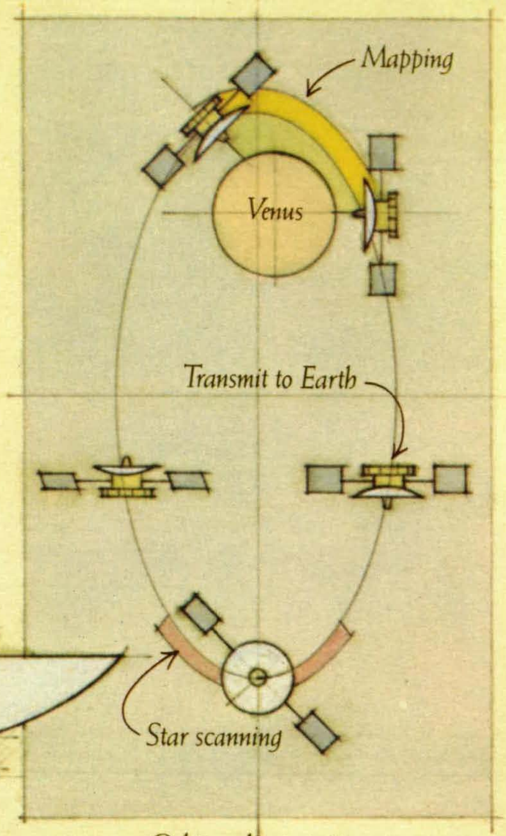
NASA Tech Briefs

Transferring Technology to American Industry and Government

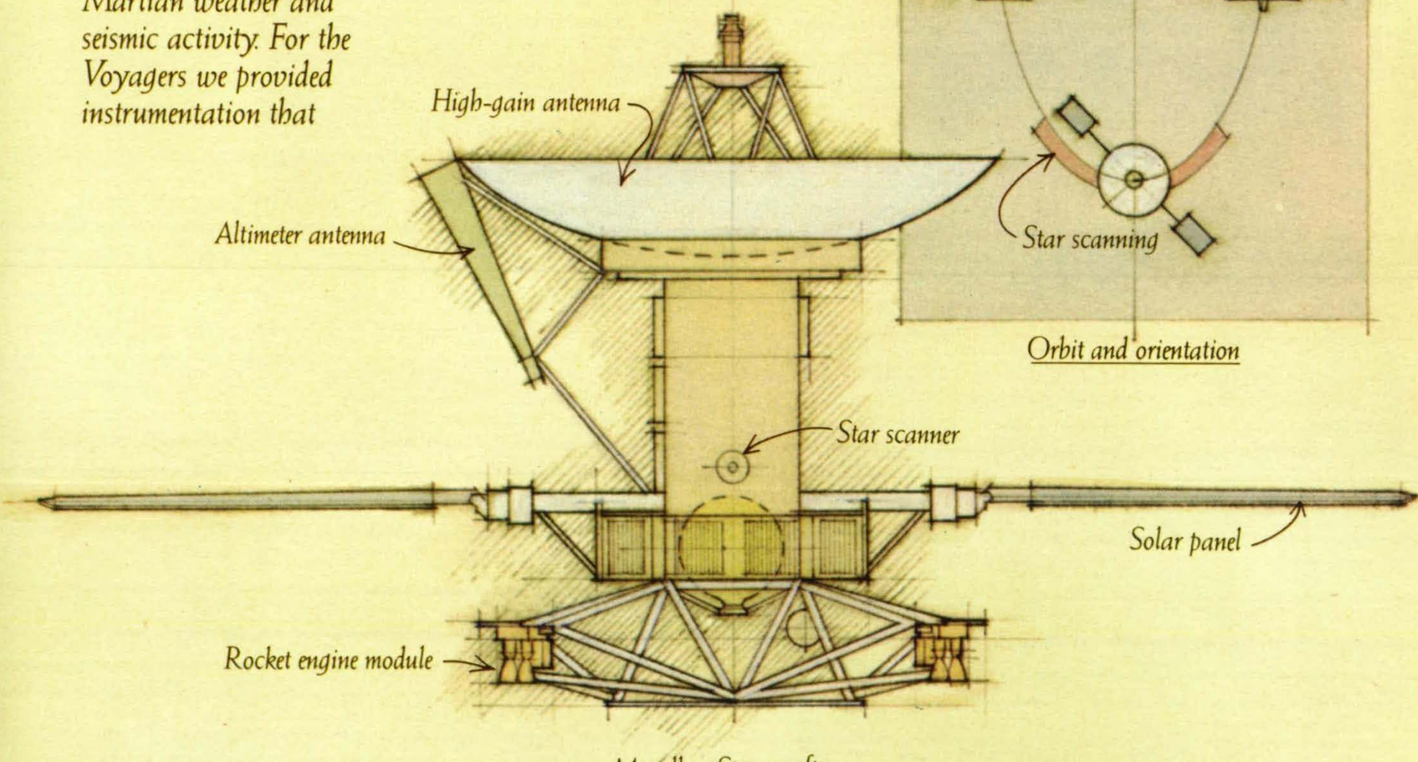
June 1989
Volume 13
Number 6

In space: looking back to look forward.

What can the nature and origin of the universe tell us about the future of Earth? To help answer that question, we make craft and instruments for traveling billions of miles in space and seeing as far as 15 billion years back in time. Martin Marietta was the integrator and builder of two Viking landers, which sent back remarkable photos of the surface of Mars, examined soil samples, and studied Martian weather and seismic activity. For the Voyagers we provided instrumentation that reported on electromagnetic activity near Jupiter and Saturn–Voyager 2 went on to Uranus, some 2 billion miles from Earth. That was nine years after launch; next destination, Neptune, in 1989. These are but a few results of Martin Marietta's ability to create survivable, mystery-solving craft and their instruments–from concept through mission completion.



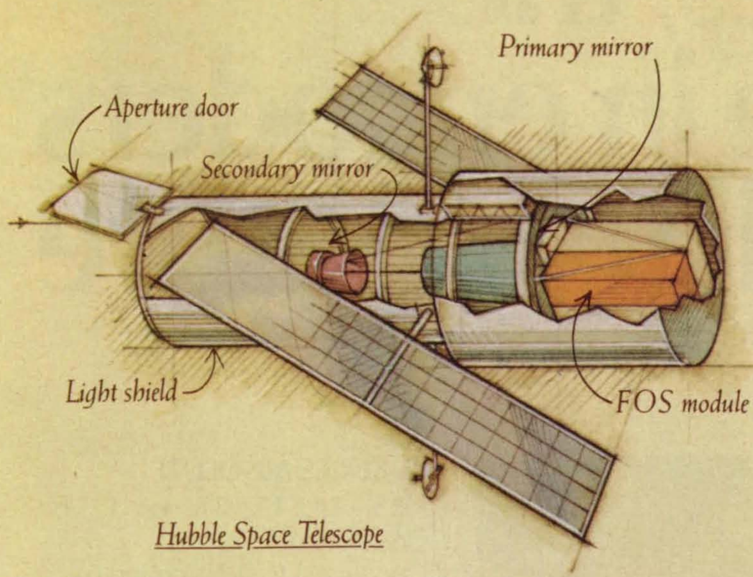
Orbit and orientation



Magellan Spacecraft

Mission: map Venus.

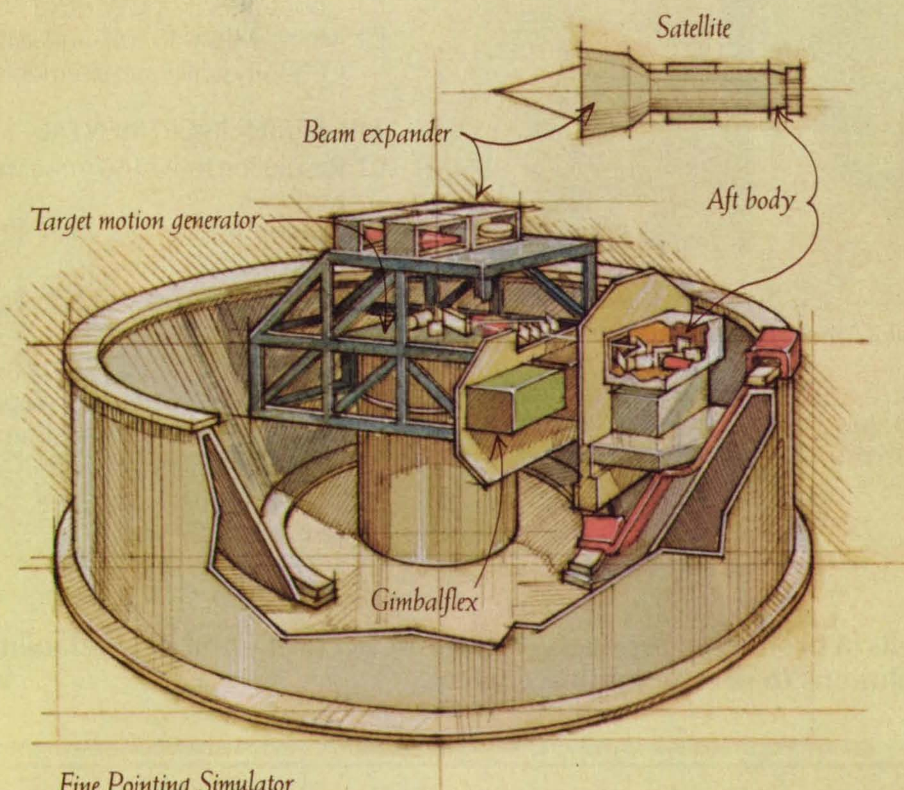
From orbit, Magellan's radar will penetrate the planet's thick, gaseous cloud cover and send back photo-like images of nearly 90% of its surface. Our role: design, integrate, build and test the craft.



Hubble Space Telescope

Viewing the infant universe.

For the Hubble Space Telescope we are providing the Faint Object Spectrograph (FOS), which will see objects up to 15 billion light-years away. Since the universe is estimated to be 18-20 billion years old, astronomers will witness events close to its birth.



Fine Pointing Simulator

The fine points of fine pointing.

Precisely controlled, space-spanning energy delivery and collection systems create difficult pointing and retargeting challenges, which we can now simulate. This new lab is working toward the precision to zero in on a football-size object 3,000 miles away, in support of the Strategic Defense Initiative research program.

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- ☐ Meets MIL-I-45208 and MIL-Q-9858 quality requirements

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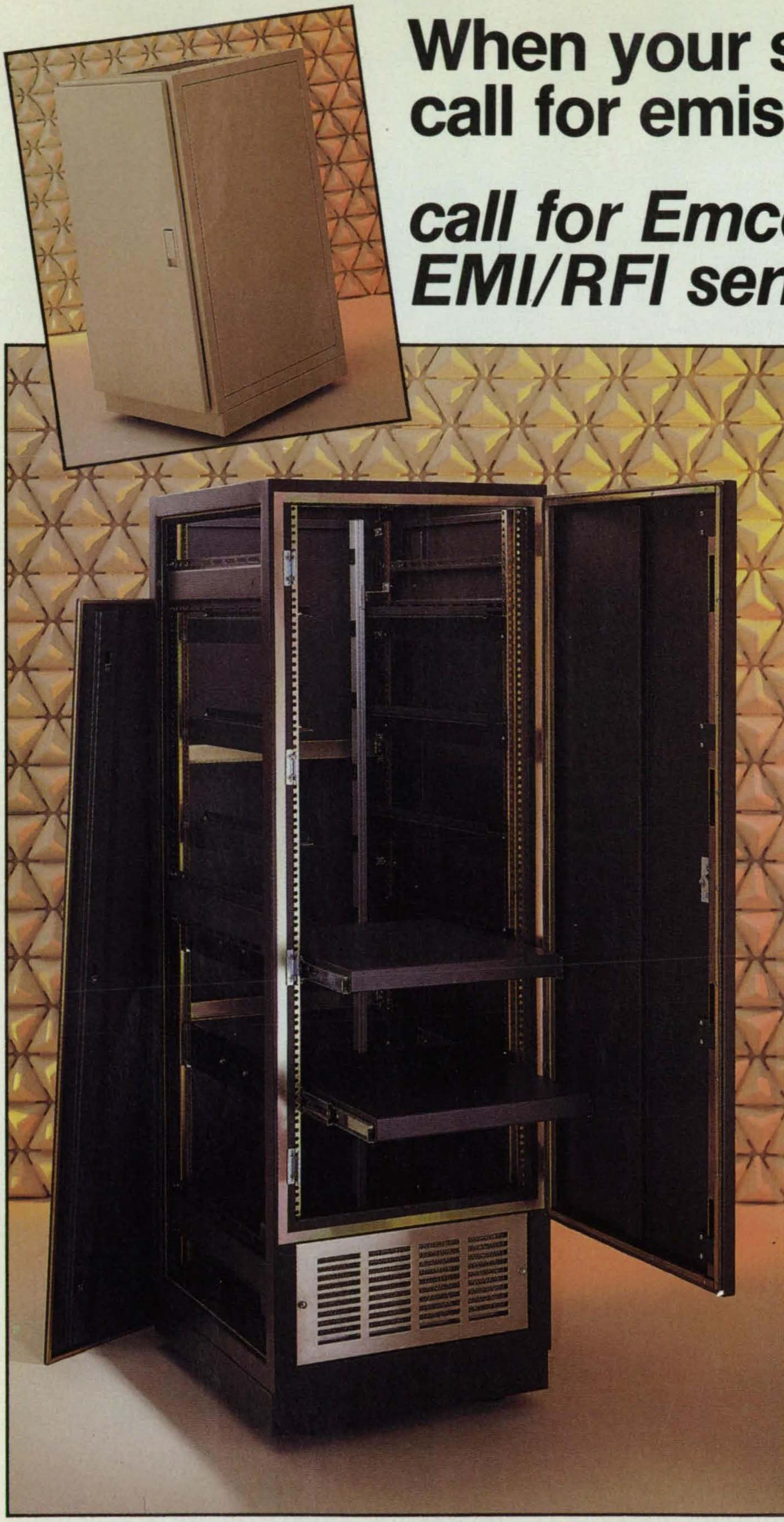
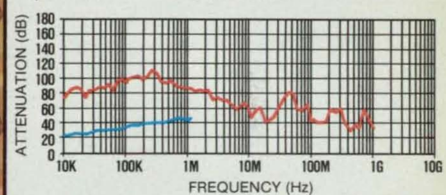


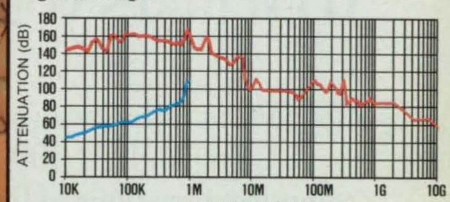
FCC Level

Emcor offers shielding solutions. Shown at left is an Emcor EMI/RFI enclosure —designed for commercial applications and tested to MIL STD 285. Fabricated with 14-gauge cold-rolled steel, these enclosures have the rigidity to maintain shielding continuity. They are also fully zinc-plated — both frame and external components — and come with a full complement of accessories.



Tempest Style

To meet the most demanding levels of shielding often required by the military, Emcor offers its Tempest style line of enclosures as shown in the top photo. Also tested to MIL STD 285, this line combines high strength with modular options and attractive esthetics. Features include a rigid, 12-gauge frame plus a unique latching system and door design (patent pending). These enclosures are nickel-plated with copper finger stock gasketing.



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JUNE 1989
Volume 13 Number 6

SPECIAL FEATURES

Photo courtesy NASA

A simulation tool originally developed for the Space Shuttle program is now aiding research on mechanical hearts. The computer simulation shown above illustrates the geometry used in analyzing fluid flow through a model of the Penn State artificial heart. For more on this Mission Accomplished story, turn to page 117.

TECHNICAL SECTION

DEPARTMENTS

On The Cover: Using powerful supercomputers, NASA scientists have simulated the complex flow of blood in an artificial heart. The cover image shows particle traces color-coded by the height of the point at which they were released from the heart's inflow valve.

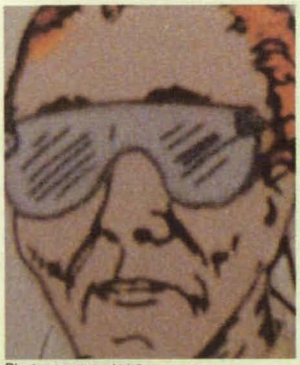

Photo courtesy NASA

NASA is designing high-tech sunglasses to improve low-vision eyesight. See page 16.

ABP BPA

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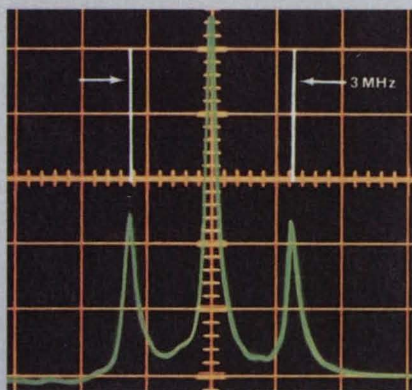

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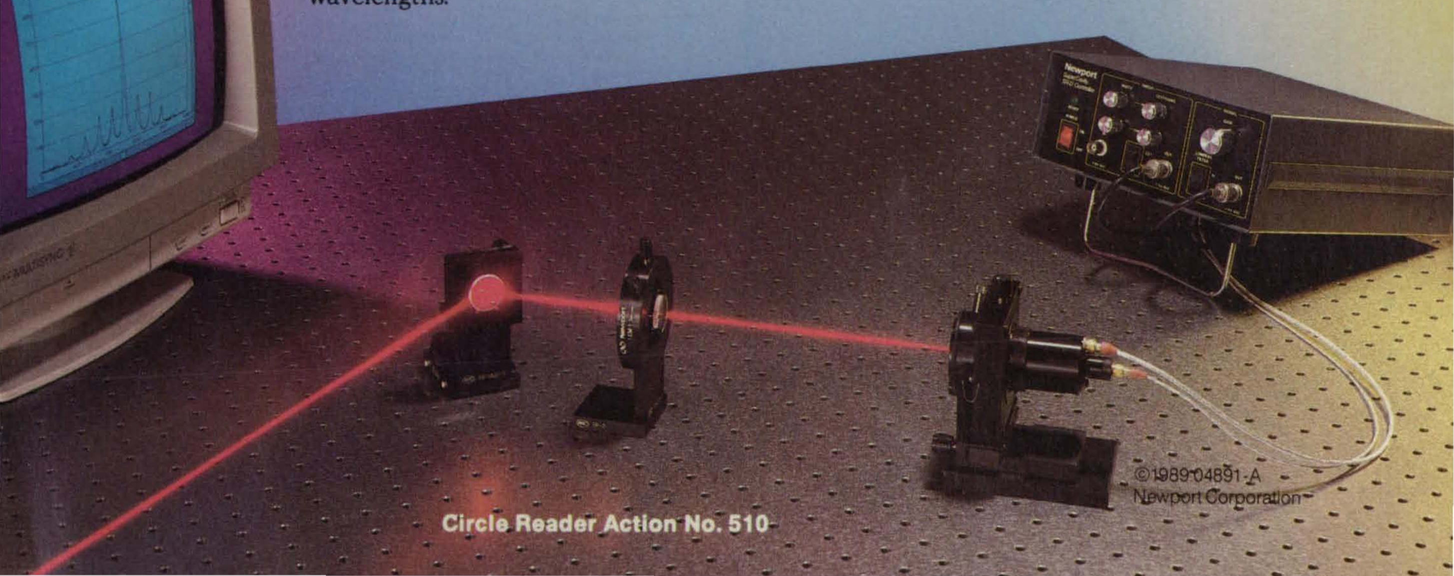

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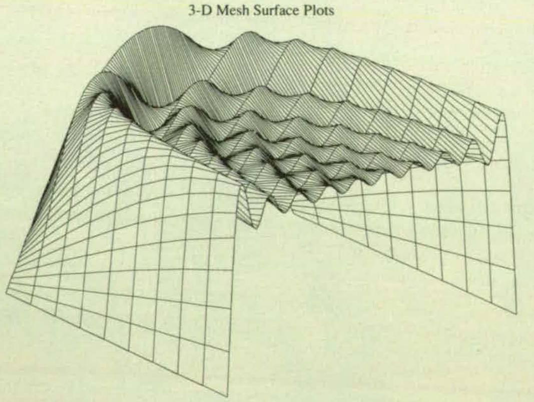

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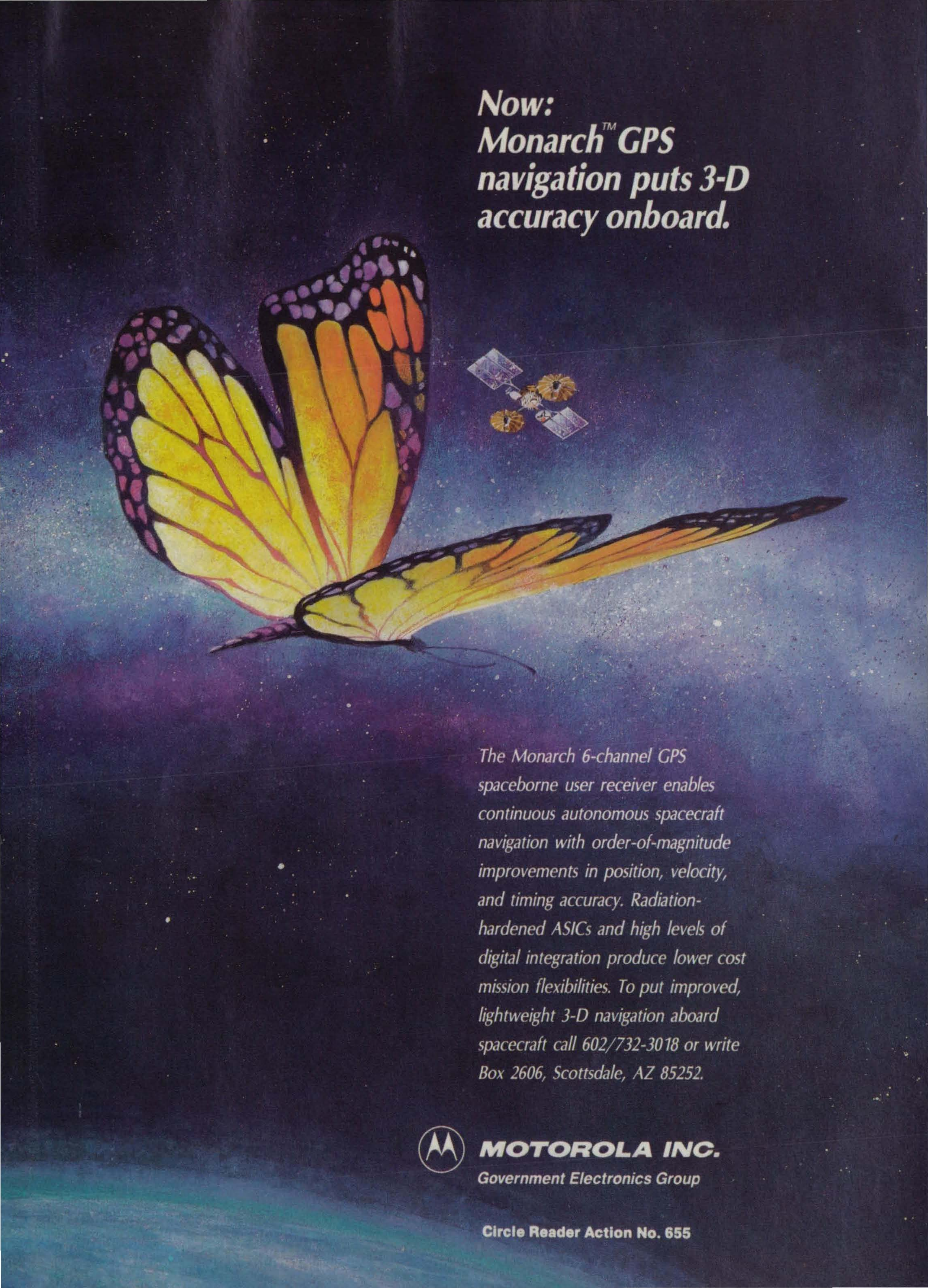
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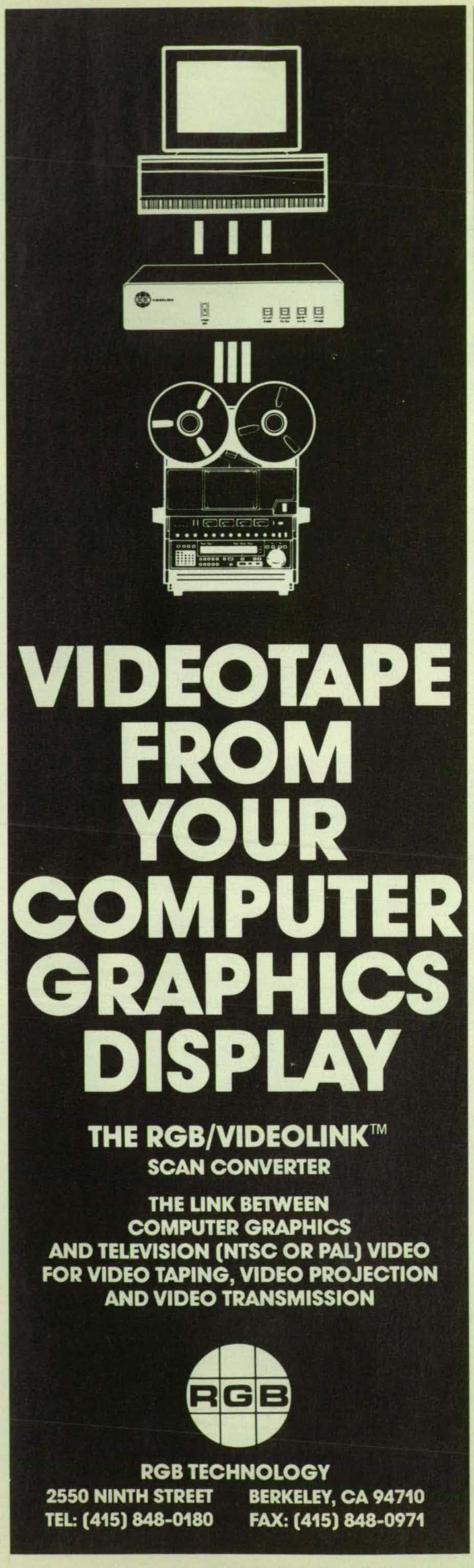

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New Product Ideas

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.

