provides shading and hidden line removal at high speeds. VersaCAD/386 can address up to 16 MB of memory, breaking the 640 KB barrier and enabling users to create much larger models while easily running popular networks, third-party application programs, and memory utilities such as Sidekick.

Circle Reader Action Number 780.

Optical Coating Laboratory Inc., Santa Rosa, CA, has developed an innovative method for **applying multilayered coatings on plastic substrates**. The coatings are produced via an ion coating process that allows deposition to occur at near room temperature, eliminating optical distortion and durability problems associated with conventional deposition methods on plastics. Potential applications include antireflection coatings on plastic windows, conductive coatings, sunglass coatings, and laser rejection coatings.

Circle Reader Action Number 788.

SilentPartner, a new handheld **remote keyboard** for IBM-compatible PCs, is now available from Presentation Electronics Inc., Rocklin, CA. Useful for electronic presentations in the form of computer slide shows, SilentPartner consists of an infrared remote control with a 35-foot range and a receiver that plugs into the keyboard port or serial port of the PC, be it a desktop or laptop. The transmitter features three "Page Select" buttons, each of which represents a separate memory page on which another 20 "soft" buttons can be programmed, using menu-driven SProgram® software. Each button can represent a single key, a string of keys up to 79 characters, and special key combinations, such as "control-break" or "alt-f." The product sells for $349.

Circle Reader Action Number 778

ND Industries, Troy, MI, is offering free samples of its five major **locking and sealing processes**. These include ND PATCH™, a sprayed-on nylon coating which makes fasteners self-locking yet fully adjustable; ND PELL-IT™, a nylon locking plug inserted into a drilled hole; ND VIBRA-TITE® , a vibration-resistant coating; ND EPOXY-LOCK® , a locking/sealing adhesive with tremendous breakaway torque; and ND STRIP™, a nylon locking bar inserted into a milled slot in the fastener's threads.

Circle Reader Action Number 784.

The new ThermAtrace® **infrared scanner** from the the Pyrometer Instrument Company, Northvale, NJ, offers a cost-efficient alternative to conventional thermal imaging cameras. Unlike other scanners, its detector operates without expensive cryogenic cooling. Measurements can be made over five selectable temperature spans from 10° to 1000° C. An electronic offset control permits detailed examination of any portion of the thermal line scan, or "A-trace", which represents the tem- perature distribution along a single line on the target. The scanner can be operated on either a self-contained rechargeable power pack or off an AC line.

Circle Reader Action Number 782.

Subject Index

Earth Observations and Global Change Decision Making: A National Partnership
National Press Club—Washington, D.C.
September 18–19, 1989

NASA and NOAA, in conjunction with the Environmental Research Institute of Michigan (ERIM), will host a major conference on the national global change program. The conference will discuss the U.S. strategy for global change research and how this strategy fits within an evolving international effort. It will begin a dialog to form a partnership between the federal government and various communities (research, academia, industry, media, public interest groups, and policy makers) concerned with global change. Scheduled speakers include Vice President Dan Quayle and Senator Albert Gore.

For more information, contact:

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P.O. Box 8618
Ann Arbor, MI 48107-8618
(313) 994-1200 ext. 3234

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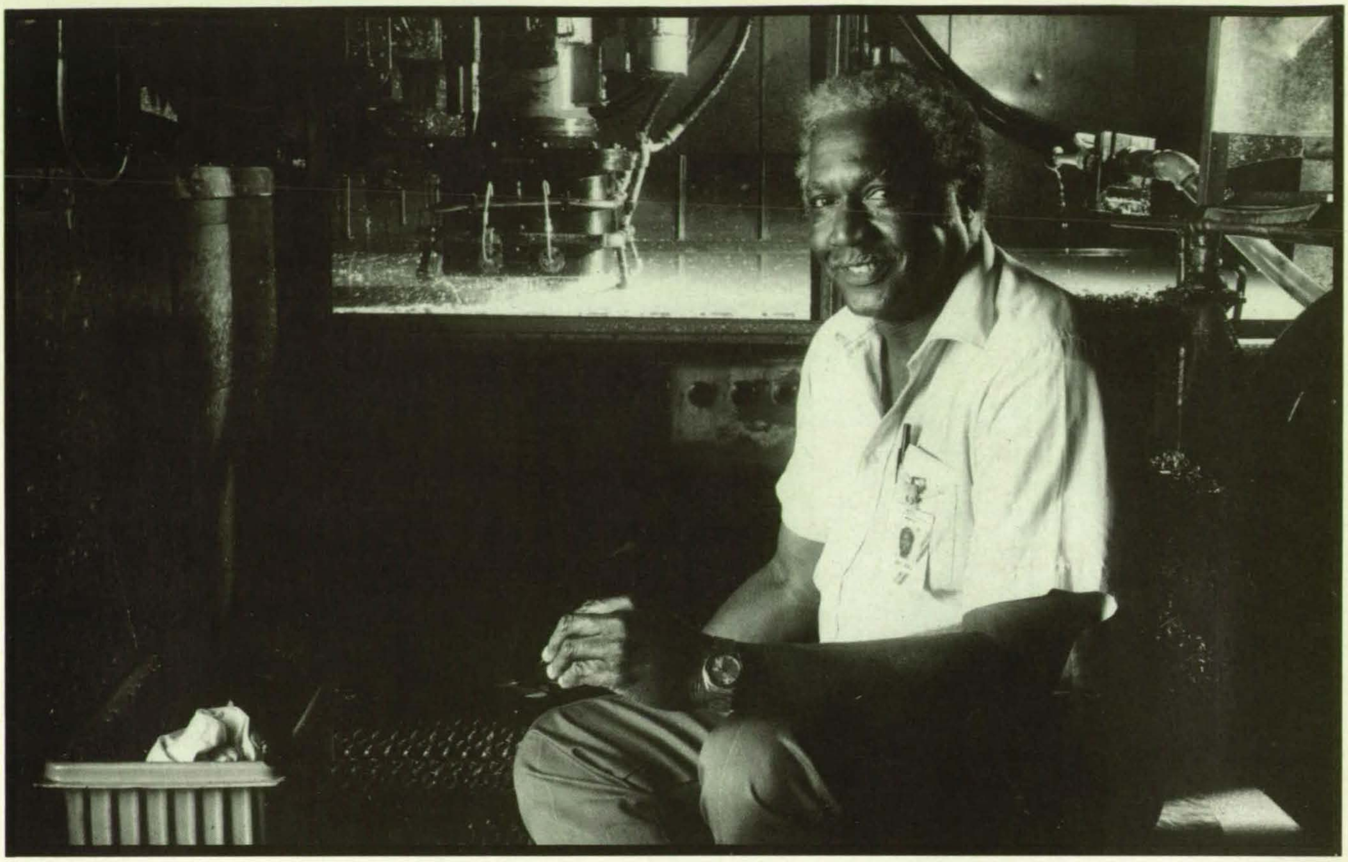

"We call it a skin, this big sheet of aluminum that lines the inside of the Delta rocket.

The specifications say I've got five thousandths of an inch leeway in cutting out these triangular pockets on its surface. But I like to get closer than that.

So before I load the skin onto my machine, I go over the whole table with a polishing stone. Then I check the numbers after every cut and make adjustments as I go. That way I hold my tolerances tighter—to plus or minus three instead of five.

There's a guy down the line that has to do his job with the skin I make. I'm just making sure he can rely on me. He's doing his job the same way. That's the best way—maybe the only way—to build reliability into our rockets." *—Joe Hall, Delta Rocket, Numerical Control Machine Operator*

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