Three-Dimensional Robotic Vision System

A digital image-processing system would act as an "intelligent" automatic machine-vision system by processing views from stereoscopic television cameras into three dimensional coordinates of a moving object in view. The stereoscopy and the effects of motion on the two images would complement each other in providing clues to the natures and locations of principal features. (See page 43).

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Robot Hand Grips Cylinders Securely

A robot hand includes two pairs of parallel jaws that can grasp rods, pipes, tubes, struts, and other long, heavy cylindrical objects. The hand features a compact rotary drive and a butterfly configuration that simplify robot maneuvers. (See page 82).

Advanced Fuel-Cell Modules

A stack of alkaline fuel cells is based on modules, each of which consists of three fuel cells and a cooler. Each cell has an active area of .1 ft^2 (0.09 m^2). The materials and configurations of the parts were chosen to extend life expectancy, reduce weight and manufacturing cost, and increase reliability. (See page 28).

Thermal Brushes for Memory-Metal Actuators

Proposed thermoelectric elements with wire-brush contacts would remove or add heat to memory-metal actuators and thereby enable them to respond faster than previously possible. A memory-metal actuator is formed to a shape while hot, then to another shape while cold. (See page 84).

Continuously-Variable Vernier Scale

The continuously-variable vernier scale is designed to provide greater accuracy to scientists and technologists in reading numerical values from graphical data. It is placed on the graph and used to interpolate the coordinate value of a point on a curve or a plotted point on a figure. (See page 98).

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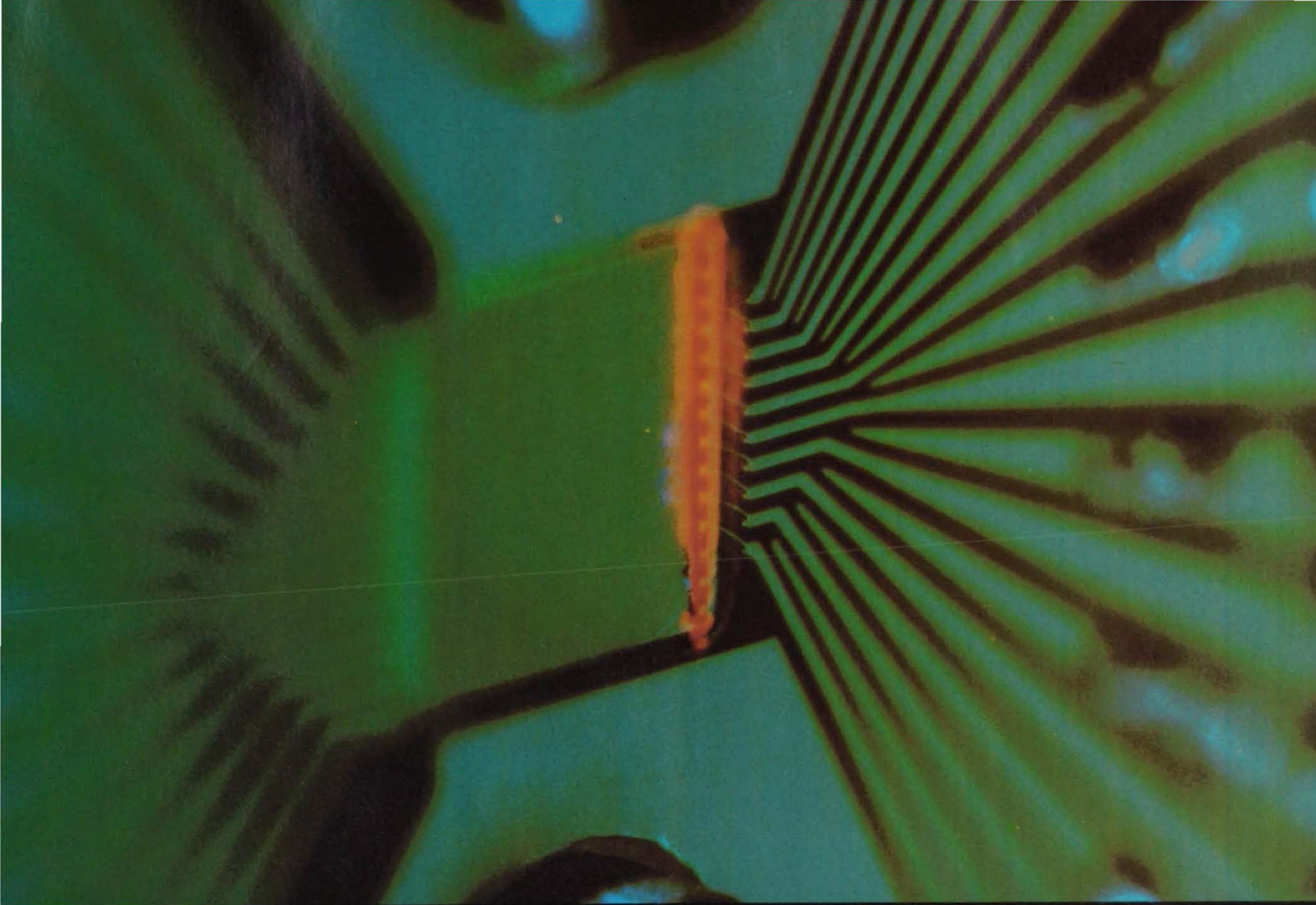

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The powerful new laser pictured here — called a Grating Surface Emitting Array (GSE) — is 100 times brighter than any previous device.

This new semiconductor diode laser technology was developed at the David Sarnoff Research Center, which has been in the forefront of major advances in diode laser devices for the past 25 years.

Some day circuits will talk to each other by means of light because of what Sarnoff researchers in interdisciplinary "centers of excellence" have accomplished in optoelectronics.

The Sarnoff Research Center, today a thriving contract research facility in Princeton, NJ, and a subsidiary of SRI International, had its genesis as RCA Laboratories. Internationally known for its pioneering development of all-electronic, compatible color television, it has a worldwide reputation in electronics, communications, and solid state physics. Many of the electronic advances of the past 45 years had their birth in Sarnoff's Princeton laboratories.

The GSE laser is but one example of the creativity of Sarnoff scientists. We at Sarnoff are in the problem-solving business. What others may consider problems, our researchers consider as challenges to their imagination and ingenuity.

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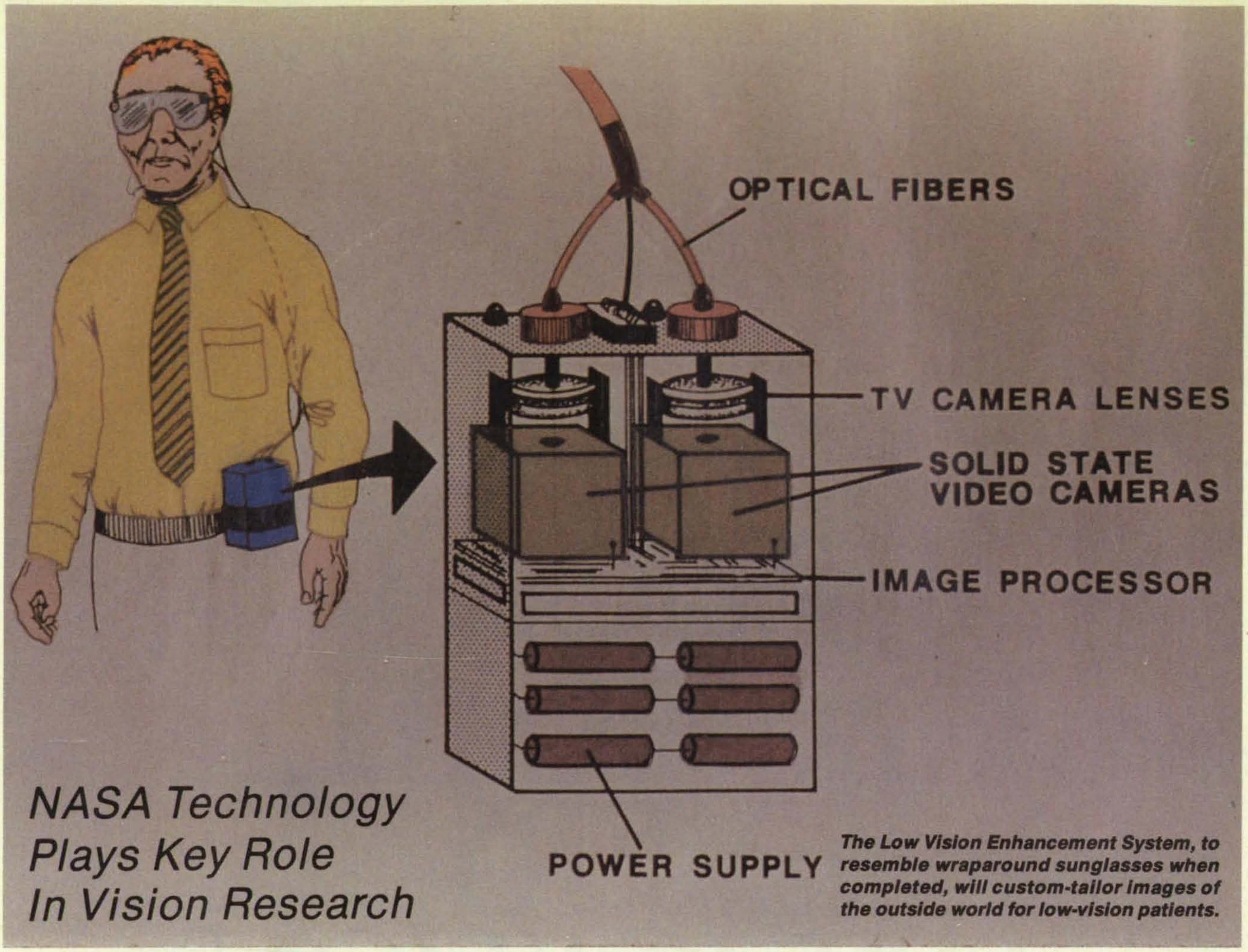


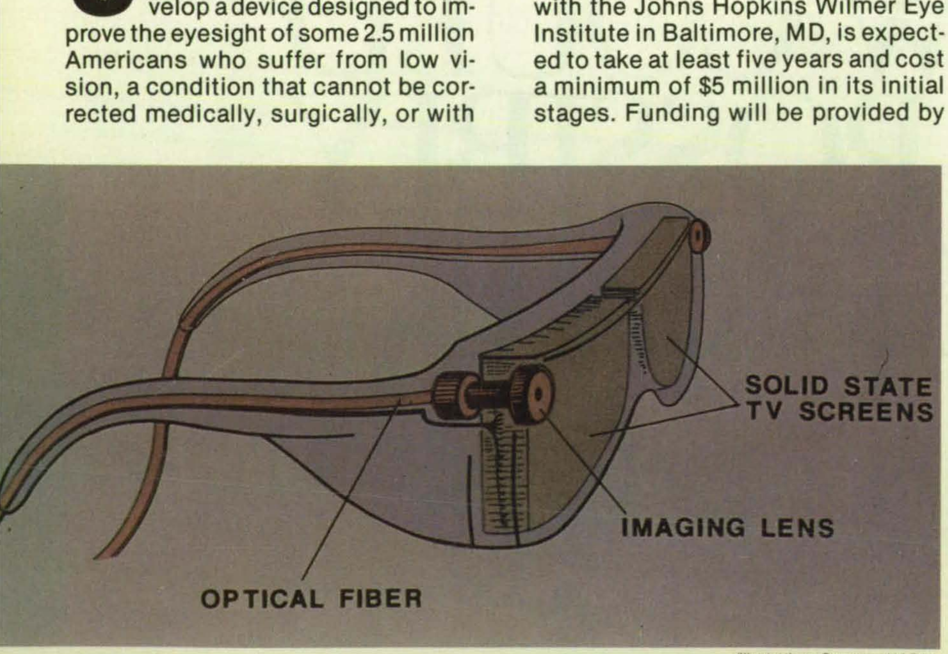
NASA Technology Plays Key Role In Vision Research

The Low Vision Enhancement System, to resemble wraparound sunglasses when completed, will custom-tailor images of the outside world for low-vision patients.

Space-Age Vision Aids

Using space-based imaging techniques, NASA will develop a device designed to improve the eyesight of some 2.5 million Americans who suffer from low vision, a condition that cannot be corrected medically, surgically, or with prescription eyeglasses.

The project, a collaborative effort with the Johns Hopkins Wilmer Eye Institute in Baltimore, MD, is expected to take at least five years and cost a minimum of $5 million in its initial stages. Funding will be provided by Wilmer and NASA's Technology Utilization Office.



(Illustrations Courtesy NASA)

The Stennis Space Center's Earth Resources Laboratory will coordinate the project for NASA, with potential technical contributions from the Jet Propulsion Laboratory (JPL), Ames Research Center, and the Johnson Space Center. All three feature strong vision research programs.

The invention, dubbed the Low Vision Enhancement System, will employ digital image processing technology—originally developed at JPL to enhance photographs of the moon and Mars captured by distant spacecraft. Experimentors will apply such processing techniques as magnification, spatial distortion, and contrast adjustment to compensate for blind spots in the patient's visual field.

As now conceived, the device will resemble mirrored wraparound sunglasses. Low-vision patients will view the outside world on color flat-panel television screens located in the lens

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Circle Reader Action No. 331

PRODUCT UPDATE—NICOLET'S SYSTEM 500

New Power in Waveform Acquisition and Analysis

Unique software helps make the System 500 "turn-key" ready

At first glance, Nicolet Instrument's unveiling of its new System 500 seems newsworthy because of the 500's industry-leading hardware. Indeed, in the world of waveform aquisition and analysis, where more is better, the System 500 is in a class by itself. The 500 has more channels, more memory, more speed and more resolution.

Each digitizer board, with its own independent trigger circuitry, time base and up to 1 megasample record length, is worthy of a full review. This multi-channel system can be configured to have as many inputs you need — up to several hundred. The digitizer boards are designed to be the equivalent of having a 12 bit digital scope on a card.

Turn-key system

But after you get your hands on the System 500, the the most important news becomes apparent. Someone has finally developed a very powerful, competitively priced system for waveform aquisition and analysis that truly is a "turn-key" system.

You literally can take this system out of the box, plug in the power cord, connect the GPIB cable between the aquisition unit and the controller, and turn it on. The System 500 is now ready to take data. This turn–key readiness promises to save time by considerably reducing the learning curve needed to perform complex waveform aquisition and analysis.

Intuitive windows software

The primary reason for System 500's easy operation is Nicolet's unique software which operates under Microsoft Windows/386®. The powerful Nicolet software can easily be controlled through pulldown menus that can be accessed by mouse or keyboard.

Measuring waveforms becomes as simple as pointing to the data point of interest on a waveform and clicking the mouse — the voltage and time values for the selected point is immediately displayed on the screen. By using the Delta Numerics function relative measurements like peak to peak or rise time can easily be made.

Also, Nicolet's unique software, combined with the System 500's built–in processor and co-processor, make incredibly fast waveform processing and analysis possible.

Local processing

While other data aquisition systems need to transfer data to another computer for analysis, Nicolet has built calculation capabilities into the new System 500. Complex calculations can be performed on acquired data as it resides in the digitizer's memory.

There is no need to transfer data to a computer for analysis, no need for complex programming to handle normalizing sets and long record lengths. Functions are performed on the powerful 32 bit processors with a few clicks of the mouse. This local processing of data greatly decreases the time it takes to generate answers.

The bottom line is that the System 500 is a unique turn-key waveform acquisition system. For full details you'll need to read the product brochure.

Call Nicolet Test Instruments (800) 356-3090

The new Nicolet System 500 offers multi-channel flexibility with up to 10 MegaSamples/Second digitizing rates.

portion of the glasses. Lenses and glass fibers will be embedded on each side of the wraparound section, where the front and ear pieces join. The lenses will transport images along the fibers to a miniature solid-state camera carried in a belt or shoulder pack. Images will be processed by a battery-powered computer in the pack and then transported via fiber back to the display screens for viewing.

The vision system may incorporate a programmable remapper developed at the Johnson Center to perform real-time spatial remapping between input and output video. The Remapper would "wrap" images around the patient's blind spot, warping the image so that it is pulled, like a rubber sheet, away from the blind area and magnified.

NASA expects a lightweight prototype to be ready in about five years, with clinical testing to follow soon after. The first head-mounted model may be similar to an imaging system invented by Ames scientists for human factors research (NTB Vol. 12, Num. 7). This "Virtual Workstation" combines three-dimensional graphics, wide field-of-view optics, and advanced eye-tracking techniques to create a stereoscopic experience that gives the user a sense of being inside the display.

A Dynamic Vision Aid

The Low Vision Enhancement System should benefit patients with central vision loss, the part of vision normally used for reading. These patients may have macular degeneration associated with aging, or diabetic retinopathy, in which diabetes causes swelling and leakage of fluid in the center of the retina. It also could help patients with impaired side vision due to eye diseases such as retinitis pigmentosa.

"This system won't restore lost vision," said Dr. Robert Massof, Director of Wilmer's Vision Research and Rehabilitation Center. "Rather, it will help patients make the best use of their remaining vision."

Ongoing Wilmer research supported by the National Eye Institute will provide information on how images must be changed and enhanced for the low-vision sufferer. "The effect of visual impairment on reading, face and object recognition, orientation, and mobility are important research areas that will guide us in developing the Low Vision Enhancement System," said Dr. Gary Rubin, an assistant professor of ophthalmology at Wilmer.

The First Step

NASA first will assemble a basic research system for Wilmer that will

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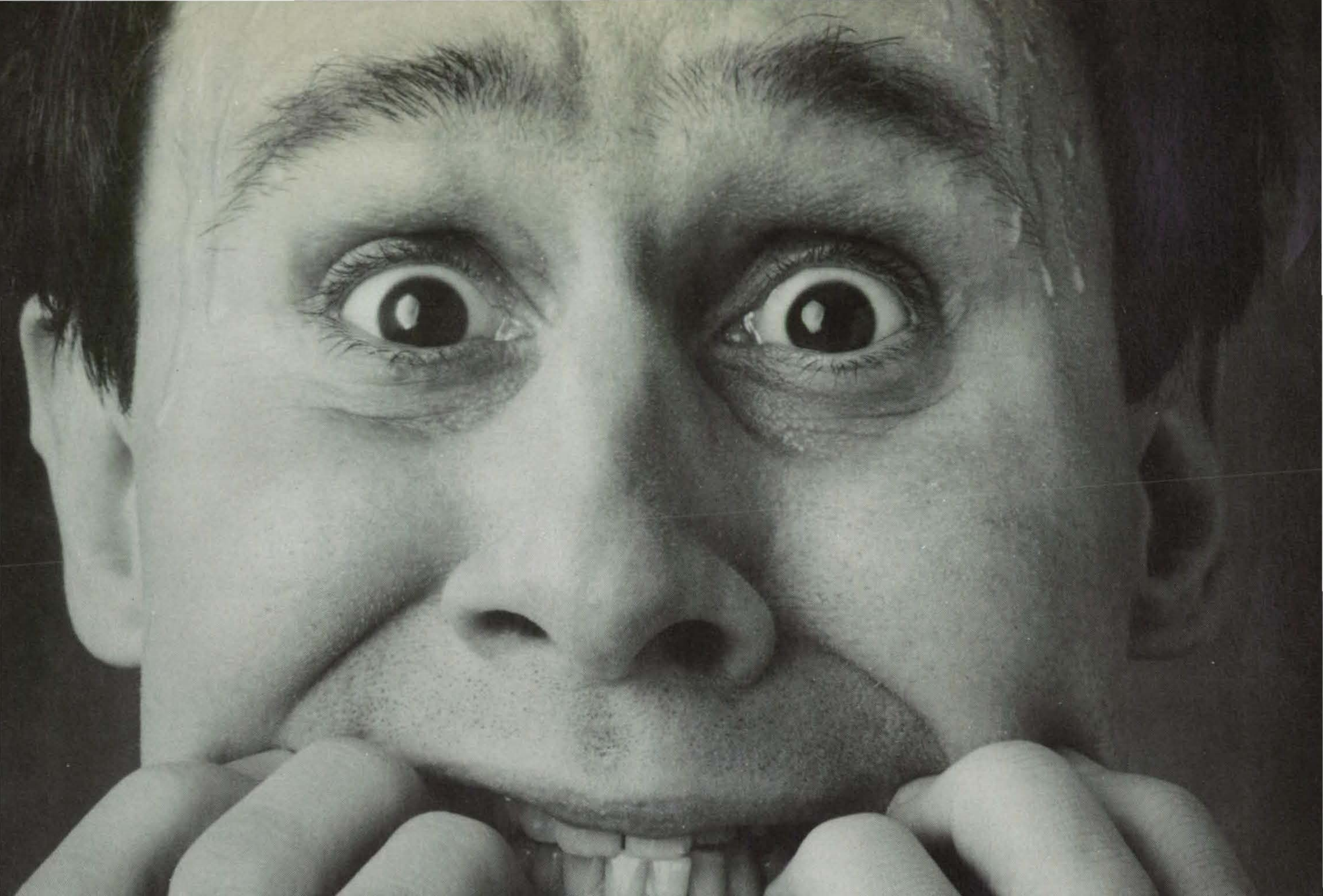

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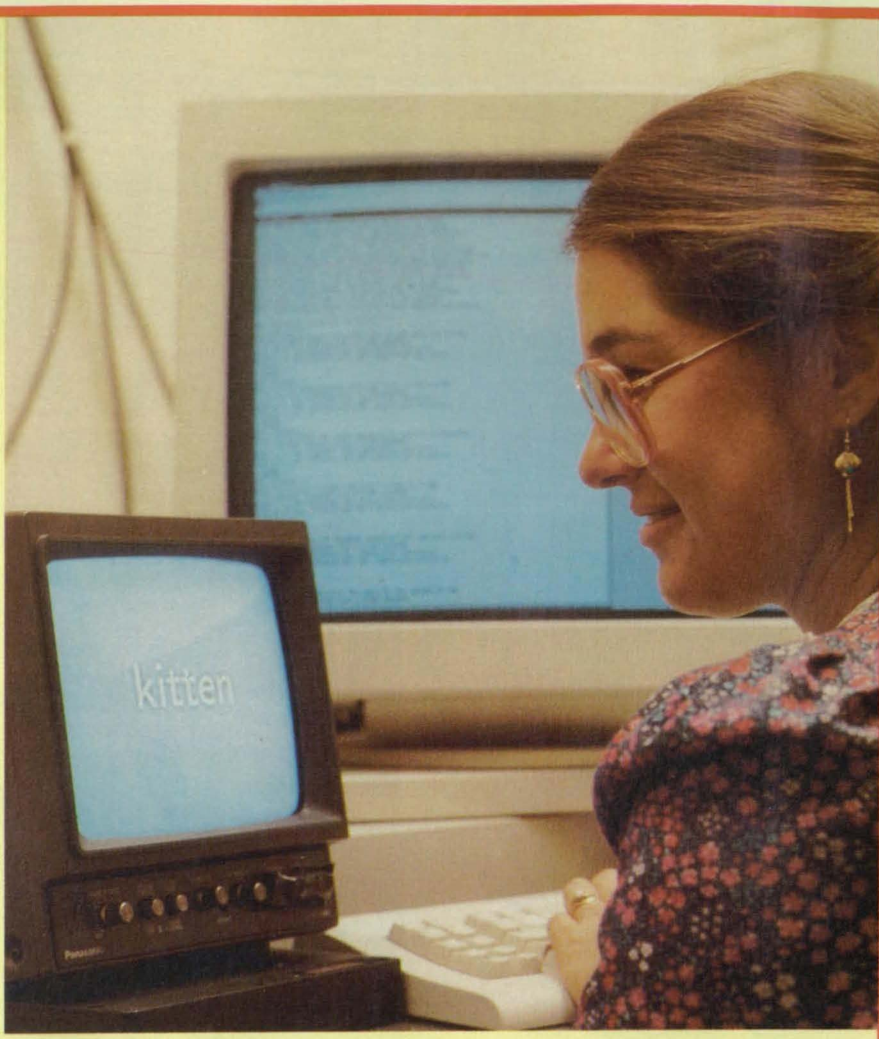
JPL's High-Tech Reading Machine



Dr. Lawton's filtered images appear slightly blurred to the ordinary observer, but are more easily readable by the person for whom the enhancement formula was made.

The first computerized reading aid for low-vision sufferers is nearing completion at NASA's Jet Propulsion Laboratory (JPL), Pasadena, California. Expected on the market by 1991, the system changes the spatial contrast of printed material to compensate for maculopathies, or central vision losses. Maculopathy patients, mostly elderly, can no longer see fine detail or read due to the breakdown of key cells in the retina.

"Until now," said Dr. Teri Lawton, the system's inventor, "there's been virtually nothing to help people with central vision problems." Because maculopathy is a degeneration of nerve cells rather than a problem of the lens or other parts of the eye, it does not respond to conventional treatment or corrective lenses. Powerful magnifiers, which spread a few fuzzy letters over the entire visual field, provide minimal relief.

Like the Low Vision Enhancement System, Lawton's invention is based on digital image processing technology. She uses a computer workstation to test the patient's visual acuity and then, with customized image processing software, to enlarge and filter printed words on a closed-circuit television screen so they have the right amount of brightness for the patient to read clearly.

In recent experiments using the screening method, patient reading speeds increased from two to four times—with up to 70 percent less magnification needed for word recognition—compared to reading unfiltered text.

"The next step," Lawton said, "is to incorporate this technology in a desktop system, something like a microfilm or microfiche reader. I'd like to get some of these out to low-vision clinics for evaluation." Books and magazines would be inserted and moved past the TV camera's lens for reading.

JPL is collaborating with Visualtek, Inc., a leading manufacturer of reading aids based on closed-circuit TV technology, to produce an inexpensive commercial model that should be available within two years.

"Our ultimate goal," Lawton said, "is to develop a portable reading machine in the form of eyeglasses. We'll need liquid crystal displays with higher contrast than what's available today, so we're probably looking five or ten years down the road." □

Dr. Teri Lawton is a psychologist and mathematician researching fundamental vision functions in JPL's Robotics, Teleoperators, and Human Factors Research Group. For more on her work, turn to the tech brief on page 36.

include a general-purpose computer for real-time image processing. The computer will be connected to image processing workstations with multiple input and output devices, enabling Wilmer researchers to simultaneously perform a variety of experiments.

"The idea is to first get a working image processing system going and then to add on new and better pieces of technology as they evolve," explained Dr. Douglas Rickman, who is heading the low vision project at Stennis. "We'll use feedback from the experimentors to make hardware modifications and to design the finished software."

The software environment will be highly flexible, according to Rickman. "In the past," he said, "vision scientists had to build specialized hardware tools to perform experiments. We want to give them a generalized software tool that will allow them to create, edit, and manipulate images in many different ways."

Building Better Robots

NASA scientists hope this research will one day help them to build robots with improved "eyesight" for teleoperations in space. "During the course of this project we may gain a better understanding of how the human brain handles visual data," explained Rickman, "which could prove useful in designing improved ma-

(Continued on page 112)

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Circle Reader Action No. 319

Ultra-Stable Superconducting-Maser Oscillator

Frequency fluctuations would be reduced to as little as 2×10^{-19}.

NASA's Jet Propulsion Laboratory, Pasadena, California

Unprecedented stability of frequency in a superconducting, triple-cavity ruby maser oscillator would be achieved by the incorporation of a proposed amplitude-control subsystem. At present, fluctuations in frequency of 10^{-16} represent the state of the art. The new design should enhance ultrastable measurements of time by reducing the fluctuations to 2×10^{-19} routinely, and to as little as 10^{-20} in exceptional cases.

Fluctuations in the amplitude of the oscillator signal cause fluctuations in the polarization magnetic field in the ruby, which is the active element of the oscillator. Because the magnetic field affects the frequency of oscillation, the amplitude fluctuations result in frequency fluctuations; in fact, the change in frequency is a known function of the change in amplitude. Heretofore, amplitude (and, therefore, frequency) fluctuations have been controlled by placing a power detector and an electronically variable attenuator at room temperature in the pump-signal transmission line. However, this configuration is insensitive to changes in amplitude that occur in the transmission line beyond the power detector or in the ruby itself.

In the new system (see figure) currents are induced in a superconducting pickup coil by changes in the magnetic field in the ruby. The currents from the coil are fed to a superconducting quantum-interference device (SQUID) magnetometer, the output of which is used to generate the control signal for the electronically variable attenuator. Thus, the attenuator varies the pump-signal amplitude in response to the magnetic-field fluctuations in the ruby. A very high feedback-loop gain is used for sensitivity of control and adequate compensation of fluctuations.

This work was done by Donald M. Strayer and G. John Dick of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 149 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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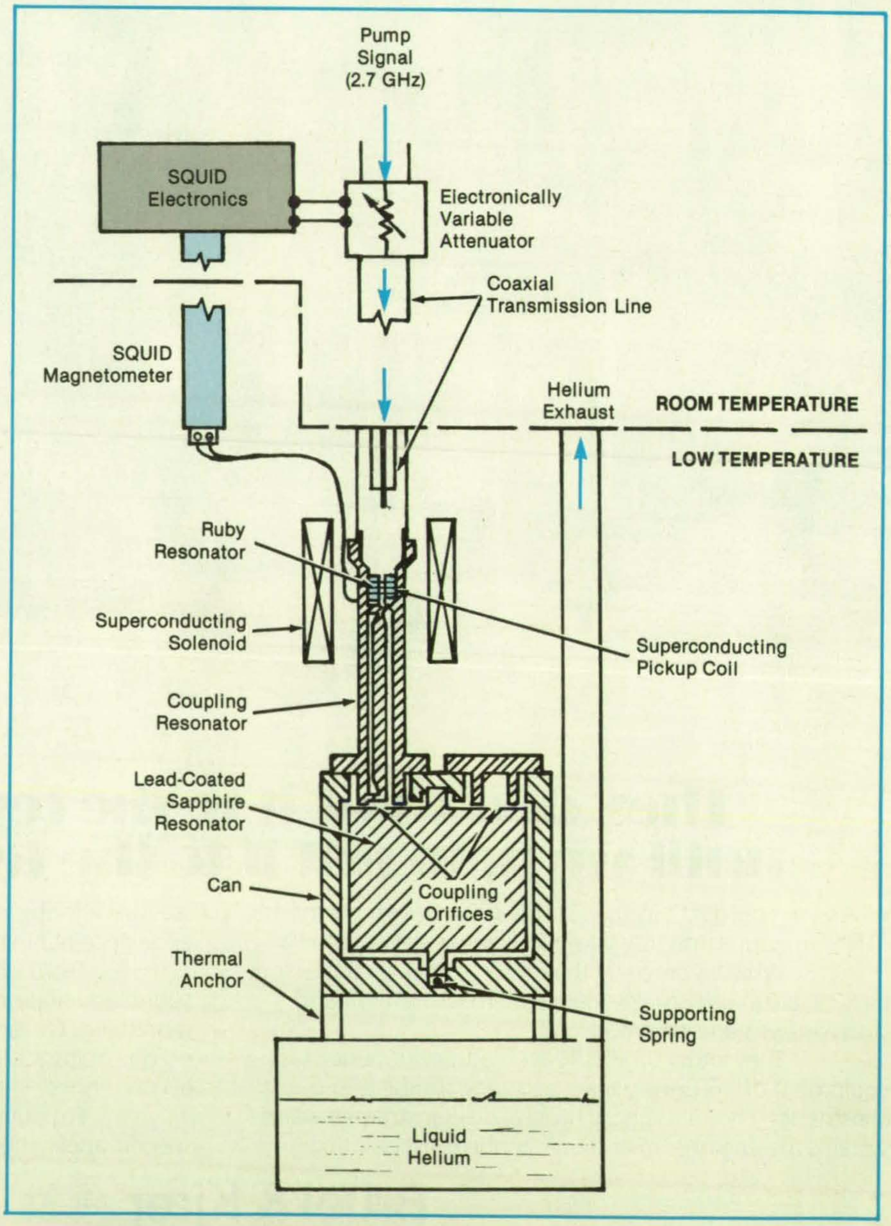
Refer to NPO-17090, volume and number of this NASA Tech Briefs *issue, and the page number.*



In the **Ultra-Stable Superconducting-Maser Oscillator**, the amplitude (and, therefore, the frequency) of oscillations is controlled in response to the condition of the active ruby element at low temperature. In the previous design, the amplitude was stabilized at a point in the transmission line, at room temperature.

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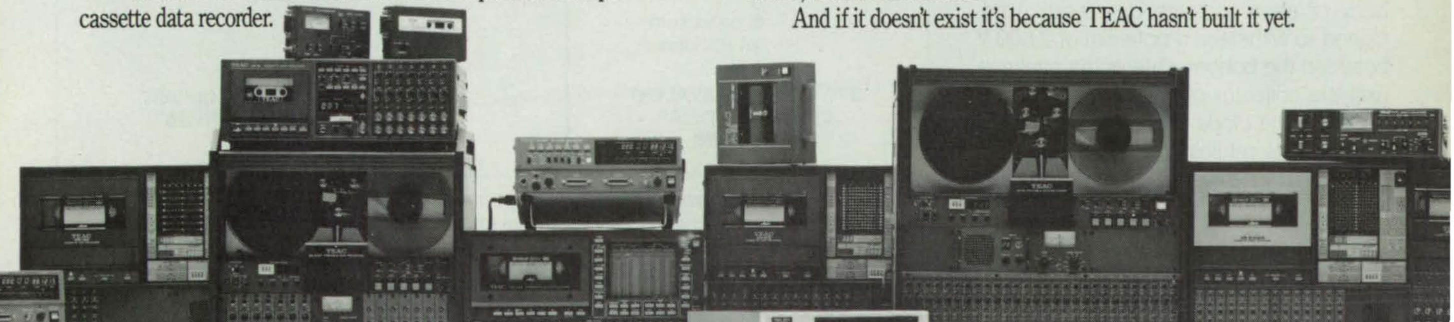

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Circle Reader Action No. 344

High-Performance Power-Semiconductor Packages

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Lewis Research Center, Cleveland, Ohio

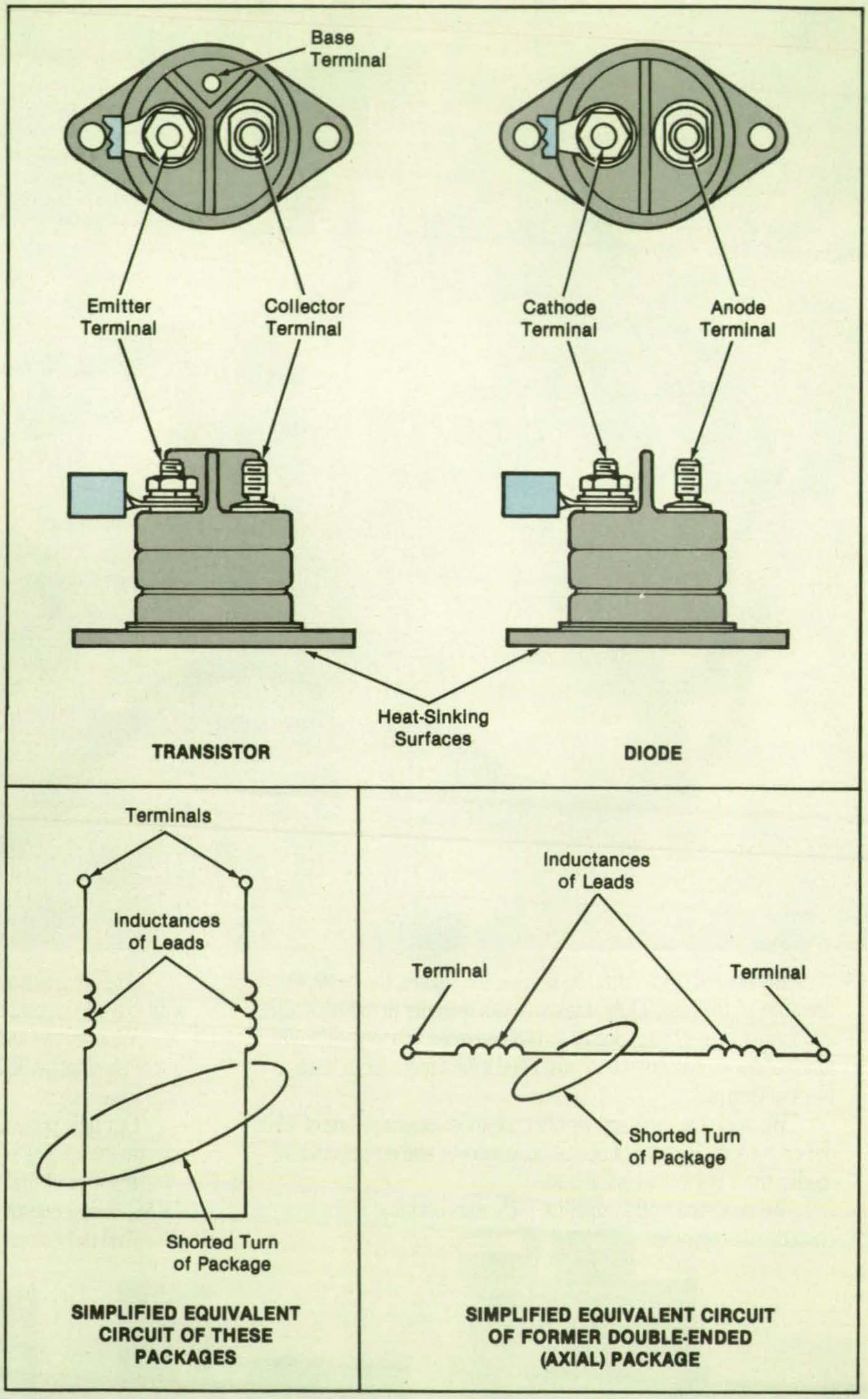
A 600-V, 50-A transistor and a 1,200-V, 50-A diode in rugged, compact, lightweight packages are intended for use in inverter-type power supplies that have switching frequencies up to 20 kHz. The packages provide low-inductance connections, low loss, electrical isolation, and a long-life hermetic seal. The design of the packages solves the historical problem of separation of the electrical interface from the thermal interface of a high-power semiconductor device.

The low inductance is achieved by making all electrical connections to each package on the same plane (see figure). This also reduces high-frequency losses by reducing coupling into the inherent shorted turns in the packaging material around the conductor axes. Stranded internal power conductors aid conduction at high frequencies, where the skin effect predominates. Other conductors are large and made of oxygen-free, high-conductivity copper for low electrical resistance. All conductors are made as short and thick as possible to minimize inductance. The insulators have high dielectric strength and a low dissipation factor.

The semiconductor device is electrically isolated from the package by a beryllia pad. The prime consideration in the design is the transfer of heat generated by the device to the heat sink, and beryllia was chosen because it provides the requisite electrical insulation yet is sufficiently thermally conductive. This feature also reduces the capacitance between the device and the heat sink, thereby reducing both the radiation of electromagnetic interference and common-mode currents in the heat sink.

Both semiconductor devices have glass-passivated junctions. All electrically active components are isolated from the main body of each package by insulation designed to withstand a potential of 2,500 V between the bottom plate of the package and the collector of the transistor or the anode of the diode. The hermetic seal of the package retains an atmosphere of nitrogen. All of the interior surfaces are coated with an extra insulating layer of parylene. If the hermetic seal is broken, this coat enables the device to passthrough the Paschen minimum-breakdown voltage without failure and protects the electrical parts from the environment.

Each package fits within a rectangular parallelepiped of 1.445 by 2.250 by 1.640 in. (36.7 by 57.2 by 41.7 mm). The complete diode and transistor packages weigh 84.5 and 86.0 g, respectively.



All Electrical Connections are made on a plane at the upper end of the package. This reduces inductance and the losses due to the shorted-turn effect of the package materials.

This work was done by David Renz and Irving Hansen of **Lewis Research Center** *and Albert Berman of Microsemi Corp. Further information may be found in NASA CR-180829 [N87-28825], "Space Station Power Semiconductor Package Development."*

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Circle Reader Action No. 346

Asymmetrical SRAM Cells for Radiation Tests

Features of circuits are altered to increase or decrease sensitivity to radiation.

NASA's Jet Propulsion Laboratory, Pasadena, California

The features of static random-access memory (SRAM) integrated circuits can be altered to increase or decrease the susceptibility of memory cells to single-event upsets — changes in logic states induced by impacts of energetic charged particles. The ability to do this is important for the design of radiation-detecting integrated circuits (deliberately made more sensitive to ionizing radiation) and "radiation-hardened" integrated circuits — those intended to be relatively invulnerable to intense radiation.

As the drain of a transistor is enlarged, it can intercept more radiation, thus becoming more susceptible to single-event upsets. However, the capacitance of the affected circuit node also increases, thus decreasing the change in drain voltage caused by the deposition of a given amount of charge from an impact, and this effect decreases the susceptibility to single-event upsets. Because these two competing effects occur to different degrees in different transistors of a memory cell, they can be traded off against each other. Selected areas of different transistors can be enlarged by different proportions that result in a specific overall increase or decrease in the susceptibility to single-event upsets.

For example, in the SRAM cell of Figure 1, the rate of upsets can be increased by the use of asymmetrically enlarged drain regions in pullup transistor Q_2 and pulldown transistor Q_5. For a given level and type of radiation, this design is estimated to increase the rate by a factor of about 3 over that of a symmetrical design.

The rates of upsets can be estimated by a state-space-analysis technique based on the use of a mathematical model of the memory cell with drains of various sizes. The technique is illustrated in Figure 2, where the horizontal and vertical axes represent the voltages on nodes *b* and *a* of Figure 1, respectively. If the voltage on node *a* is initially made higher than the critical voltage by a pulse of ionizing radia-

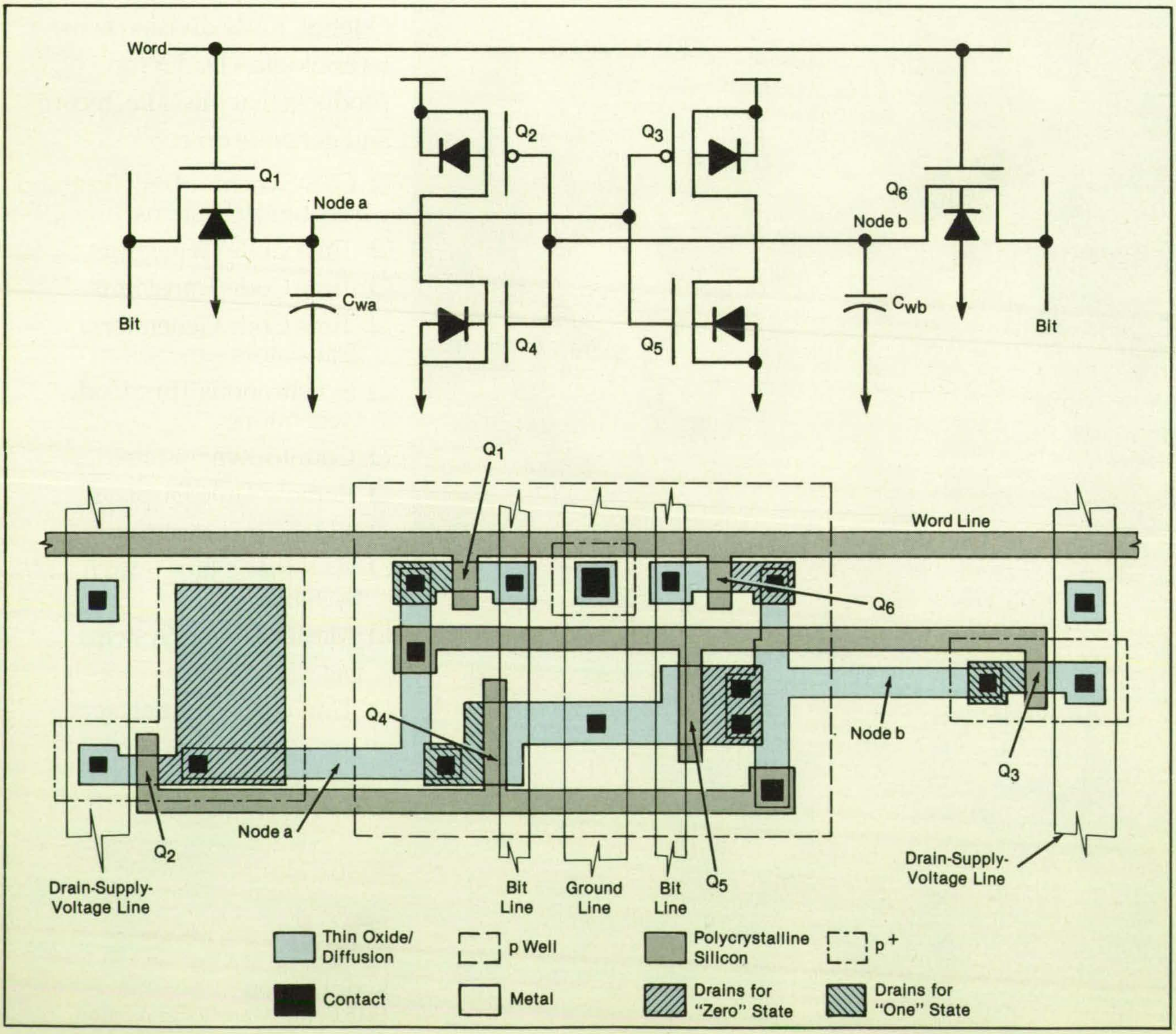

Figure 1. This **Six-Transistor SRAM Cell** was made in versions with different sizes of the areas sensitive to single-event upsets (cross hatched areas).

tion, the cell will change state. For example, if node *a* is initially held at a low voltage and is suddenly raised past the critical voltage by the impact of an energetic ion, then the logic state of the cell will change from "zero" to "one".

In general, the critical deposited charge that causes a given kind of upset depends on these voltage-state-space relationships and the capacitances of the nodes. The sizes and asymmetry of the drains can be chosen not only to make the cell less sensitive (higher critical charge) but also to make one-to-zero upsets more likely than zero-to-one upsets (or vice versa).

This work was done by Martin G. Buehler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 95 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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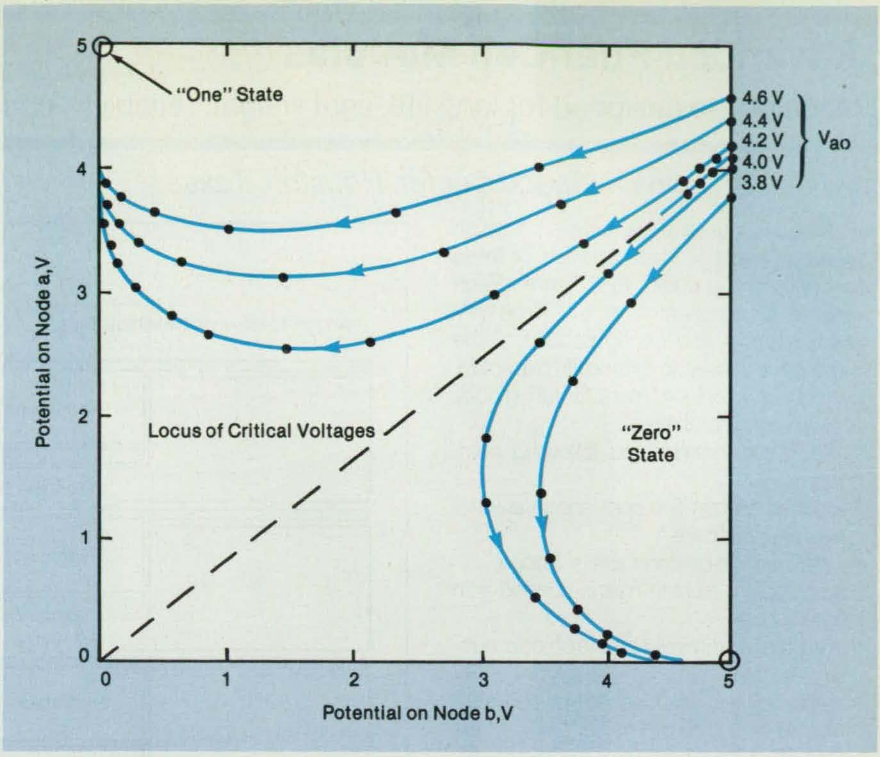
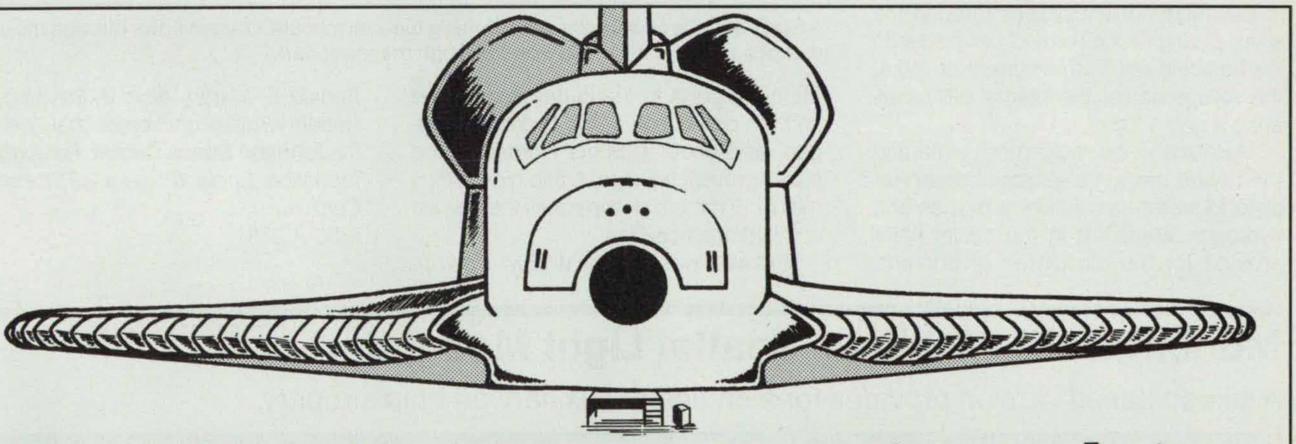


Figure 2. **State-Space Analysis** is used to analyze the single-event-upset behavior of a memory cell like that shown in Figure 1. When the voltage on node a is set at one of the indicated initial values V_{ao} and then released, the voltages on nodes a and b then follow the indicated trajectory to a final logic "one" or logic "zero" state.



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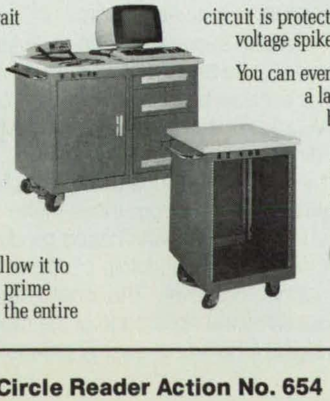

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Advanced Fuel-Cell Modules

Modules are designed for long life, light weight, reliability, and low cost.

Lyndon B. Johnson Space Center, Houston, Texas

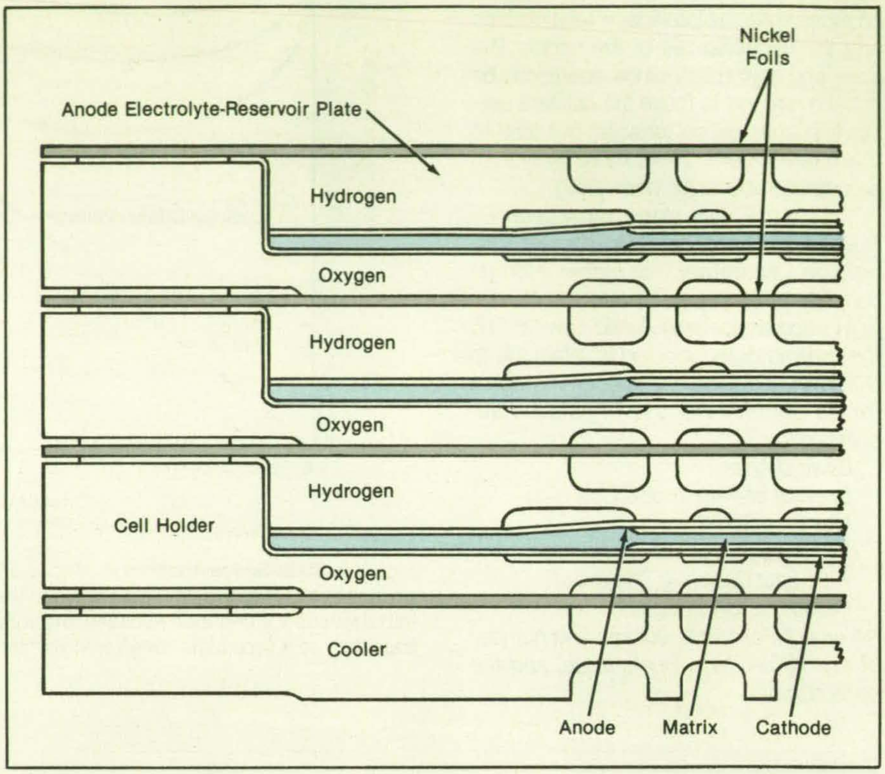
A stack of alkaline fuel cells is based on modules, each of which consists of three fuel cells and a cooler (see figure). Each cell has an active area of 1 ft^2 (0.09 m^2). The materials and configurations of the parts were chosen to extend life expectancy, reduce weight and manufacturing cost, and increase reliability.

Each cell includes the following components:
- a ribbed carbon fine-pore anode electrolyte-reservoir plate,
- a platinum-on-carbon catalyst anode,
- a potassium titanate matrix bonded with butyl rubber,
- gold-plated nickel-foil electrode substrates, and
- a silver-plated, gold-flashed molded polyphenylene sulfide cell holder.

The materials were chosen for resistance to corrosion. Structural components are generally molded to reduce costs. A simple cell-edge seal further reduces costs. The use of carbon for the electrolyte-reservoir plate and a thin nickel-foil electrode substrate help to keep weight low.

Electrical current passes through the silver plating of the molded cell holder to the adjacent cell. With a current of 140 A, the voltage across the internal cell resistance is only 1.5 mV.

Manifolds in the molded cell plate and the ribbed carbon electrolyte-reservoir plate allow the circulation of oxygen and hydrogen. Manifolds in the cooler plate provide for the circulaton of coolant.



A **Stack of Cells on a Cooler** constitutes a fuel-cell module. Oxygen flows through the upper part of a cell, and hydrogen flows through the lower part.

Metering ports in the plates ensure the uniform distribution of the hydrogen, oxygen, and coolant. Seals molded in the plates prevent leakage. A thin nickel foil 5 mils (0.13 mm) thick separates the oxygen and hydrogen cavities.

This work was done by William F. Bell III, Ronald E. Martin, Albin J. Struning, and Robert Whitehill of International Fuel Cells for **Johnson Space Center**. *For further information, Circle 121 on the TSP Request Card.*

MSC-21338

Monolithic III–V/Silicon Spatial Light Modulator

A silicon-based version provides for a choice of auxiliary on-chip circuitry.

NASA's Jet Propulsion Laboratory, Pasadena, California

Current techniques for the growth of device-quality GaAs on silicon substrates should enable the fabrication of a proposed silicon-based version of a photodiode-coupled spatial light modulator. High-density, two-dimensional arrays of picture-element modulators (e.g., a 1,000- by 1,000-element array on a 2-cm-square chip) could be used for real-time processing of images or parallel processing of arrays of data at very high throughput rates. The use of silicon would make available a wider range of auxiliary on-chip signal-processing circuitry for the coding and decoding of data, the addition or subtraction of brightness levels, spatial reformatting, and rescaling.

The proposed modulator would be a layered structure grown on a silicon substrate (see figure). First, a p-doped/intrinsic/n-doped (PIN) photodiode would be formed on the silicon substrate. Then a GaAs buffer layer would be grown over the silicon to form a suitable base for the growth of the InAs/GaAs multiple-quantum-well (MQW) PIN diode structure.

The relative positions of the two diodes would be reversed from those in the original version of the GaAs-based modulator (NPO-16298). The principle of operation is the same, however. The photo-carriers produced by the absorption of the modulating signal (photons of energy greater than the 1.1-eV band gap of Si) in the PIN diode would change the voltage on the MQW diode, and thus the field acting on the MQW's, controlling its transmission of the signal to be modulated (photons of energy near the MQW exciton level and less than the Si band gap). As in the original modulator, the use of InAs/GaAs allows the modulated light signal to pass freely through the substrate and offers the flexibility of tailoring the quantum level of the MQW structure to adjust the wavelength of the modulated beam to values often used with fiber optics; e.g., 1.3 or 1.5 μm.

The confinement of misfit dislocations generated by the 4-percent mismatch be-

Circle Reader Action No. 658

tween the GaAs and Si lattices and the critical problem of control of the initial nucleation of GaAs on Si is being solved in several laboratories world-wide by using modulated-beam epitaxy and related vapor-phase deposition techniques.

This work was done by Joseph Maserjian and Sverre T. Eng of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 98 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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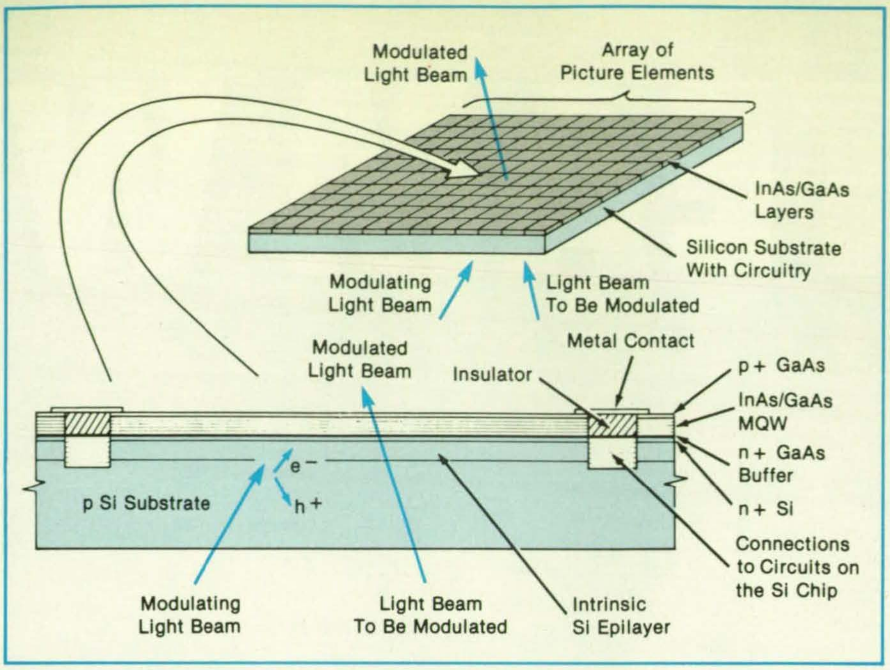


A **Monolithic Photodiode-Coupled Light-Modulator Array** could be constructed on a silicon substrate by growing InAs/GaAs multiple-quantum-wells over a silicon PIN diode layer. An intermediate GaAs buffer layer would confine lattice-misfit dislocations to the vicinity of the silicon.

Stabilizing Semiconductor Devices With Hydrogen

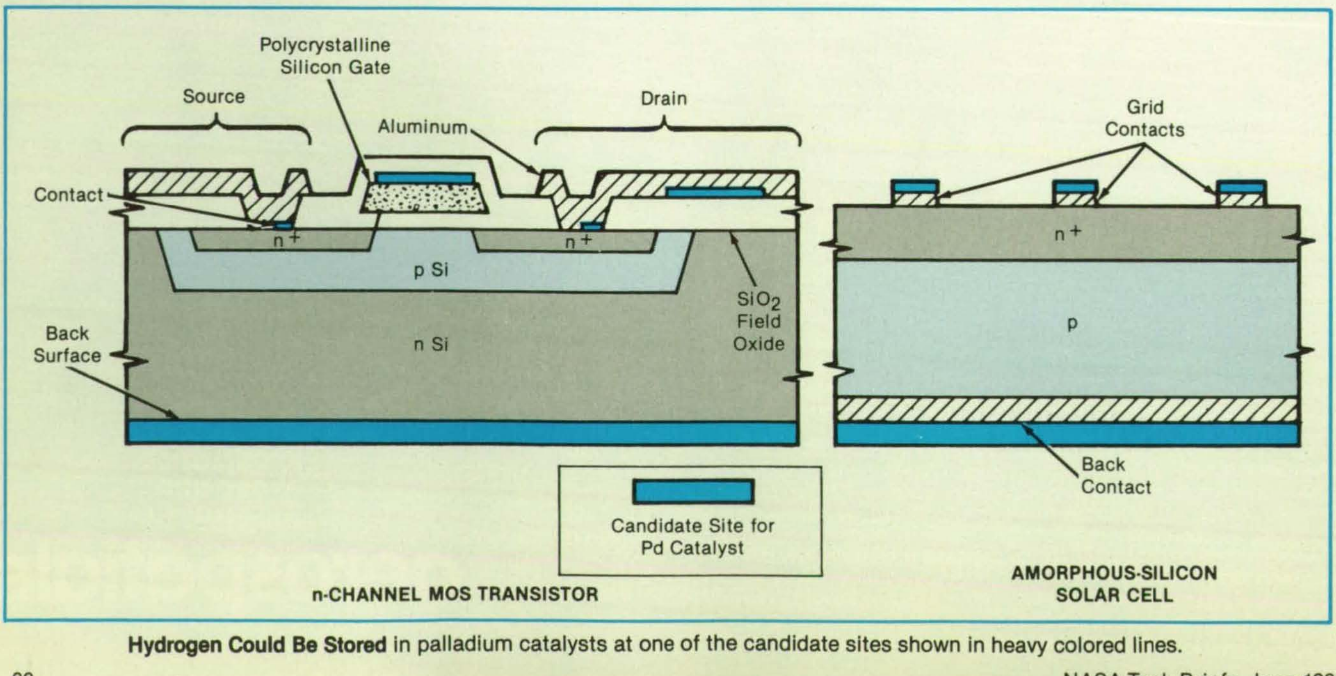
Damage by radiation would be healed rapidly.

NASA's Jet Propulsion Laboratory, Pasadena, California

Palladium would be incorporated into semiconductor devices to store hydrogen near the active regions, according to a proposal. This feature would provide the continuous, rapid recovery of the devices from degradation caused by hot electrons, photons, and ionizing radiation.

In a metal-oxide/semiconductor device, ionizing radiation degrades performance by causing charges to be trapped in the oxide and by generating undesired interface states at the Si/SiO_2 interface. In a very-large-scale integrated circuit with channel lengths of about 1 μm or less, the injection of hot carriers from the channels into the oxide also generates interface states, which can degrade the characteristics of transistors to the point of failure. In amorphous-silicon solar cells, ionizing radiation gives rise to electronic traps and recombination centers in the active region, which decrease the energy-conversion efficiency.

In these devices, the damage involves the breaking of existing bonds between hydrogen and silicon atoms or the creation of new unsaturated bonds between silicon atoms. The deleterious effects can be reversed quickly by providing atomic hydrogen to passivate the unsaturated silicon bonds. The hydrogen can be stored in palladium, which also catalyzes the dissociation of hydrogen from the diatomic



Hydrogen Could Be Stored in palladium catalysts at one of the candidate sites shown in heavy colored lines.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molecular to the monatomic form.

The figure shows several candidate sites for palladium film catalysts, which would be inserted during manufacture as integral parts of the devices. The palladium films could be made by evaporation, sputtering, or chemical-vapor deposition. If additional storage were required, a thick layer of palladium could be plated on the inside of the package that surrounds the device. The hydrogen would be stored by exposing the palladium to hydrogen gas just before the package is sealed hermetically.

This work was done by Albert W. Overhauser and Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 25 on the TSP Request Card.*

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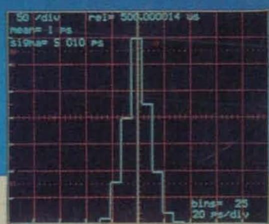

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Advanced Small Rechargeable Batteries

Lithium-based units may offer the highest performance.

A paper reviews the status of advanced, small rechargeable batteries. It covers aqueous systems including lead/lead dioxide (better known as "lead/acid"), cadmium/nickel oxide, hydrogen/nickel oxide, and zinc/nickel oxide, as well as nonaqueous systems. All based on lithium anodes, the nonaqueous systems include solid-cathode cells (lithium/molybdenum disulfide, lithium/titanium disulfide, and lithium/vanadium oxide); liquid-cathode cells (lithium/sulfur dioxide cells); and a new category, lithium/polymer cells.

The use of rechargeable batteries continues to expand as their specific energies and volumetric energy densities increase. In consumer applications particularly, greater volumetric energy densities translate into smaller sizes of equipment.

The latest interest focuses on the nonaqueous lithium systems. They offer substantially higher specific energies (100 to 125 watt-hours/kilogram) and volumetric energy densities (150 watt-hours/liter) than aqueous systems. Lithium systems are still largely experimental. Only one, the lithium/molybdenum disulfide ("Molicel") type, is being manufactured in a commercial pilot plant and is available only as samples for evaluation. The most promising development in lithium nonaqueous systems is the use of polymer electrolytes instead of liquid electrolytes. The solid polymer eliminates leakage and makes it possible to produce batteries on a continuous assembly line with a minimum of handling.

Many advanced types of aqueous batteries are readily available. The best known of these are the small sealed lead/lead oxide and nickel/cadmium. Less well known are the nickel/hydrogen versions, most of which are too large and expensive for use by consumers.

The paper reviews the criteria for the selection of a battery and describes packages for small batteries. It reports on aqueous technology, noting several important innovations, including notably the bipolar versions of the sealed lead/lead oxide battery. These versions are designed for high pulsed power and deep discharge.

This work was done by Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "Advanced Small Rechargeable Batteries," Circle 139 on the TSP Request Card.*
NPO-17396

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Electronic Systems

Counterrotator and Correlator for GPS Receivers

All-digital design provides high accuracy and reduces cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

An accurate, all-digital, high-speed processor comprising a correlator and downconverter has been developed for receivers in the Global Positioning System (GPS). This processor reduces roundoff and commensurability errors to extremely small values. The use of digital chip and phase advancers provides outstanding control and accuracy in phase and feedback. Great flexibility is imparted by the provision for arbitrary starting time and integration length. A minimum-bit design requires a minimum number of logical elements, thereby reducing the size, power, and cost.

The digital baseband processor in a GPS receiver (see Figure 1) consists of two major components: the tracking processor and the high-speed digital processor (see Figure 2). Control information sent by the tracking processor consists of the starting time, the sum interval length, the initial phase and phase rate, and the initial delay and delay rate. Based on this input, the high-speed digital processor accepts input data sampled at 1.5 to 2 MHz for the C/A channel and 15 to 20 MHz for the P channel and counterrotates the carrier, cross-correlates with the pseudorandom code, and accumulates the result over a nominal 20-ms interval.

All high-speed components are timed by the P or C/A sampling clock. The resulting correlation sums are collected by the tracking processor and reduced to extract measured phase, delay, and data bits. The tracking processor analyzes these phase and delay values, averages them to obtain feedback values to drive the digital equipment, and averages them over longer time intervals to reduce the output data rate.

Because all operations, including carrier downconversion, are digital, the phase and delay can be tracked and measured with extremely small errors. Great flexibility in control is provided by the fact that this design requires user-supplied values for starting time, integration length, phase, phase rate, delay, and delay rate. Another flexible feature of this design is the sampling rate. The design itself does not restrict the rate range of the sampling clock.

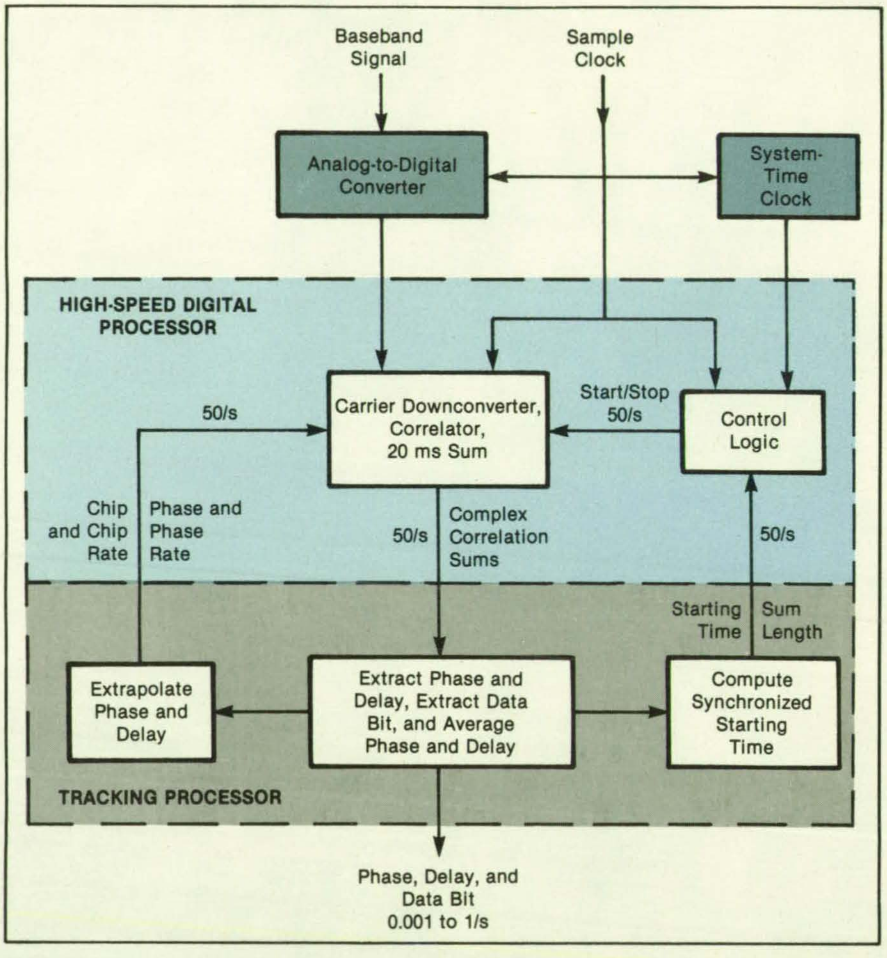

Figure 1. The **Digital Baseband Processor** in a GPS receiver recovers weak signals modulated by pseudorandom sequences.

Limits on the sampling rate will be set by the speed range of the specific equipment.

Even though the basic design would apply to any number of levels per sample, the minimum-bit design has been illustrated in Figure 2. In this design, there is a voltage loss of 4 percent in the voltage signal-to-noise ratio (SNR) due to three-level quantization of the downconversion sinusoids and a 20-percent loss if two-level sampling of the baseband signal is used. If three-level sampling is used, there is a loss of approximately 10 percent. If these small losses are acceptable in a given application, one can implement the minimum-bit design and arrive at a digital logic with a minimum number of logical elements, thereby greatly reducing the size, power consumption, and cost of the chip(s) fabricated to carry out these operations.

The design can also be used for quadrature processing, even though Figure 2 illustrates a single nonquadrature channel. To process complex signals, the operations are applied separately to each quadrature channel in parallel equipment channels. Both quadrature channels can be served by the same circuitry for generation of the delay code and counterrotation phasers. At the end of an integration inter-

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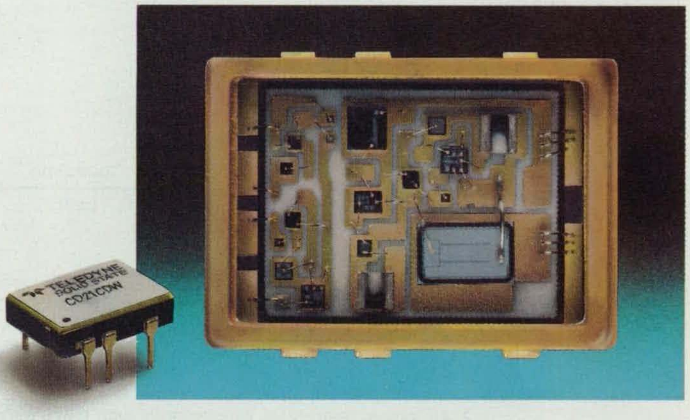

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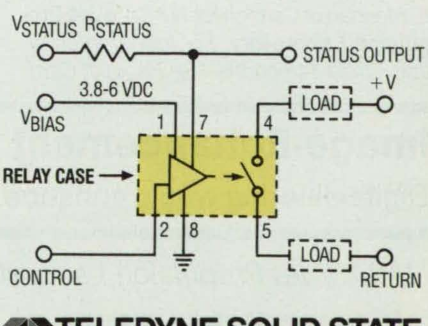
PART # CD21CDW

Review the electrical characteristics and call us for immediate application assistance.*

ELECTRICAL CHARACTERISTICS (–55°C to +105°C unless otherwise noted)	Min	Max	Units	
Bias Voltage (V_{BIAS})	3.8	6.0	V_{DC}	See Note 1
Bias Current (I_{BIAS})		15.0	mA	$V_{BIAS} = 5V_{DC}$
Control Voltage (V_{IN})	0	18.0	V_{DC}	
Control Current (I_{IN})		250	μA	$V_{IN} = 5V_{DC}$
Turn-Off Voltage $V_{IN\,(OFF)}$	3.2		V_{DC}	
Turn-On Voltage $V_{IN\,(ON)}$		0.3	V_{DC}	
Continuous Load Current		1.2	A	–55°C to +25°C
I_{LOAD} @ 60 VDC		0.7	A	+85°C
Output Trip Current (I_{TRIP})	2.4 (Typ.)		A	+25°C, 100ms
On-Resistance (R_{ON})		0.65	Ohms	
Turn-On Time (T_{ON})		1.5	ms	
Turn-Off Time (T_{OFF})		0.25	ms	
Status Voltage (V_{STATUS})	1	18	V_{DC}	
Status Current (I_{STATUS})		2	mA	$V_{SAT} \leq 0.3V_{DC}$ See Note 2

Notes: 1. Series resistor is required for bias voltages above $6V_{DC}$. $RS = (V_{BIAS} - 6\,V_{DC})/15$ mA
2. A pull up resistor is required for the status output. $R_{STATUS} = (V_{STATUS} - 0.3)/I_{STATUS}$
3. Output will drive loads connected to either terminal (sink or source).
4. Status circuit is a built-in test feature checking the input circuitry of the relay. Status output is low (on) when the input is on.

All power FET relays may drive loads connected to either positive or negative referenced power supply lines (source or sink modes).



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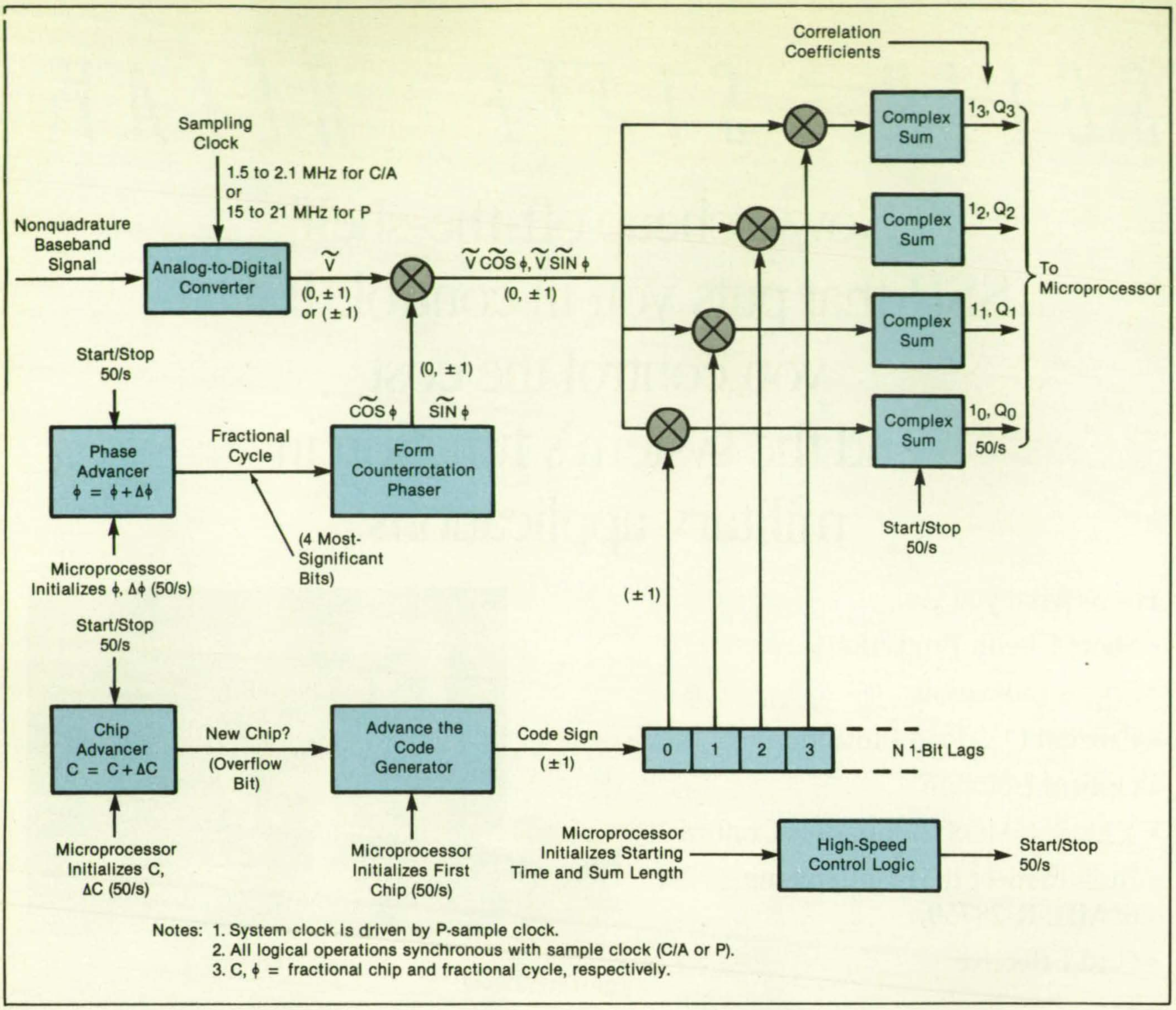

Figure 2. The **High-Speed Digital Processor** is accurate, flexible in operation, compact, conservative of energy, and relatively low in cost.

val, subsequent processing combines the complex sums with appropriate signs for the real and imaginary parts.

This work was done by J. Brooks Thomas, Jeffrey M. Srinivasan, and Thomas K. Meehan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 148 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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Refer to NPO-16998, volume and number of this NASA Tech Briefs *issue, and the page number.*

Image-Enhancement Aid for the Partially Sighted

Digital filtering would enhance the ability to read and to recognize objects.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental digital electronic image-processing system may eventually assist partially sighted people in reading and in recognizing objects or small visible features. The system is intended primarily to help individuals who have central vision losses such as age-related maculopathies. These disorders degrade the high resolution central vision, forcing one to rely on the lower resolution peripheral areas of the retinas to recognize patterns. It should be possible to construct a portable vision aid by combining miniature video equipment to observe the scene and display the images with very-large-scale integrated circuits to implement real-time digital image-data processing.

In effect, the system is digitally "fitted" to each eye. First, the patient's contrast-sensitivity function would be measured by asking the person to look at and detect patterns of various spatial frequencies and contrasts in a visual testing and training instrument. The contrast-sensitivity function maps out the range of one's visible spatial frequencies. Generally, the afflicted observers can see only low and intermediate spatial frequencies (below about 8 cycles per degree).

The clarity of the perceived image can be partly restored by enhancing those spatial-frequency components that are less visible to the afflicted than to a normal observer of the same age. A measure of the required enhancement as a function of

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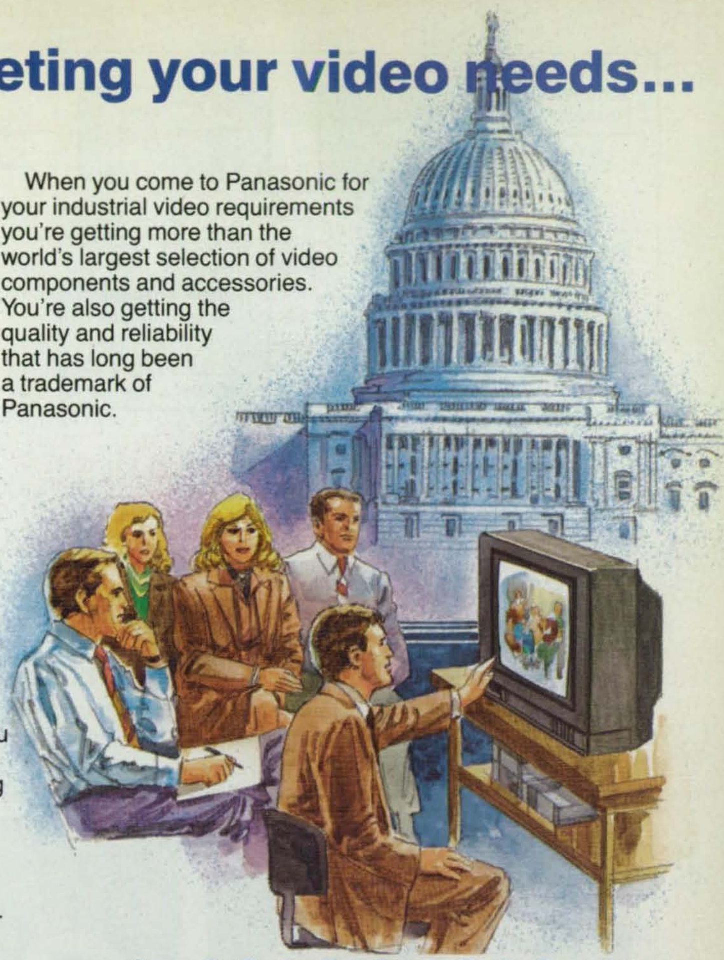

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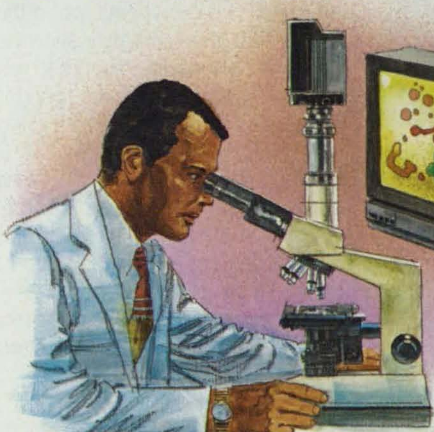

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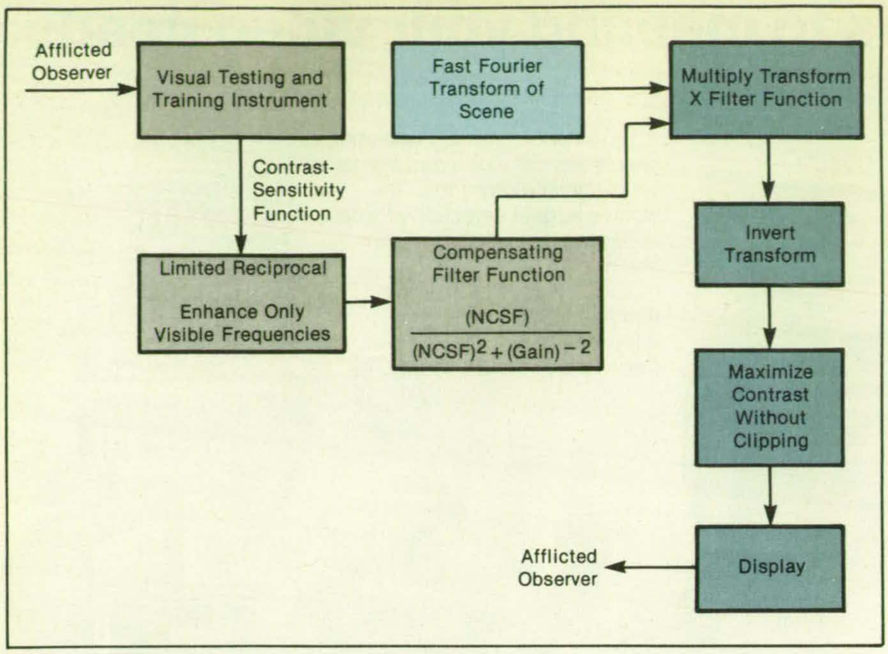

Figure 1. A **Digital Filter in the Spatial-Frequency Domain** is derived from the afflicted observer's normalized contrast-sensitivity function (NCSF) and used to enhance the spatial frequencies that appear less visible.

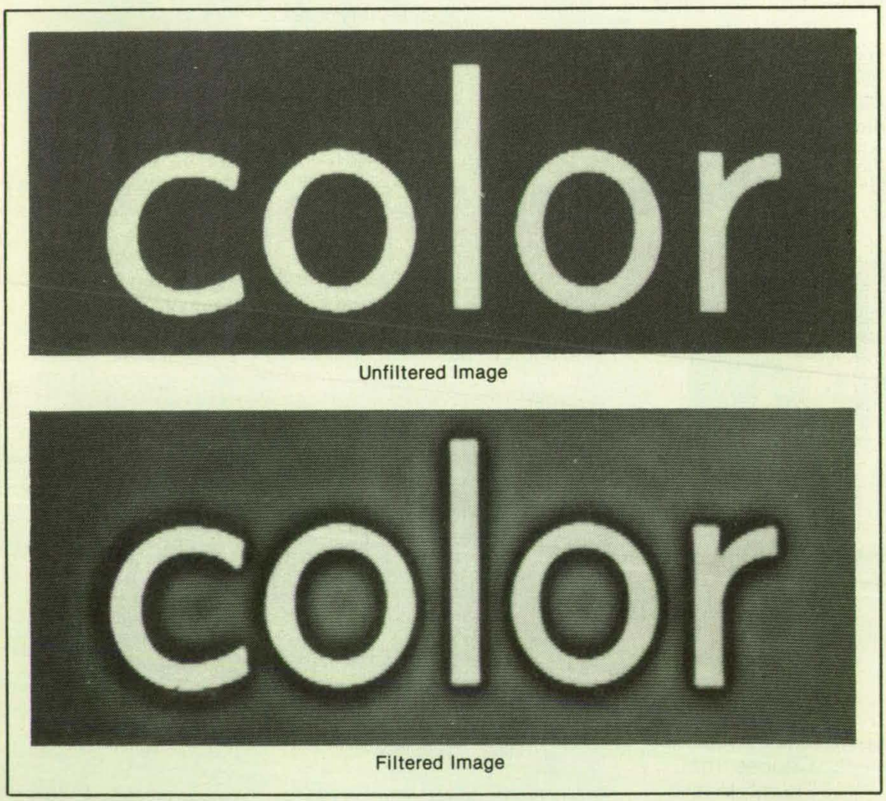

Figure 2. The **Filtered Image** of the word is more easily recognized by an afflicted observer than is the unfiltered image.

spatial frequency is provided by the reciprocal of the afflicted observer's normalized contrast-sensitivity function (NCSF), which is the afflicted patient's contrast-sensitivity function divided by the contrast-sensitivity function of the normal observer. The reciprocal of the NCSF is limited to the spatial frequencies between the lowest and highest spatial frequencies visible to the afflicted observer.

The digital compensating filter derived from the NCSF is implemented as a transfer function that multiplies a fast Fourier transform of the scene in spatial-frequency space (see Figure 1). The individualized compensation filter that is marketed will be filtering in the spatial domain for fast, inexpensive image enhancement. The compensating filter includes a gain term that controls the compromise between enhancement of resolution and rejection of noise. The fast Fourier transform is then inverted, and the contrast of the resulting processed image (see Figure 2) is adjusted to prevent clipping at the bright and dark extremes of the scene.

An afflicted observer could view the scene through a magnifier to shift the spatial frequencies downward and thereby improve the perceived image. However, the less the magnification needed, the larger the scene that can be observed. Thus, one measure of the effectiveness of the new system is the amount of magnification required with and without it. In a series of tests, it was found that 27 to 70 percent more magnification was needed for the afflicted observers to recognize unfiltered words than to recognize filtered words.

This work was done by T. A. Lawton and D. B. Gennery of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 44 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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Refer to NPO-17307, volume and number of this NASA Tech Briefs *issue, and the page number.*

Airplane-Acceleration Display for Low-Gravity Research

A bar-graph display facilitates precise control of trajectories.

Lewis Research Center, Cleveland, Ohio

An acceleration display for an airplane helps the pilot to fly trajectories that produce the effect of zero gravity or fractions of Earth gravity (g) within the airplane. With the help of the display, the pilot can adhere to a predetermined fraction of g, with minimal lateral acceleration.

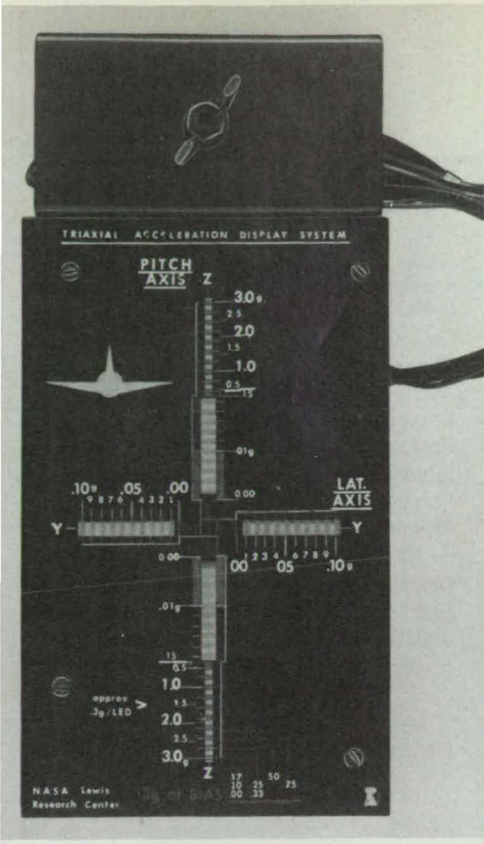
Developed for a Learjet used for microgravity research, the display consists of light-emitting-diode (LED) bar graphs (see figure). A pitch-axis bias switch lets the pilot select one of nine settings for the zero reference of the display so that any of the following trajectories can be flown: 0 g, $\frac{1}{20}$ g, $\frac{1}{10}$ g, $\frac{1}{6}$ g (Lunar gravity), $\frac{1}{5}$ g, $\frac{1}{4}$ g, $\frac{1}{3}$ g (Martian gravity), $\frac{1}{2}$ g, and $\frac{3}{4}$ g. The accelerations can be sustained within 0.01 g for 5 s, 0.02 g for 7 s, and 0.04 g for 20 s.

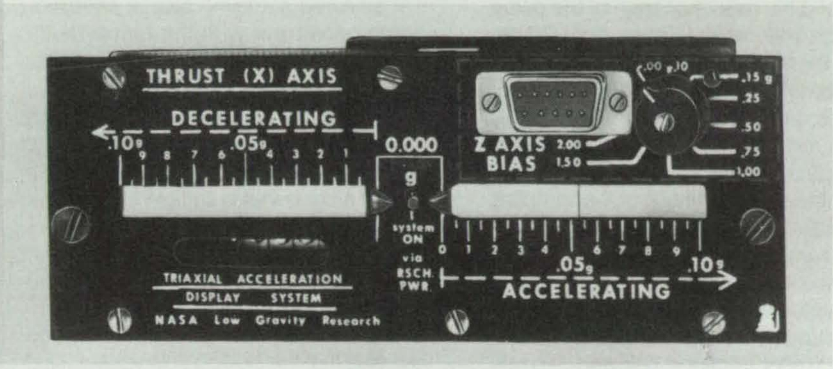
Three LED bar displays present acceleration in the x (thrust), y (lateral), and z (pitch) axes. The pitch and lateral displays are located in front of the pilot, who controls the yoke and rudder. The thrust display is located in front of the copilot, who controls the throttles.

In comparison with the usual needle displays, the LED bar-graph displays take up less panel space and are easier to align with the axes they represent. They have no moving parts and are not subject to parallax. However, they are not legible in direct Sunlight and have resolution limited by the finite sizes of the individual LED's.

The overall display system includes an accelerometer block, a power-supply-and-interface box, the thrust-axis display, and the pitch-and-lateral-axes display. The accelerometer block includes three servoaccelerometers orthogonally mounted on an adjustable triaxial base that allows fine alignment of the accelerometers with respect to the airplane. The accelerometer block and the power-supply-and-interface box are located near the center of gravity of the airplane in the luggage area.

The pitch-axis bar graph has two regions. The innermost LED's (10 positive and 10 negative) have a high-resolution logarithmic scale. The outermost LED's (10 positive and 10 negative) have a low-resolution linear scale. The inner LED's are set to correspond to a range of 0.06 g and the





PILOT'S SIDE **COPILOT'S SIDE**

The **Pilot, Who Controls Pitch and Yaw**, views the display of pitch and lateral accelerations. The copilot, who controls the throttles, views the thrust-acceleration display.

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outer stacks to a range of 3 *g*. The inner LED's are driven by comparators with logarithmic increments to provide finer resolution about zero than would otherwise be possible with a linear scale.

This work was done by Marc G. Millis of **Lewis Research Center**. *Further information may be found in NASA TM-87358 [N87-18801/NSP], "Acceleration Display System for Aircraft Zero-Gravity Research."*

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LEW-14650

Chip Advancer for GPS Receiver

Instrumental errors can be made negligible.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a Global Positioning System (GPS) receiver, a pseudorandom code sequence can be generated by simple digital logic that incorporates the effects of time, the delay, and the rate of change of the delay. For each integration interval, both the delay and the rate of change of the delay can be initialized to a small fraction of a chip — for example, to the order of 10^{-7} — thereby making feedback control and the extraction of delay highly accurate and flexible. With appropriate selection of the sampling rate relative to the chip rate, commensurability errors can be reduced to extremely small levels.

By supplying the proper initial integer chip value to initialize the code generator and the proper fractional chip and chip rate for the chip advancer, external hardware or software can control a code sequence that starts at a fraction of a given chip and advances at the selected chip rate. In a GPS receiver, the initial chip value (integer plus fractional parts) would be based on the starting time and the feedback delay, while the chip rate would be equal to the sum of the rate of change of the delay and the fundamental chip rate divided by the sample rate. The chip advancer is activated and deactivated by a "start" line. Over a correlation interval, the model delay consists of a linear time function.

As illustrated in the figure, the chip advancer is initialized by external hardware or software that supplies an initial fractional-chip value in the form of an integer equal to the fractional chip times 2^N and a chip rate in the form of an integer equal to the chip rate (in chips per sample point) times 2^N, where N is the number of bits in the fractional-chip register. Simultaneously, the external device also initializes the registers of the code generator so that the code generator will produce the correct code sign for the first sample point.

When processing is started, the chip advancer is clocked by the sampling clock. For each new sample point, the chip advancer adds the number in the rate register to the number in the fractional-chip register. When the fractional-chip register overflows, indicating a transition to a new chip, a pulse is generated. That pulse triggers enabling logic circuitry that lets the concurrent sampling clock advance the code generator to the next chip. If the code generator does not receive a new-chip-advance signal for a given sample point, the previous code sign persists for that sample.

If selected sampling rate is effectively incommensurate with the fundamental chip rate, the integrated error due to discrete sampling of the model code sequence can be reduced to negligible levels after integration over a fairly short time. In selecting a sampling rate, it is advisable to choose a value that is sufficiently removed from highly commensurate ratios (e.g., 2/1, 3/2, etc.) so that the Doppler shift cannot change the chip rate to a value highly commensurate with the sampling rate.

An important option in using the chip advancer is that the starting chip value, including the fractional chip, can be set exactly every sum interval. Thus, the measured delay will be corrupted by roundoff errors at the level of 2^{-N} or less, which is less than 100 nanochips for a 24-bit chip advancer. The buildup of the roundoff error due to roundoff in the rate register can be eliminated by computing the roundoff accumulation and offsetting the initial delay to compensate. Further, the flexibility of accurately resetting the chip and the chip rate for each correlation interval is very useful in many applications; for example, those involving multiplexing schemes. The flexibility in the starting time and the sum interval is very useful in aligning the correlation interval with the beginnings and endings of data bits.

This work was done by Thomas K. Meehan, Jeffrey M. Srinivasan, and J. Brooks Thomas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 147 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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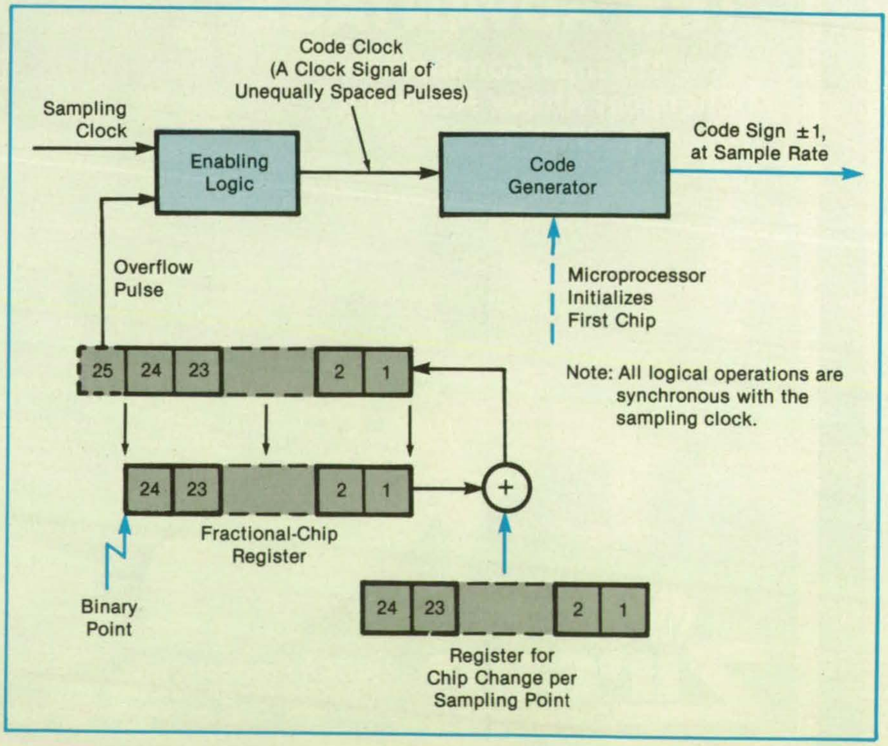

The **Chip Advancer**, part of a correlating receiver, advances a pseudorandom sequence of data in small increments.

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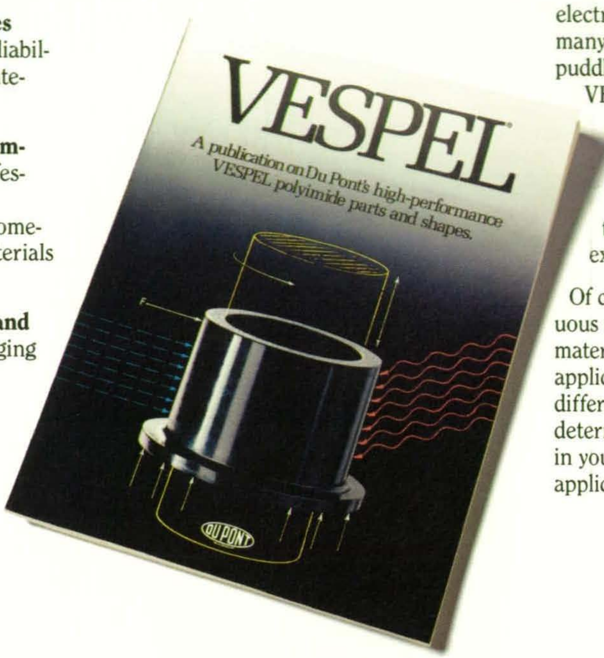

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Three-Dimensional Robotic Vision System

Stereoscopy and motion would provide clues to the outlines of objects.

Marshall Space Flight Center, Alabama

A proposed robotic vision system would analyze views from two television cameras to detect rigid three-dimensional objects and reconstruct them numerically in terms of the coordinates of corner points. The stereoscopy and the effects of motion on the two images would complement each other in providing the image-analyzing subsystem with clues to the natures and locations of principal features.

The brightnesses of picture elements would be turned into information about the object in view by three digital processes (see Figure 1): a low-level process to extract the corner points, a middle-level process to establish the correspondences between points in the stereoscopic (spatial) and motional (temporal) modalities, and a high-level process to compute the three-dimensional coordinates of the corner points by integration of the spatial and temporal correspondences.

Corner points would be detected by the Zuniga-Haralick corner-detecting algorithm, in which a step-edge operator based on zero crossings of second directional derivatives of brightness provides a measure of the "cornerness" of a point. The spatial correspondence of the corner points from two stereoscopic images would be found by the epipolar-line technique (see Figure 2), in which a point in the left (or right) image is tentatively said to correspond to a point in the right (or left) image if it lies close to the imaginary line (the epipolar line) in the left (or right) image that represents the line of sight from the right (or left) camera to the point in the right (or left) image. The ambiguities would be resolved and tentative identifications affirmed or denied in the higher level processes.

The temporal correspondence between points in successive images would be found by a cooperative-relaxation matching algorithm, which selects matching according to the consistencies of points and distances between points at successive image times. The temporal correspondence from two successive pairs of images would be used to resolve the ambiguities in the spatial correspondence by a two-step integration of the spatial and temporal correspondences to produce a cooperative and consistent correspondence for each pair of successive images. In the first step, matching points would be required to satisfy both spatial and temporal correspondences. In the second step, matching points would be required to exhibit the least deviation from rigidity.

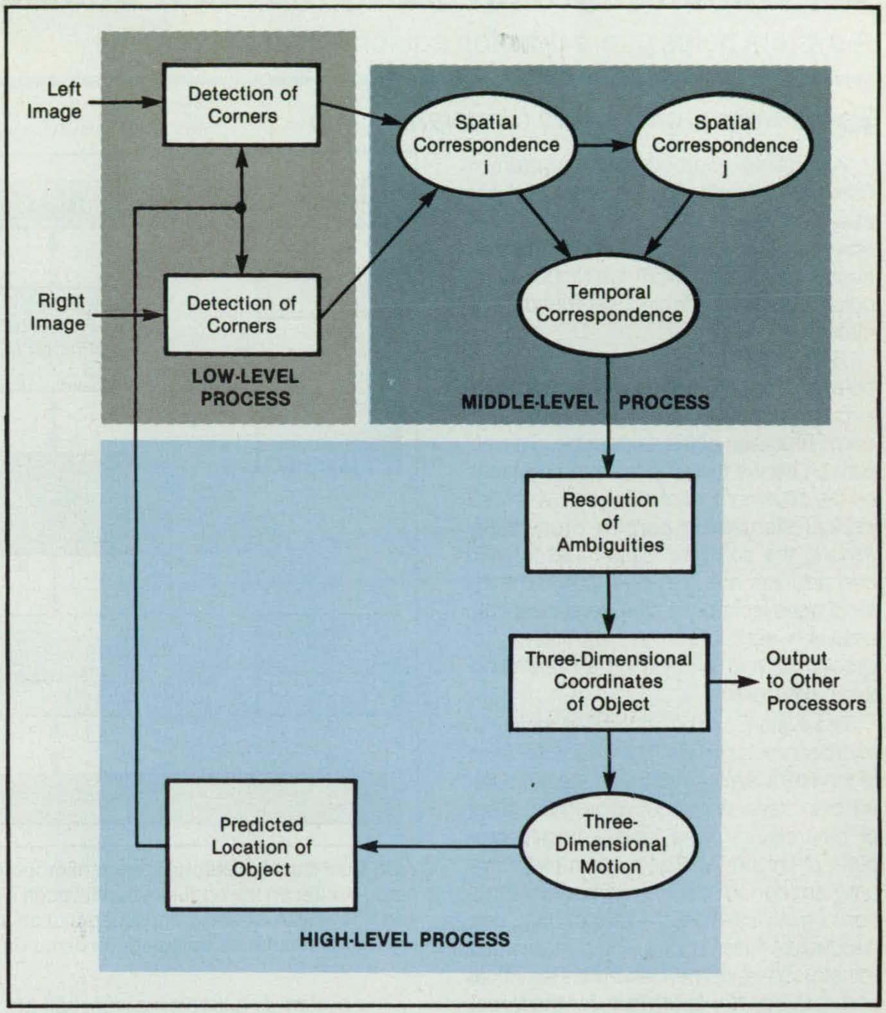


Figure 1. This **Digital Image-Processing System** would act as an "intelligent" automatic machine-vision system by processing views from stereoscopic television cameras into three-dimensional coordinates of a moving object in view.

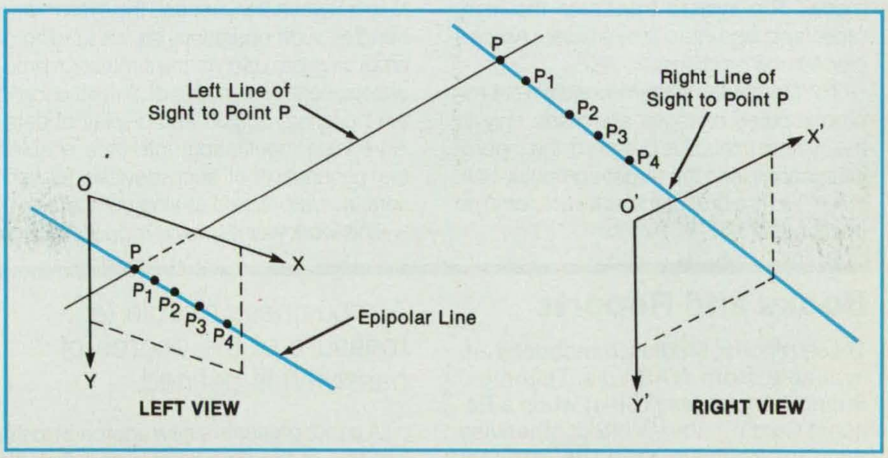


Figure 2. The **Epipolar-Line Technique** would be used to find corresponding points in stereoscopic views. Points close to the epipolar line in the left view are tentatively identified as corresponding to points on the line of sight in the right view.

Once the final correspondence is established, the corner points in three-dimensional space could be determined easily as the intersections of the lines of sight to the points in the right and left views. The motion of the object could then be estimated as an affine transformation that uses the least-squares method based on the computed points of the object in two consecutive frames.

This work was done by Thinh V. Nguyen of Multisignal Technology Corp. for **Marshall Space Flight Center**. *For further information, Circle 48 on the TSP Request Card.*
MFS-27191

Experimenting With Multiprocessor Simulator Concepts

A system helps users develop equipment and programs.

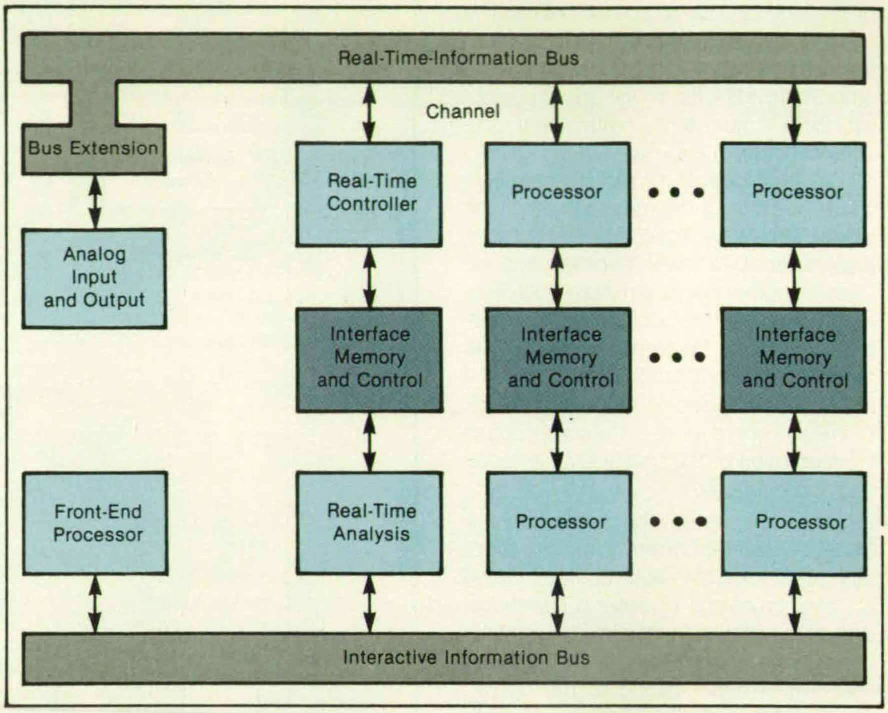
Lewis Research Center, Cleveland, Ohio

A multiple microcomputer system is used to investigate the application of parallel processing to real-time simulation. The system, called the real-time multiprocessor simulator (RTMPS), is a tool for developing low-cost, portable, user-friendly simulators.

RTMPS includes off-the-shelf microcomputer boards and minimal custom interface circuitry to provide as many interprocessor communication paths as possible. This approach allows the emphasis to be placed on the development of software, which is a critical element in parallel processing. Among the software issues that RTMPS can address are high-level programming languages, scheduling the transfer of data between computers, the partitioning of programs, and support by an operating-system program.

The system can be based on a variety of microcomputer types. The characteristics of the hardware of each type are accounted for in a system executive program, a set of macroinstructions, and a target-computer-definition file. The system executive program performs such rudimentary functions as initialization, transfer of data, and handling of interruptions. The system macroinstructions define basic mathematical and data-transfer operations for the target hardware. The target-definition file provides information in high-order language about the microcomputer programming model. The system translates the high-order language into a time-efficient Assembler source program.

To retarget the system to a different microcomputer, changes are made only in the system executive program, the macroinstructions, and the target-computer-definition file. The bulk of the software remains unchanged.



With **Dual-Bus Architecture**, each microcomputer communicates with a corresponding microcomputer on the opposite bus through a dual-port interface memory. Transfers of data to and from the front-end processor occur on the interactive information bus. Transfers of data related to simulation calculations occur on the real-time-information bus.

The system is based on a dual-bus architecture with multiple microcomputers on each bus (see figure). The front-end processor is the main processor: It is the interface between the user and the system and handles such operations as the loading of programs into each of the simulation processors; control of modes of simulation; and the handling, output, and display of data. An analog input/output interface enables the connection of such devices as sensors, actuators, and analog computers.

This work was done by Richard A. Blech and Anthony D. Williams of **Lewis Research Center**. *Further information may be found in NASA TM-38802 [N86-28651/NSP], "Hardware Configuration for a Real-Time Multiprocessor Simulator."*

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Books and Reports

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Passivity in Analysis of Robustness of a Control System

A robustness margin (a measure of the degree of passivity) is defined.

A paper presents a new approach to the analysis of the stability of a multivariable feedforward-and-feedback control system that consists of an exponentially stable linear time-invariant (LTI) feedforward subsystem and a nonlinear time-varying (NTV) or a dynamic feedback subsystem. Whereas older methods of analysis are based on small-gain conditions (e.g., maximum and minimum singular conditions, H_∞ norm, and μ measure), the new method is based on the notion of passivity, which is quantified by a robustness margin. In effect, this margin provides a bound on the magnitudes of perturbations, below which the perturbations will not make the system unstable.

The feedforward subsystem is assumed given, and the problem is to characterize a class of feedback subsystems that preserve the exponential stability of the system. By finding as large a stability region as possible under the nominal control, the controller can be tuned to enhance the robustness margin by effectively moving the nominal feedback system to a different point.

The measures of robustness used in the small-gain methods involve only the magnitude (but not the phase) information of the feedforward subsystem. Based on experience in the design and analysis of classical compensators, it is known that the phase of the nominal controlled system is frequently of critical importance. Ignoring this information can sometimes lead to conservative design. The argument of passivity is motivated by this observation.

The characterization of robustness involves the Hermitian part of a transfer function, which contains both the gain and phase information. The importance of passivity lies in the concept of energy. The condition for the stability of the system can be stated as follows: If energy generated by one block can be dissipated by the other block, the system is stable. The amount of energy generated or dissipated by a system is characterized by a quantity called the ν index, which is a measure of the minimum amount of parallel dissipation required to render a system passive. This energy-transfer perspective is powerful because nonlinear systems can be considered within the same context. Thus, hitherto inadmissible perturbations like saturation of actuators, coulomb friction, stiction, and hysteresis can all be analyzed.

Three classes of perturbations are considered: memoryless, NTV, exponentially stable LTI, and general nonlinear dynamic. The theoretical basis of the stability condition is on the theorem of absolute stability for the first class of perturbations and the theorem of hyperstability for the latter two. These perturbations are represented in terms of a lower bound involving an inner product and an upper bound on the norm. The stability condition then shows trade-offs between the two bounds. When only the bound on the norm is imposed, the H_∞ stability criterion is recovered. Because the Lyapunov technique is used rather than the multivariable Nyquist theorem, nonlinear perturbations (both memoryless and dynamic) are permitted. For nonlinear dynamic systems, the small-gain condition involves truncated L_2 norms.

When the perturbation is characterized by a matrix that contains additional block diagonal structure, a robustness margin is derived for each block. The derivation is based on the generalization of the Gorshgorin theorem to block-diagonal matrices. If each of the diagonal blocks is of size one, then a margin for positive and negative variations of each diagonal element can be obtained by repeated application of the passivity argument to the feedforward subsystem with signs of some of its columns and rows reversed. An upper bound for the μ measure is easily computed by use of the same analysis.

This work was done by John Ting-Yung Wen of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Robustness Analysis Based on Passivity," Circle 81 on the TSP Request Card.*
NPO-17589

Absolute Stability and Hyperstability in Hilbert Space

Theorems on the stabilities of feedback control systems are proved.

A paper presents recent developments regarding the theorems of the absolute stability and the hyperstability of a feedforward-and-feedback control system. These theorems are applied in the analysis of nonlinear, adaptive, and robust control. In this paper, the theorems are extended to provide sufficient conditions for stability in a system that includes a nonlinear feedback subsystem and a linear time-invariant (LTI) feedforward subsystem, the state space of which is a Hilbert space, and the input and output spaces of which have fi-

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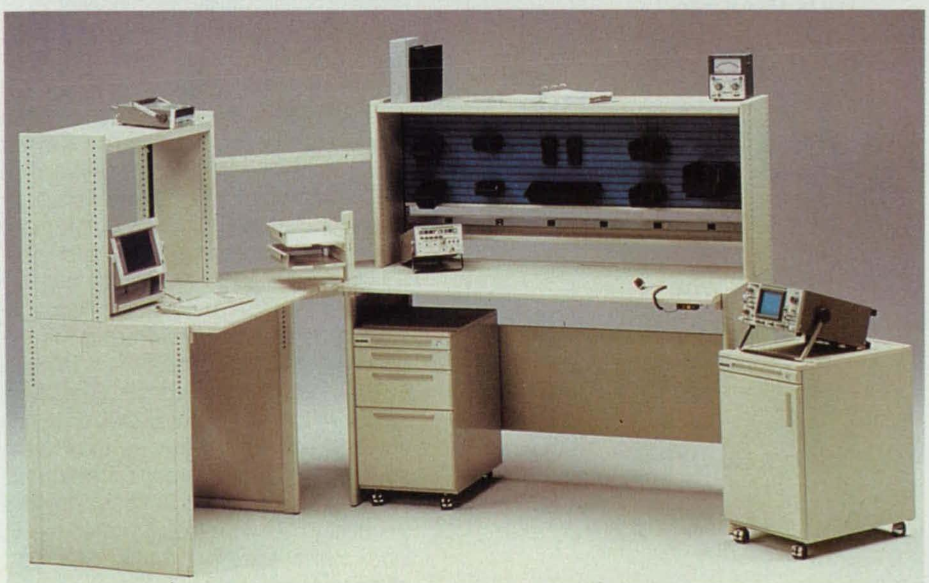

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nite numbers of dimensions. (In the case of absolute stability, the feedback subsystem is memoryless and possibly time varying. For hyperstability, the feedback system can be a dynamical system.)

It had been shown previously (by the positive-realness lemma) that a sufficient condition for closed-loop exponential stability is the positive realness of some transfer function involving the feedforward subsystem. Later, this result was generalized to the case of a dynamic feedback subsystem. This generalization, termed hyperstability, has become the cornerstone of the field of adaptive control.

Positive realness is typically stated as a frequency-domain condition of the nonnegativity of the Hermitian part of the transfer function of a given stable LTI system. It can be shown that if a system is positive real, then it cannot generate energy. If, furthermore, the system is strictly positive real, it dissipates energy. From the energy point of view, the theorems of absolute stability and hyperstability simply state the conditions under which the system dissipates energy and thus is stable. Specifically, if both the feedforward and the feedback subsystems dissipate energy, the system must be stable.

In this paper, the proofs of stability in the infinite-dimensional Hilbert space are based on a Lyapunov type of analysis that incorporates energylike quadratic Lyapunov functions similar to those used in the finite-dimensional case. Essentially, it is shown that if the state belongs to L_2 under any L_2 input, then the state is strongly asymptotically stable. Using the foregoing result, it is shown that if the feedforward subsystem is strictly positive real and the feedback subsystem is characterized by a nonnegative operator, then the system is exponentially stable. If the feedback subsystem is dissipative in the sense of Popov's inequality, then the interconnected system is asymptotically stable. If a stronger exponential Popov's inequality is satisfied, the interconnected system attains exponential stability.

When the feedforward system is not strictly positive real and/or the feedback system is not dissipative, one would expect intuitively that if one of the subsystems dissipates "more energy" than the other could generate, stability would be preserved. This heuristic notion is rigorized by the introduction of an index, called the ν index for convenience, that measures the closeness of a given system to positive realness in terms of the minimum amount of additional parallel dissipation needed for the system to be positive real. General conditions for the stability of the system can then be stated in terms of the ν index.

The amount of energy that the feedforward subsystem can generate is bounded by its ν index. Hence, if the feedback subsystem under positive feedback by an amount equaling the ν index of the forward subsystem remains dissipative (in the sense of nonnegativity of the inner product of its input and output), the interconnected system is exponentially stable. The theorem of hyperstability states the same result except that the energy-dissipation criterion used for the feedback subsystem is in the sense of the L_2 inner product between its input and output (i.e., via the Popov inequality). The type of stability of this more general characterization of energy dissipation is weakened to asymptotic stability unless a stronger exponential Popov inequality is satisfied, in which case exponential stability obtains.

The ν index is a time-domain characterization, which, in general, is difficult to calculate directly. It is shown via the Hilbert-space version of the positive-realness lemma that the ν index is equivalent to a frequency-domain attribute, called the ν_F index, which is based on the Hermitian part of the transfer function. Because the input and output spaces are finite-dimensional, the ν_F index, and hence the ν index, can be easily computed. The utility of these results is demonstrated in an application to the analysis of the robustness of an infinite-dimension linear quadratic regulator. It is shown that the generalization of the classical (½,∞) gain margin and $(-\frac{\pi}{3},\frac{\pi}{3})$ phase margin hold for this case. It is further

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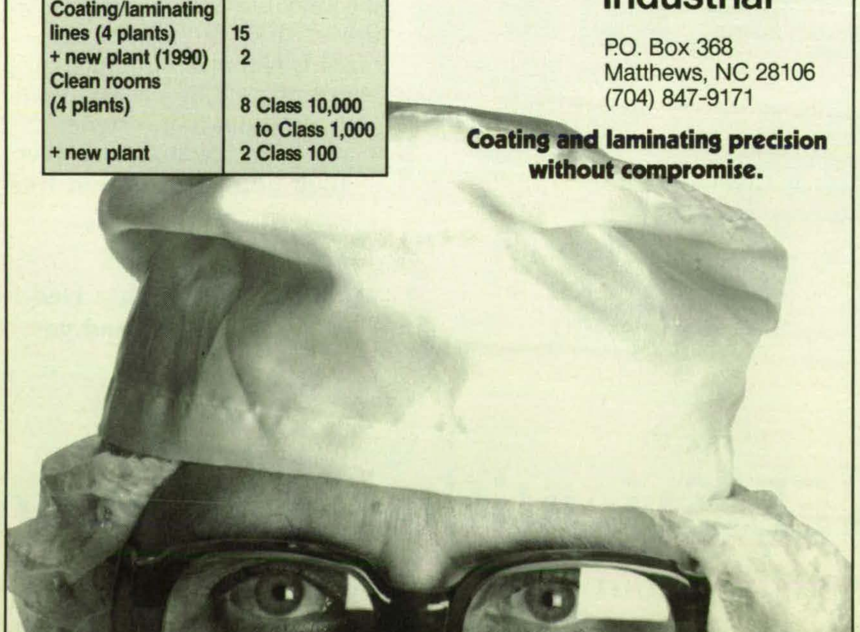

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shown, by a modified design, that the gain margin can be widened to (γ, ∞) and $(-\frac{\pi}{2}+\eta, \frac{\pi}{2}-\eta)$ for any $\gamma>0$ and $\eta>0$.

This work was done by John Ting-Yung Wen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Absolute Stability and Hyperstability in Hilbert Space," Circle 143 on the TSP Request Card.*
NPO-17590

Pilot Delays for Three Cockpit Controllers

The pilot effective delay increases with the system delay.

A report compares the pilot effective time delays measured in simulations of aircraft-control systems equipped with a Space Shuttle rotational hand controller and with two versions of a conventional stick-type hand controller. The report should be of interest to those concerned with the design of multiple-axis controllers in aircraft, armored vehicles, industrial machinery, and remote manipulators: the operator response or delay is critical to the stable and accurate operation of such systems.

Each of the three controllers was installed in a Space Shuttle cockpit simulator. The Space Shuttle hand controller had three degrees of freedom and nonlinear gearing. The more-conventional two-degree-of-freedom control stick had linear gearing and was equipped first with a stiff set of springs (heavy conventional stick), then with a softer set of springs (light conventional stick). The signal from the control stick was processed through the cockpit simulator with a 40-ms frame time, then sent to the critical-task tester. The total inherent delay between the pilot and the critical-task tester was 46 ms: 20 ms of sampling delay plus 26 ms of computation time.

The critical-task tester is a specialized electronic subsystem used to measure the pilot effective delay, τ_e, in response to a simulated first-order, closed-loop, compensatory tracking task. The critical task involves an unstable controlled element, the instability of which increases with time. Eventually, the system reaches a critical point beyond which the unstable system cannot be controlled. The amount of instability at that point gives a measure of τ_e.

The critical-task tester was used to measure the τ_e values in the roll and pitch axes in each of the three control configurations. Measurements in each case were made without additional system delay and with 250 ms of additional system delay. Thus, the total system delays were 46 and 296 ms, respectively. The test subjects were four test pilots and one nonpilot engineer.

The test data indicate that the heavy conventional stick had the lowest pilot effective time delays in both axes, both with and without the added system delay. The light conventional stick had τ_e values similar to those of the Space Shuttle controller. With all three controllers, τ_e increased with the added system delay. The increases in τ_e caused by the increase in system delay were more significant than the differences in τ_e among the three controllers: apparently, at large system delays one controller is about as good as another.

This work was done by Cynthia M. Privoznik and Donald T. Berry of **Ames Research Center**. *Further information may be found in NASA TM-86030 [N86-19324/NSP], "Comparison of Pilot Effective Time Delay for Cockpit Controllers Used on Space Shuttle and Conventional Aircraft."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11797.

Circle Reader Action No. 436

Physical Sciences

Standard Method for Radiation Tests of Liquids

Three vials are used.

NASA's Jet Propulsion Laboratory, Pasadena, California

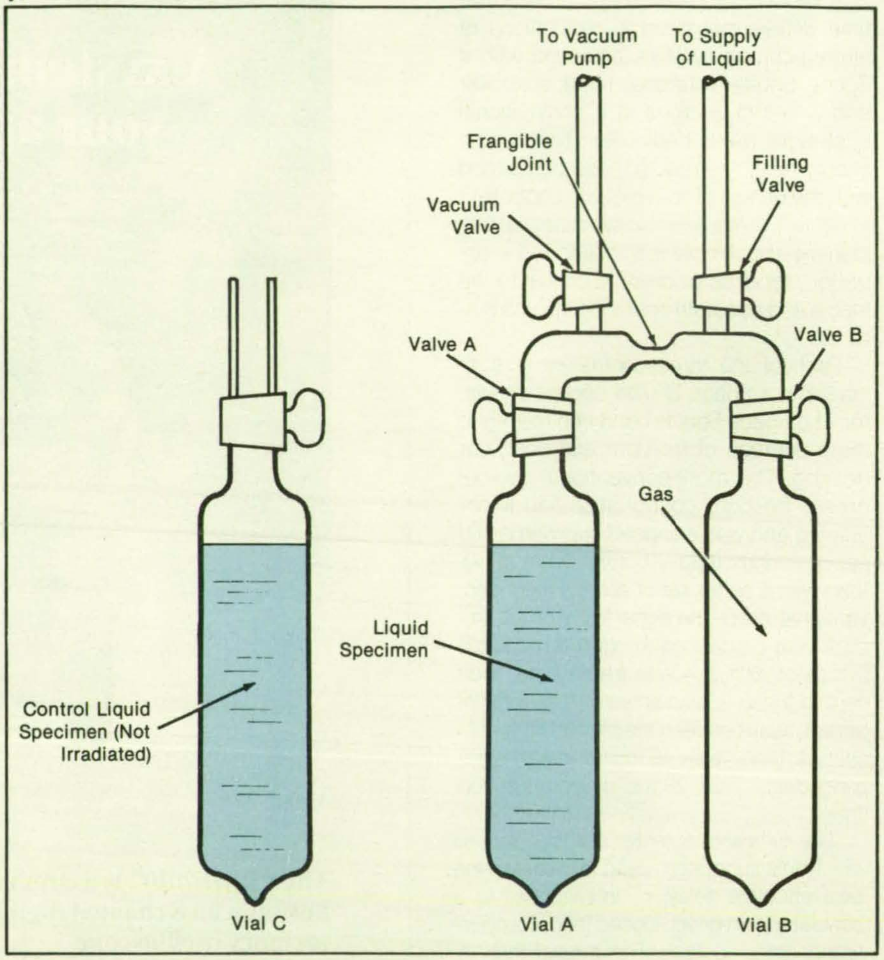
A simple procedure provides a standard method for radiation tests of liquids. It assures identical handling and dosage so that data from different test laboratories can be compared reliably. Developed for measuring properties of liquids for use in radiation-resistant liquid-dielectric capacitors, the procedure can be used for any of a variety of liquids proposed for use in the high-radiation environment — in x-ray and particle-accelerating machines and nuclear reactors, for example.

A pair of glass vials, joined by a frangible neck and equipped with valves, is used (see figure). A third vial is also used. It is filled with a control specimen and not irradiated. A technician first opens valve A, valve B, and the vacuum valve to pull contaminants from the vials. The vacuum valve and valve B are then closed and the filling valve opened to transfer the specimen liquid to vial A.

Next, the vacuum and filling valves are closed while valve A is left open and valve B is opened. The technician then irradiates the vials. The gas given off by the liquid in vial A as a result of chemical reactions stimulated by the radiation is collected in vial B. When irradiation is complete, the technician closes valves A and B, then breaks the joint to separate the vials.

The irradiated liquid in vial A is tested for such properties as viscosity, dielectric strength, and dielectric constant. The gas in vial B is analyzed in a mass spectrometer to identify its constituents.

This work was done by Frank L. Bouquet and Robert B. Somoano of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 138 on the TSP Request Card. NPO-16840*



The **Twin-Vial Portion of the Testing Apparatus** provides for standardized handling and irradiation of the liquid specimen. Vials A and B are readily separated so that each can be subjected to different tests.

Long-Wavelength Infrared Detector

Intersubband absorption in coupled quantum wells would enable detection at wavelengths from 10 to 100 μm.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed device would detect infrared photons of 10- to 100-μm wavelength by intersubband absorption in coupled quantum wells. Such a device would be made of $Al_xGa_{1-x}As/GaAs$ or other semiconductor material, even though the ma-

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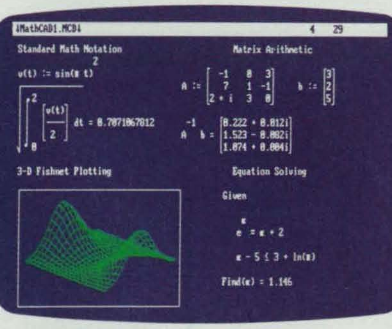

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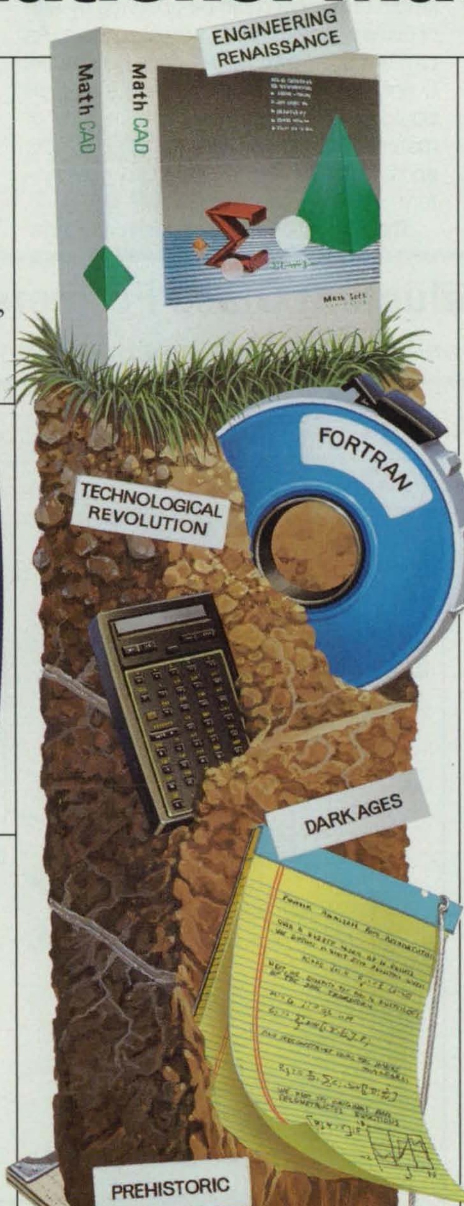

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Circle Reader Action No. 628

terial may not have any intrinsic absorption in the desired range of wavelengths.

Recently, quantum-well devices made of layers of $Al_xGa_{1-x}As$ and GaAs have been demonstrated to detect radiation at wavelengths of 8 to 11 μm. The absorption of a photon in such a device corresponds to the transition of an electron between the ground and first excited state of a quantum well formed by the discontinuity in the energy of the conduction band between a GaAs well and an $Al_xGa_{1-x}As$ barrier. The photoexcited charge carriers then tunnel out of the well and are collected with the aid of an applied electric field.

The proposed device is based on the splitting of the energy level that occurs when two quantum wells are placed so close together that the wave functions of the quantized energy levels overlap. The detector absorbs photons, the energy of which equals the difference in energy between two levels that result from the split. Because the degree of overlap of the wave functions and, therefore, the magnitude of the split can be varied by varying the width of the barrier between the two coupled wells, such a detector can, in principle, be designed to operate at any desired wavelength.

Operation at wavelengths from 10 to 100 μm requires splits of 12 to 120 meV. A split of 25 meV (corresponding to a wavelength of 50 μm) could be obtained by use of GaAs wells 70 Å thick, with $Al_{0.06}Ga_{0.94}As$ barriers, including a 14-Å-thick barrier between the wells. This approach to design could be used in other combinations of materials that exhibit quantum size effects and is not restricted to the $Al_xGa_{1-x}As$ system.

The restrictions on the design parameters of quantum wells of the proposed device are less severe than those of single-well devices. However, energy levels near the tops of the wells are still necessary so that the photoexcited carriers can tunnel out. Additional flexibility in design can be obtained by use of wells of different widths and asymmetric wells formed by barriers of different heights.

This work was done by Richard P. Vasquez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 19 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's Resident Office-JPL [see page 14]. Refer to NPO-17543

Thermal Analysis of Reluctant Glass Formers

A thermocouple holds a sample and monitors its temperature during cooling.

Marshall Space Flight Center, Alabama

An apparatus for the study of heterogeneous nucleation and crystallization in reluctant glass formers achieves cooling rates from 10 to 2,500 °C/s by providing control of both radiative and conductive cooling. Reluctant glass formers are materials that require cooling rates greater than 10 °C/s to form glasses. Laser spin melting, a prior technique, can be used only at cooling rates greater than about 1,000 °C/s and only for very small samples. The new apparatus can be used to examine the glass-formation ability of a material and the critical cooling rate to form a glass from it.

The apparatus (see Figure 1) includes an ellipsoidal furnace, which focuses radiation from a tungsten/halogen lamp onto a sample. The sample is supported between the two leads of a type S thermocouple that has a junction bead 0.005 in. (0.13 mm) in diameter. Raising the power to the lamp melts the sample, causing it to flow around the thermocouple bead. A specimen in a still atmosphere can be cooled at rates from 10 to 250 °C/s by reducing the lamp power at the appropriate rate with a variable-speed, motor-driven, adjustable transformer. Higher cooling rates are obtained by blowing helium gas onto the sample after turning the lamp off.

The temperature of the sample is derived from the thermocouple signal. During quenching, the temperature of the sample is recorded on a strip chart and/or in a microcomputer data-acquisition system. The recorded quenching curve (see Figure 2) is analyzed to determine the temperature of the sample prior to quenching; the rate of cooling prior to nucleation; the time and temperature of nucleation; the rate, time, and temperature of recalescence; and the rate of cooling after nucleation.

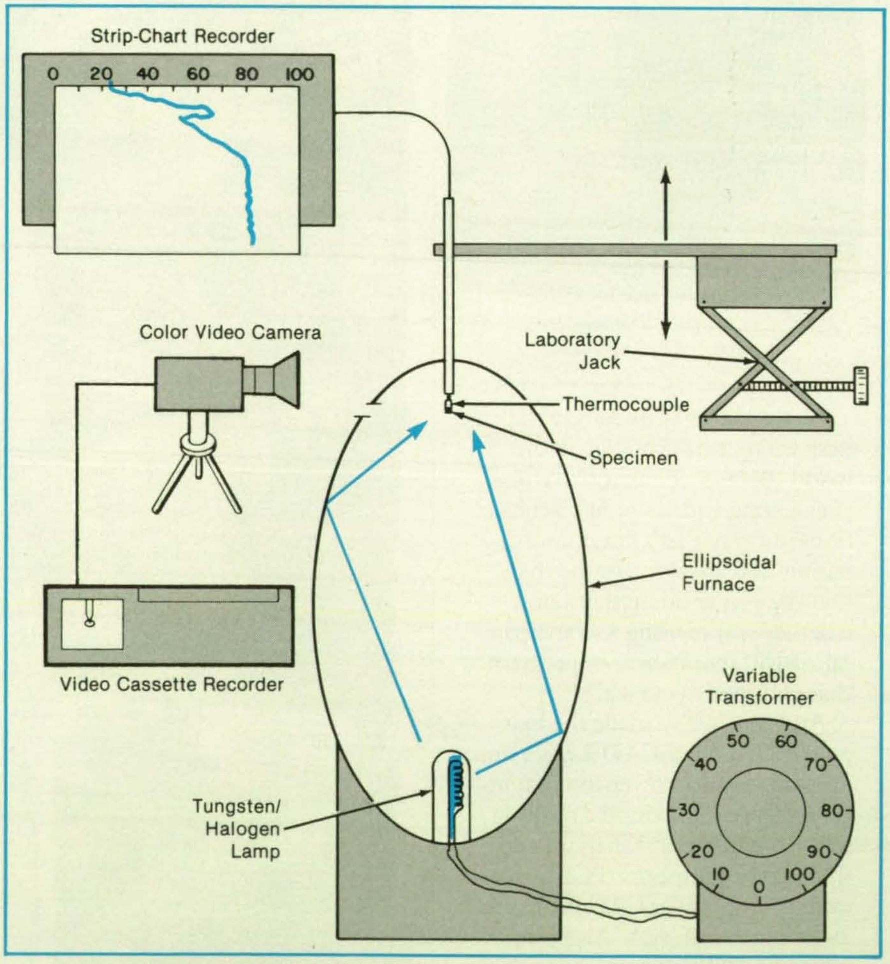
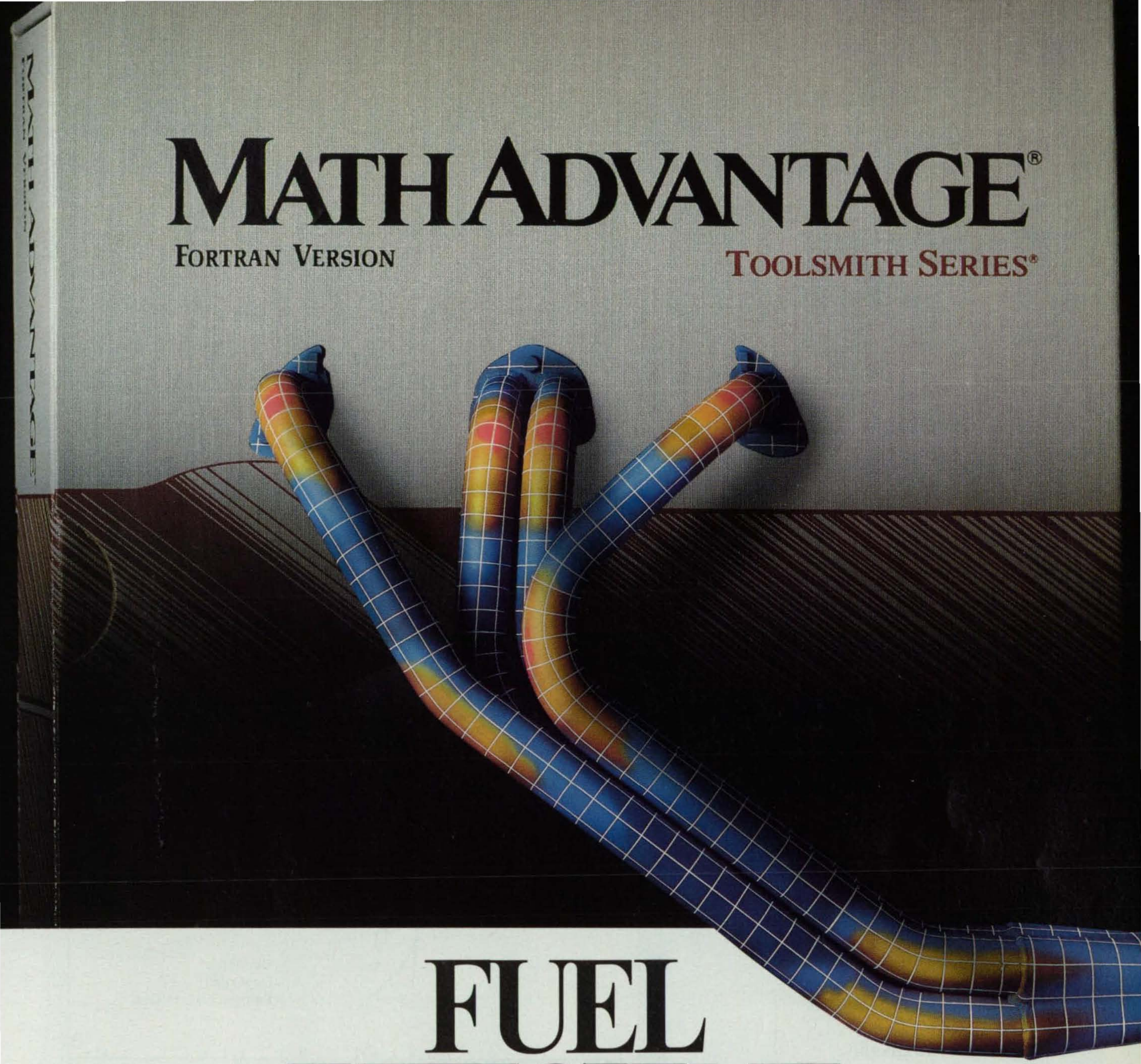


Figure 1. The **Ellipsoidal Furnace** provides controlled cooling rates for studies of the thermal properties of reluctant glass formers. A glass tube (not shown) is inserted into the furnace and used to blow helium on the specimen to cool it rapidly.

Quenched samples are inspected for crystallization. If the quenched sample is transparent and the quench curve shows no recalescence peak, it is assumed that



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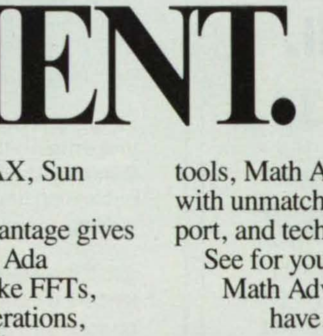

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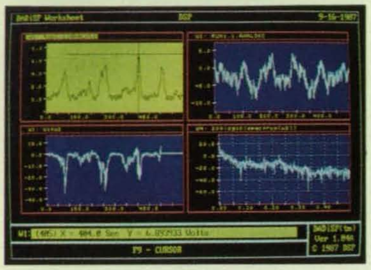

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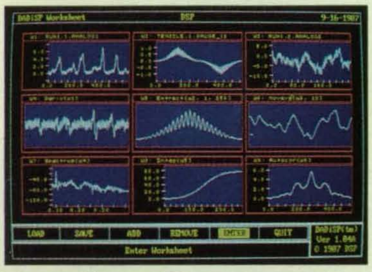

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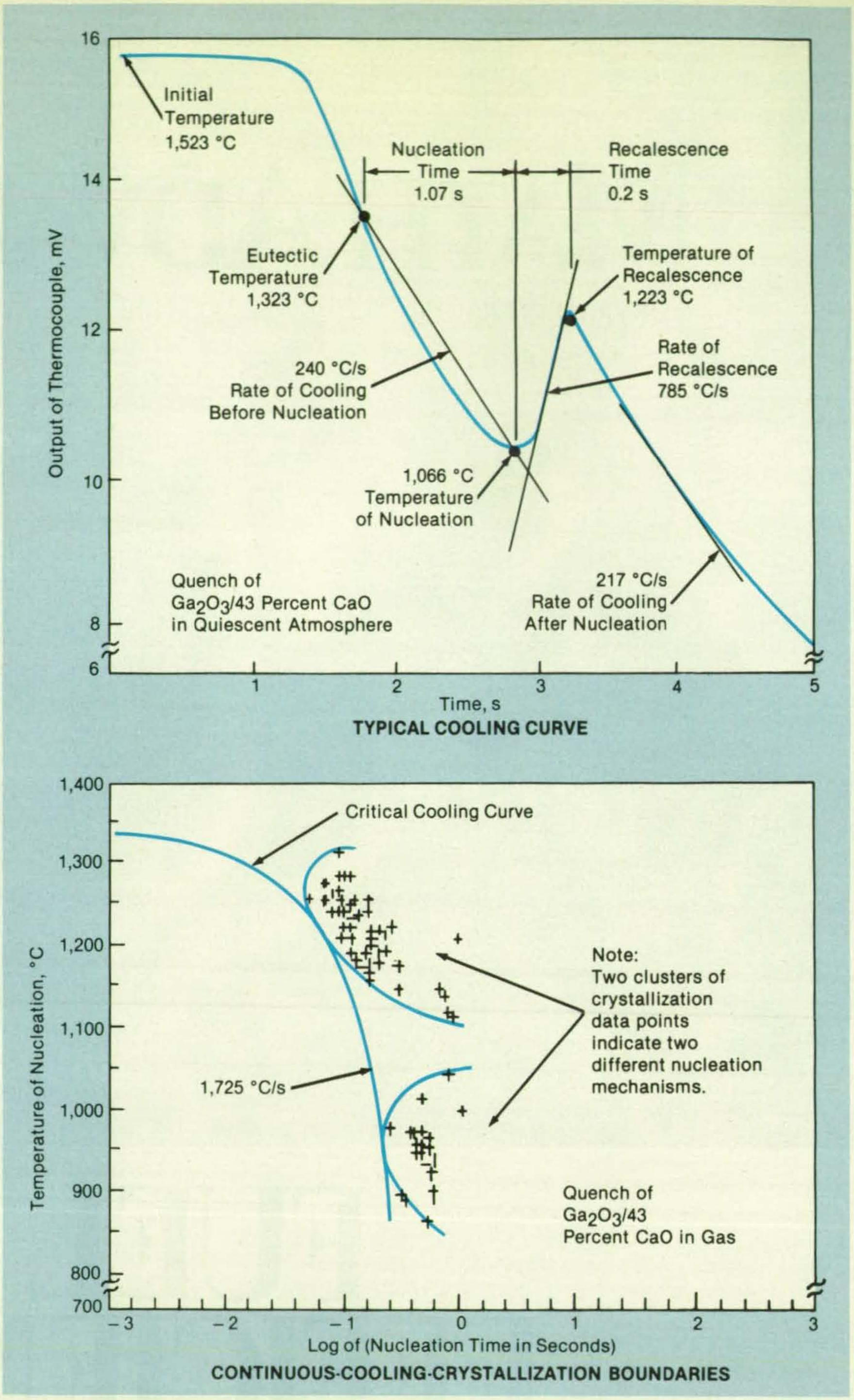

Figure 2. A **Cooling Curve** (above) can be analyzed to determine the rate of cooling and such properties of the sample as nucleation and recalescence temperatures at that cooling rate. Continuous-cooling-crystallization boundaries can be determined empirically from plots of nucleation time vs. nucleation temperature from runs at a large number of different rates of cooling.

glass has been formed. Whenever a recalescence peak is observed, the sample is opaque and predominately crystalline due to the rapid rate of crystal growth.

Nucleation times and temperatures for a large number of different quenches can be plotted to produce empirical continuous-cooling-crystallization diagrams. The nucleation of crystallization from each quench run that did not result in the formation of glass is represented by a datum on the plot.

This work was done by Edwin C. Ethridge and Peter A. Curreri of **Marshall Space Flight Center**. *For further information, Circle 50 on the TSP Request Card.* *MFS-28283*

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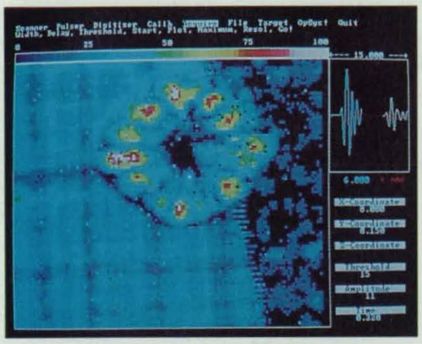

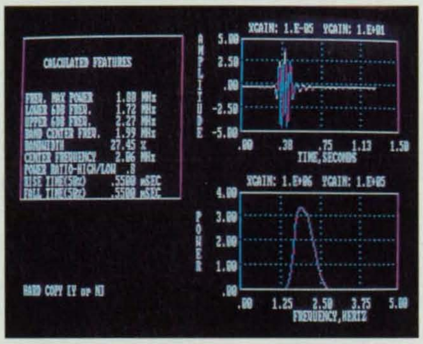

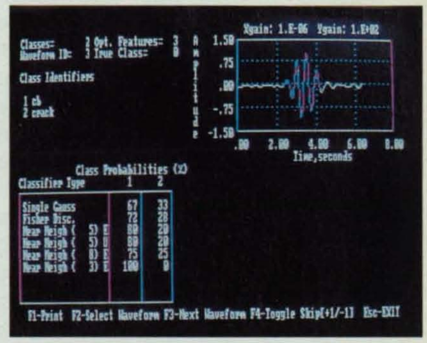

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The Integrated NDT People

Circle Reader Action No. 425

Dynamic-Range Compression for Infrared Imagery

Photorefractive crystals covering detectors would prevent saturation.

NASA's Jet Propulsion Laboratory, Pasadena, California

The results of experiments suggest that photorefractive crystals can be used to reduce the dynamic range of infrared radiation incident upon a photodetector or array of photodetectors. Such predetection range compression can be useful in infrared-imaging systems because typical scenes contain bright spots (e.g., solar radiation reflected from automobiles) on dark backgrounds, and the bright/dark contrast exceeds the dynamic ranges of photodetectors, causing their output signals to saturate. When fully developed, an effective dynamic-range-compressor plate, film, or coating would reduce the apparent contrast of the scene imaged on the detector plane to within the dynamic range of the detectors (see Figure 1); the original image contrast or intensity data could be recovered subsequently in electronic image processing because the range-compression function and its inverse would be known.

The proposed dynamic-range compressor would be made of photorefractive crystals. The two-wave-mixing process that occurs in such crystals attenuates the radiation passing through them. Because the process is nonlinear, the degree of attenuation is greater at higher intensities. Thus, a compressor plate would darken the bright spots more strongly than it would darken the other portions of an image.

One useful range-compression function is

$$I_{out} = A(I_{in})^X$$

where I_{out} and I_{in} are the input and output intensities, respectively, and A is a constant. For compression, X must be less than 1; as X decreases, the degree of compression increases. This function is approximated by the experimental data of Figure 2, in which the input dynamic range of about 365:1 is changed to output dynamic ranges of about 175:1, 160:1, and 90:1.

This work was done by Li-Jen Cheng and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 105 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 Laboratory [see page 14]. Refer to NPO-17140.

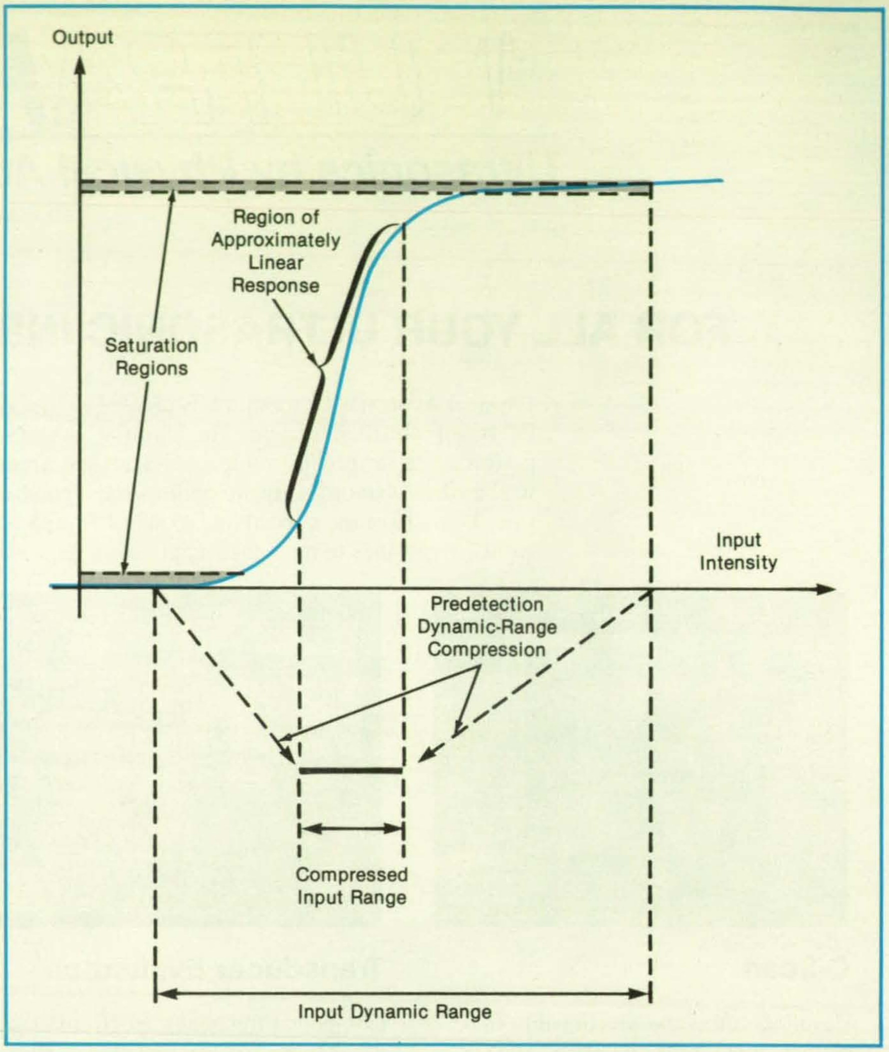


Figure 1. The **Output of a Typical Photodetector** saturates at low and high levels of input intensity. To make full use of the information in an image, it is desirable to compress the dynamic range of the input intensity to within the region of approximately linear response of the detector.

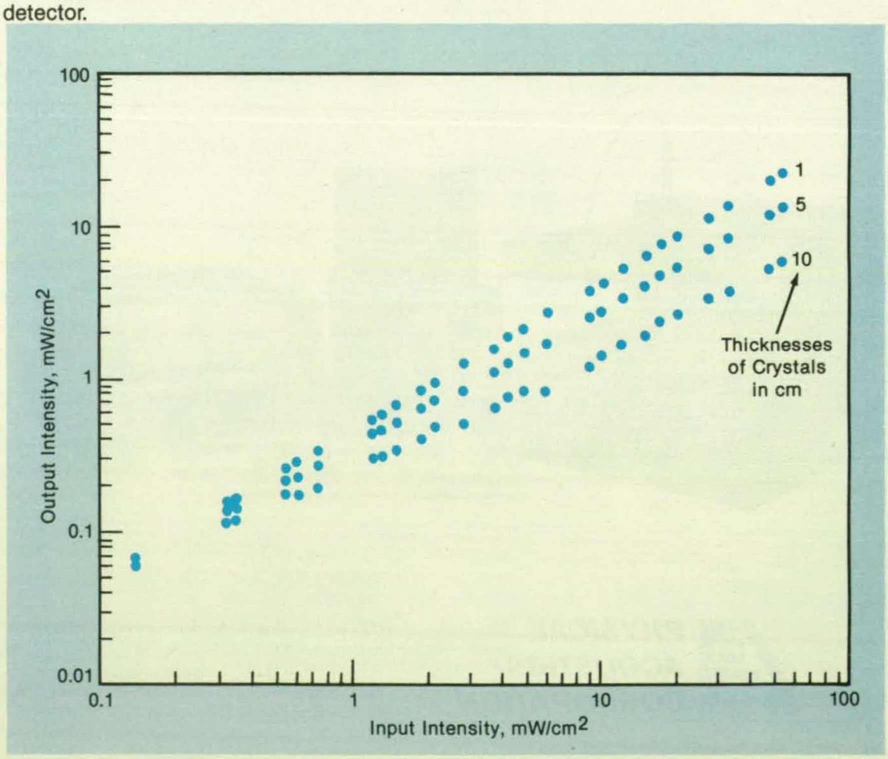


Figure 2. **Dynamic-Range Compression** is exhibited by measurements of attenuation in photorefractive GaAs.

Making Durable Specimens for Electron Microscopy

Consistent metal-oxide cross sections are prepared quickly.

Lewis Research Center, Cleveland, Ohio

High-quality specimens of metal-oxide cross sections transparent to electrons are necessary to perform some of the more sophisticated studies involving transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM). A major problem in the preparation of specimens is obtaining durable specimens in a simple and consistent fashion. A new technique can be used to prepare 3-mm-diameter specimens of cross sections of oxides of alloys intended for use at temperatures greater than approximately 600 °C (see figure).

The alloy of interest is cut into bars approximately 1.5 mm by 0.75 mm by 10 mm. Only one of the large faces of each bar need be prepared for oxidation treatments. The bars are oxidized at the appropriate experimental conditions. After the bars are cooled, a thin coat of silver paint is applied to the prepared surface of each bar. The painted surfaces are placed and held together until the paint dries. This provides enough strength for handling of the specimen-bar sandwich.

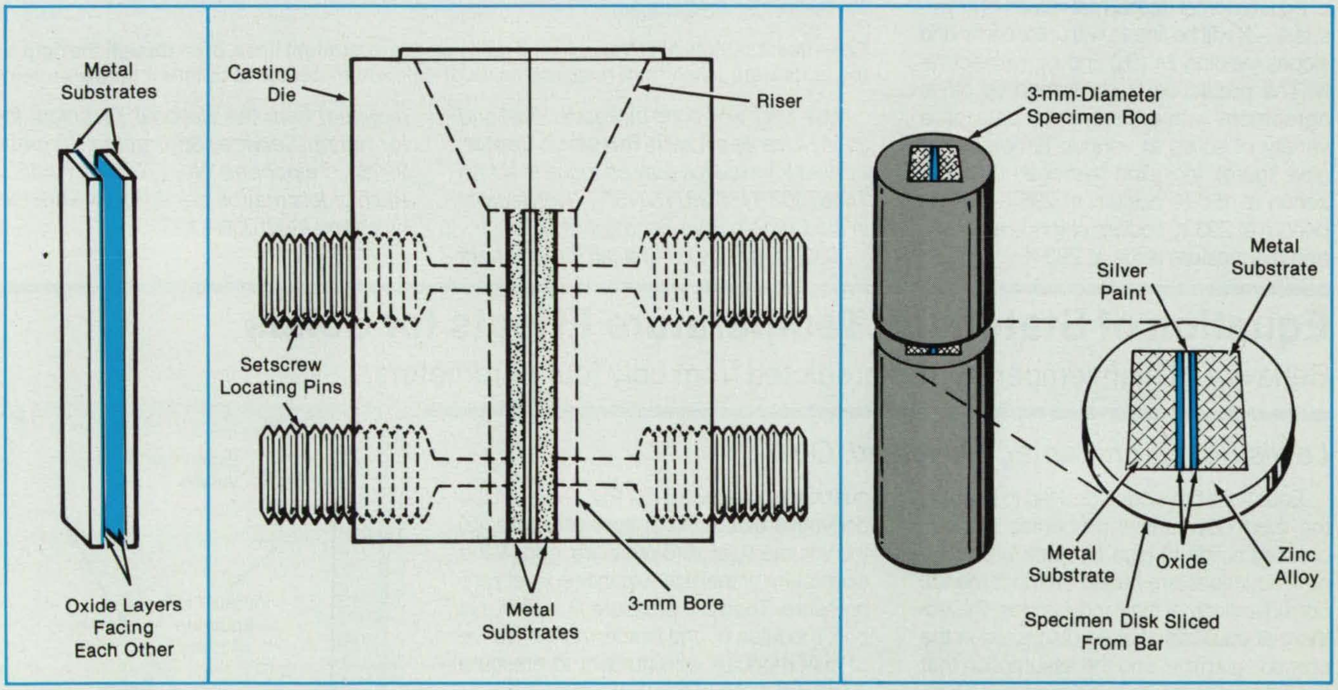
The sandwich is then placed in a specially-designed stainless-steel mold and held in place with setscrew pins. The purpose of the mold is to hold the sandwich in place inside a 3-mm-diameter bore, into which a molten alloy is injected. After the sandwich is aligned in the mold, a chunk of Zn(4 atomic percent)/Al(1 atomic percent)/Cu alloy is placed in the riser portion of the mold. This alloy was chosen because of its low melting temperature (415 °C), sufficient strength, and high coefficient of thermal expansion.

The entire mold is heated quickly with an oxyacetylene torch until the alloy is molten. A glass tube connected to a rubber bulb is placed over the riser and in contact with the mold. A blast of air causes the molten alloy to flow around and encapsulate the specimen-bar sandwich. After removal from the mold, the resulting 3-mm specimen bar is sliced into TEM specimens by use of a slow diamond saw. Finally, the specimens are polished, dimpled, and ion-thinned.

The primary advantage of this technique is that durable specimens can be prepared consistently in a very short time. In addition, epoxy resins are not used, and organic solvents can be used to clean the specimens. Yet another advantage is that two different experimental conditions can be incorporated into one specimen.

One of the disavantages of this technique is that specimens of materials that would be affected by the high casting temperature are not suitable. Furthermore, during the ion-thinning process, the zinc alloy is often sputter-deposited on the area of interest, requiring subtraction of additional background signals from quantitative-chemical-analysis spectra.

This work was done by Joseph Doychak of Sverdrup Technology Inc. for **Lewis Research Center**. *No further documentation is available.* *LEW-14755*



The **New Process** makes TEM/STEM cross sections of metal/oxide interfaces. After the specimen bars have been oxidized, they are placed in the specially designed mold. Following encapsulation in the zinc alloy, the 3-mm-diameter specimen bar is sliced into disks suitable for further preparation steps.

Isothermal Equation of State for Compressed Solids

The same equation with three adjustable parameters applies to different materials.

Lewis Research Center, Cleveland, Ohio

An improved equation of state describes the pressure on a solid as a function of relative volume at constant temperature. Even though the types of interatomic interactions differ from one substance to another, the form of the equation is determined primarily by the overlap of electron wave functions during compression. Consequently, the equation is universal in the sense that it applies to a variety of substances, including ionic, metallic, covalent, and rare-gas solids. Only three parameters are needed to describe the equation for a given material.

The equation gives the pressure, P, at a fixed temperature, T, as a function of the relative size, X

$$P(X, T) = 3B_T[(1-X)/X^2] \exp[\eta_T(1-X)]$$

where B_T = the isothermal bulk modulus at zero pressure, $X = (V/V_o)^{1/3}$, V = the volume at pressure P, and V_o = the equilibrium volume (the volume at zero pressure). The parameter in the exponential term is given by

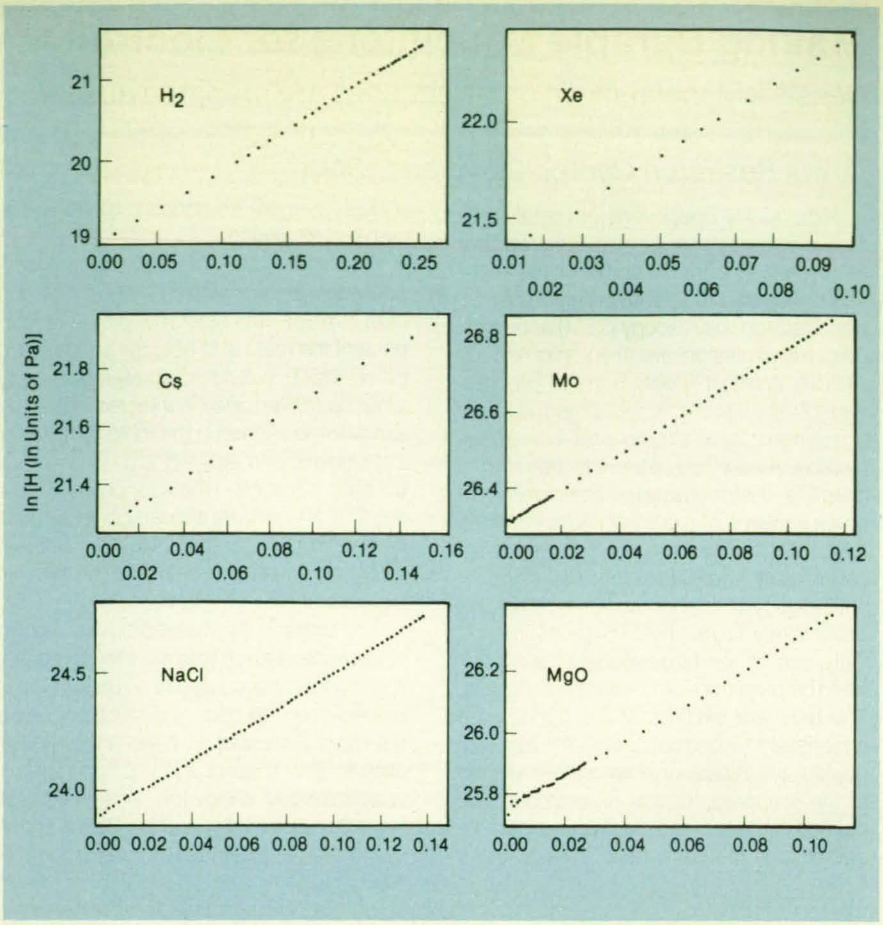
$$\eta_T = (3/2)[(\partial B/\partial P)_T - 1]$$

where B = the isothermal bulk modulus and the derivative is evaluated at zero pressure. These equations are valid over the range of pressure and volume that contains no phase changes.

To test the equation of state by comparison with experimental data, it is convenient to define a function H (not to be confused with the enthalpy, which H usually denotes in thermodynamic contexts)

$$H = \ln[PX^2/3(1-X)] = \ln(B_T) + \eta_T(1-X)$$

The pressure equation predicts that plots of experimental isothermal values of H versus $1-X$ will be linear, with intercepts and slopes yielding $\ln(B_T)$ and η_T, respectively. The prediction is confirmed by close agreement with experimental data on a variety of solids at various temperatures (see figure), including hydrogen at 4.2 K, xenon at 150 K, cesium at 295 K, molybdenum at 293 K, sodium chloride at 298 K, and magnesium oxide at 293 K.



Experimental Plots of H Versus $1-X$ all lie on nearly straight lines, even though the data in the plots were taken from measurements of different materials at different temperatures.

This work was done by Pascal Vinet and John Ferrante of **Lewis Research Center**. *Further information may be found in NASA TM-87303 [N86-28775/NSP], "Universality in the Compressive Behavior of Solids."*

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-14615

Equation of State With Temperature Effects for Solids

Behavior at high temperature is predicted from only four parameters.

Lewis Research Center, Cleveland, Ohio

Equations have been derived to express the thermodynamical properties of compressed solids at high temperatures. The new equations are based on fundamental considerations of thermodynamics, the isothermal equation of state discussed in the preceding article, and the assumption that the thermal pressure is independent of volume and varies linearly with temperature near and about the Debye temperature. Using only four parameters (three of which are those of the isothermal equation of state), the new equations describe the thermodynamic behavior of a material over a range of temperatures from approximately its Debye temperature to its melting point.

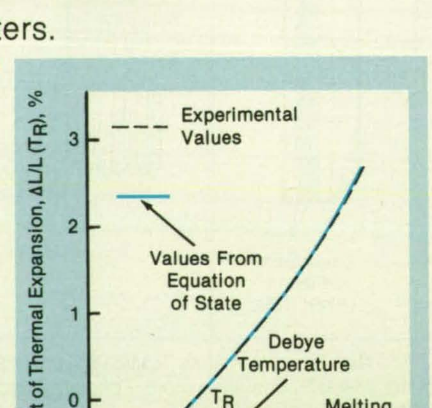
The four parameters are measured at a reference temperature T_R near the Debye temperature. They are (1) the isothermal bulk modulus B_o at zero pressure, (2) the quantity $\eta_o = (3/2)[(\partial B/\partial P)_{T_R} - 1]$ with the derivative evaluated at zero pressure, (3) the volume V_o at zero pressure, and (4) the coefficient of thermal expansion α_o at zero pressure. Then the pressure P, isothermal bulk modulus B, and isothermal derivative of bulk modulus with respect to pressure $\partial B/\partial P$ at relative size X are given by

$$P(T,X) = 3B_o[(1-X)/X^2] \exp[\eta_o(1-X)] + \alpha_o B_o(T-T_R),$$

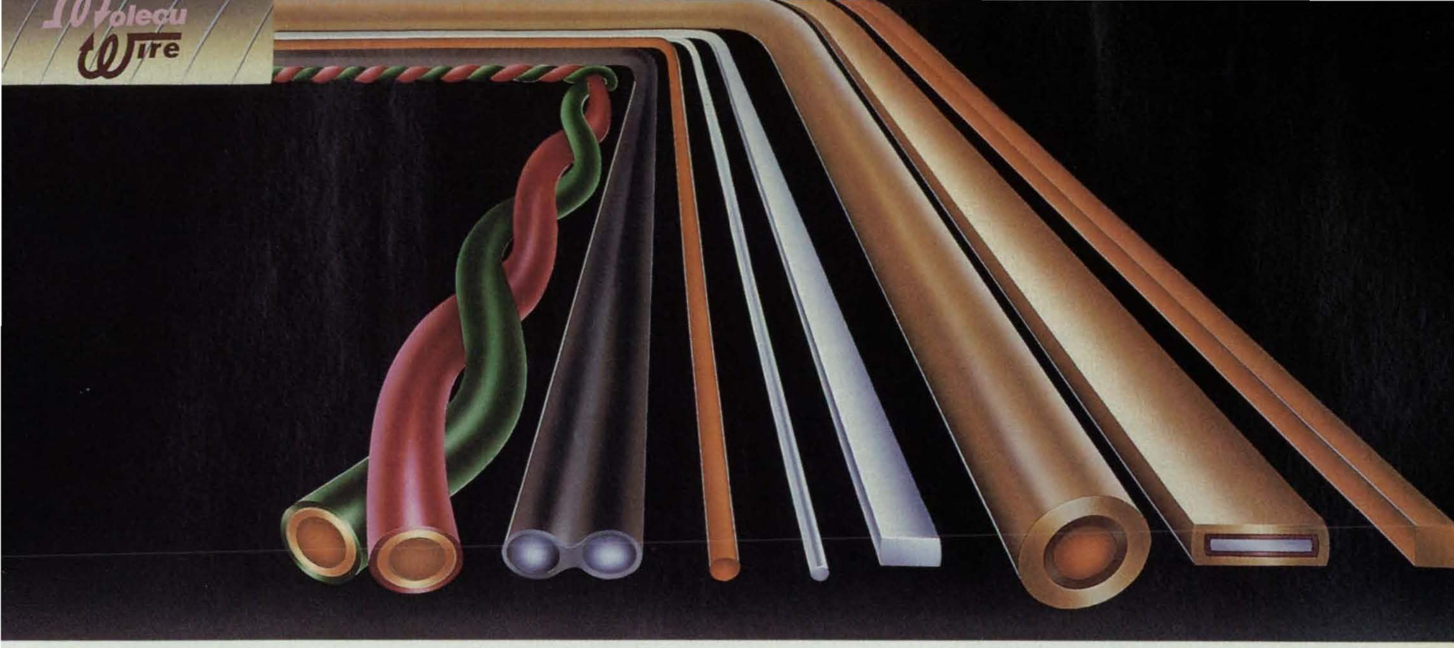
$$B(T,X) = (B_o/X^2)[2+(\eta_o-1)X-\eta_o X^2] \exp[\eta_o(1-X)], \text{ and}$$

$$\frac{\partial B}{\partial P}(T,X) = [4+(3\eta_o-1)X+\eta_o(\eta_o-1)X^2-\eta_o^2 X^3] / \left[3[2+(\eta_o-1)X-\eta_o X^2]\right]$$

where $X = (V/V_o)^{1/3}$. An equation for the temperature dependence of the coefficient of thermal expansion at zero pres-



The **Coefficient of Thermal Expansion of Xenon** relative to the size at the reference temperature T_R is closely approximated by values derived from the universal equation of state.



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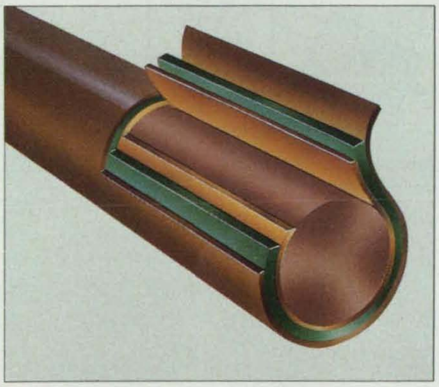

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sure can also be derived by setting $P(T,X) = 0$ and solving for $X(T)$.

These equations agreed well with experimental data on the pressures, volumes, and bulk moduli of gold, sodium chloride, and xenon at various temperatures. Even the nonlinear variation of the thermal expansion with temperature is well approximated by the values derived from the generalized equation of state (see figure): previously, the thermal expansion had been difficult to predict over a wide range of temperatures.

This work was done by Pascal Vinet and John Ferrante of **Lewis Research Center**, *John R. Smith of General Motors Corp., and James H. Rose of the Ames Laboratory of the United States Department of Energy. Further information may be found in NASA TM-87321 [N86-28776/NSP], "Temperature Effects on the Universal Equation of State of Solids."*

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-14616

Measuring Transmission Efficiencies of Mass Spectrometers

Coincidence counts would yield absolute efficiencies.

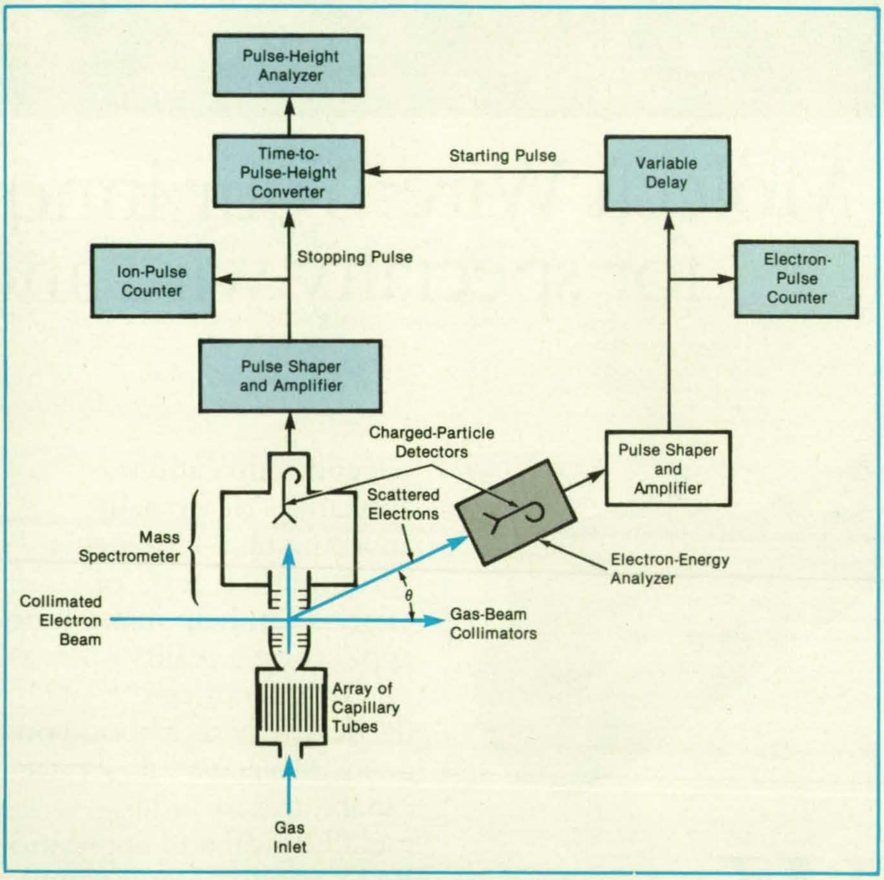
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed system would measure the mass-dependent transmission efficiencies of mass spectrometers, using coincidence-counting techniques reminiscent of those used for many years in the calibration of detectors for subatomic particles. When fully developed, the system should be compact, portable, and used routinely to calibrate mass spectrometers.

The conceptual system is connected to the inlet and to the output circuit of the mass spectrometer (see figure). A gas (e.g., H_2, D_2, He, Ne, N_2, O_2, Ar, or CO_2) is passed through an array of capillary tubes, then through a series of apertures to form a well-collimated, well-defined beam of molecules. This beam is crossed by a beam of electrons with kinetic energies greater than the ionization potential of the molecules and with an energy spread less than 300 mV. Some of the collisions between electrons and molecules produce singly ionized molecules that travel toward the entrance aperture of the mass spectrometer, and scattered electrons, the kinetic energies of which are diminished by the amounts lost in production of the ions.

The electrons scattered at some arbitrarily chosen angle θ are analyzed in energy and detected by a multichannel amplifying plate or other suitable charged-particle detector. Each detected electron gives rise to an electrical pulse that is shaped, amplified, and sent to a pulse counter: it is assumed that each pulse at a specified scattered-electron energy corresponds to an ion that has begun to travel toward the entrance of the mass spectrometer. The electron-detector output is also fed through a variable-delay unit to start a time-to-pulse-height converter.

Another charged-particle detector, another pulse shaper, and another amplifier form a pulse for each ion that arrives at the output end of the mass spectrometer. Each ion pulse serves as the stopping pulse for the time-to-pulse-height converter. Between the starting and stopping pulses, there is a time correlation for those detected ions that were produced by detected electrons. For other detected ions and electrons, there is no time correlation. Thus, the output of the time-to-pulse-height converter includes uncorrelated pulses spread over a wide range of time intervals, plus correlated pulses spread over a fixed time interval, as shown in the output of a pulse-height analyzer.



Coincidences Between Detected Ions and the Electrons That Produced Them would be counted during the operation of a mass spectrometer. Under certain assumptions regarding the inelastic scattering of electrons, the electron/ion-coincidence count is a direct measure of the transmission efficiency of the spectrometer.

The transmission efficiency of the mass spectrometer is taken to be the ratio of the number of time-correlated pulses to the number of electron pulses. The measurement can be repeated for each of the various gases to obtain the transmission efficiency for the molecular mass of each.

This work was done by Santosh K. Srivastava of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 10 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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Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16989, volume and number of this NASA Tech Briefs *issue, and the page number.*

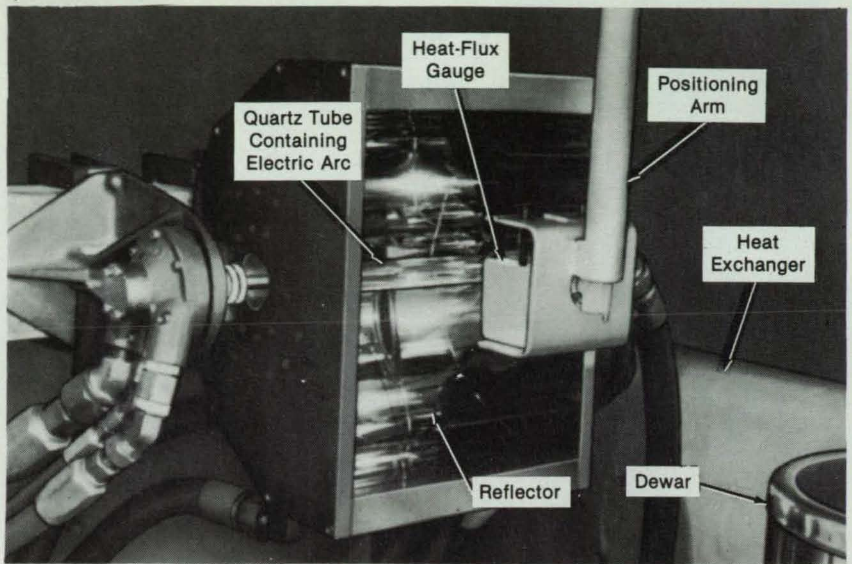
Automated Heat-Flux-Calibration Facility

Computer control speeds operation of the equipment and processing of measurements.

Lewis Research Center, Cleveland, Ohio

A new heat-flux-calibration facility has been developed at Lewis Research Center. This facility is used for fast-transient heat-transfer testing, durability testing, and calibration of heat-flux gauges. Calibrations can be performed at constant or transient heat fluxes ranging from 1 to 6 MW/m^2 and at temperatures ranging from 80 K to the melting temperatures of most materials. The facility was developed because there is a need to build and calibrate very-small heat-flux gauges for the Space Shuttle main engine (SSME). These heat-flux gauges are required for the measurement of the flux of heat to the surfaces of turbines in the turbopumps of the SSME.

The calibration facility includes a lamp head attached to the side of a service module, an argon-gas-recirculation module, a reflector, a heat exchanger, and a high-speed positioning system. The lamp head contains electric-arc-stabilization and deionized-water cooling systems. The stability of the arc, necessary for minimal fluctuation of the light (heat) source, is attained by giving the argon gas a high rotational velocity as the gas enters a quartz tube containing the arc, gas, and water (see figure).



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The water is pumped in a spiral fashion along the tube and flows between the plasma arc and the quartz tube. Also, the deionized water cools the reflector, removes electrode debris from the inside surface of the tube, and cools the quartz tube. After the water has passed through the quartz tube, it is filtered within the service module and then cooled within the heat exchanger.

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Including: LCP's, Fluorocarbon	Yes	Few
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Unscrewing	Yes	No
Tolerances exceed published Shrinkage of polymer suppliers	Yes	No
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Mold Maintances	Yes	-
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Ultra Sonic & Spin Welding	Yes	-
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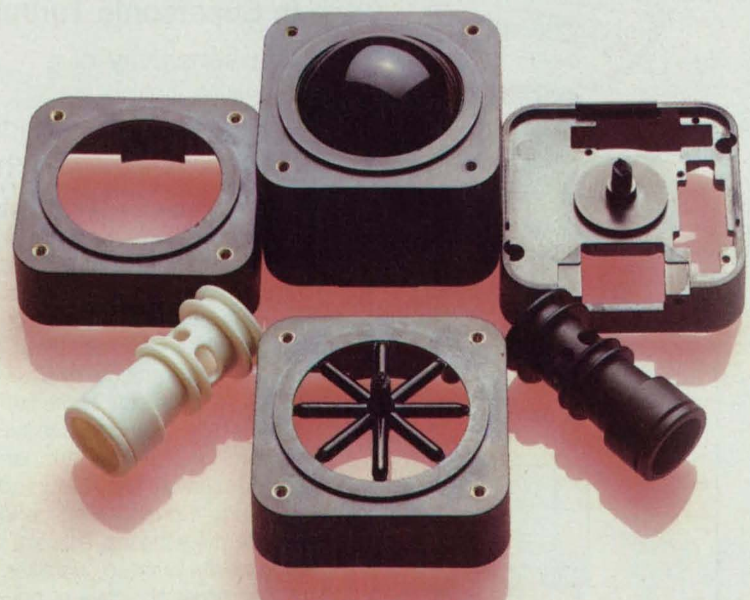
Package & Assemblies	Yes	-



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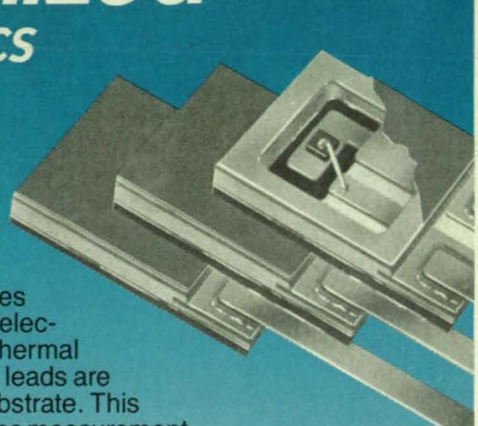

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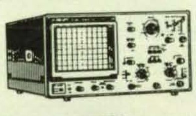
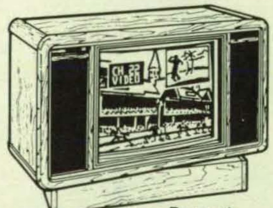
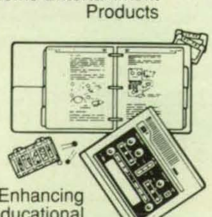


Precision Test Instruments



Dynamic Home Entertainment Products



Skill-Enhancing Educational Courses and Trainers

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A positioning arm attached to the high-speed positioning system is used to position carefully the heat-flux gauge in the focus of the reflector; the positioning system also rapidly removes the gauge from the focal position after sufficient heating. Microcomputers built into the arc lamp and positioning system are controlled by a minicomputer stationed in a nearby control room. Before and after heating by the electric arc, the gauge is cooled by programming the minicomputer to position the gauge in a Dewar filled with liquid nitrogen.

Thermocouples attached to the bodies of heat-flux gauges produce voltages that are converted to temperature data and then stored in the minicomputer. The heat flux is calculated with computer codes that use measured gauge-body temperatures as input. This type of automated heat-flux-calibration facility can be installed in industrial plants for onsite calibration of heat-flux gauges that measure fluxes of heat in advanced gas-turbine and rocket engines.

This work was done by Curt H. Liebert and Donald H. Weikle of **Lewis Research Center**. *No further documentation is available.*
LEW-14724

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.

Accuracy of Hot-Wire Anemometry In Supersonic Turbulence

The sensitivity of a hot-wire probe is compared to laser-induced-florescence measurements.

A report discusses the factors that affect the readings of a hot-wire anemometer in a turbulent supersonic boundary layer. The report presents a theoretical analysis of the responses of a hot-wire probe to changes in the flow; it also compares measurements by a hot-wire probe with measurements of the same flows by laser-induced fluorescence (LIF). Because LIF provides spatially and temporally resolved data on temperature, density, and pressure, it provides independent means to determine the responses of hot-wire anemometers to these quantities.

The usual objective of hot-wire anemometry is to measure the fluctuations in the mass flux, which is a product of flow speed and density. However, a hot wire does not respond to mass flux alone but to a combination of mass flux and total temperature, the total temperature being the temperature of a stagnation point in the flow. While comparisons of hot-wire anemometry with laser doppler velocimetry can provide partial speed calibrations, they provide no information on responses to fluctuations in density and temperature.

The basic equation of hot-wire anemometry is a linearized expression for the fluctuation in the voltage across a hot wire immersed in a flow:

$$(\Delta E/E) = S_{\varrho}(\Delta\varrho/\varrho) + S_{U}(\Delta U/U) + S_{T}(\Delta T/T)$$

where E = the voltage, ϱ = the density, U = the speed, T = the total temperature, S = the sensitivity to the subscripted quantity, and Δ denotes the fluctuation in the associated quantity. For mach numbers above 1.2 and Reynolds numbers above 20 (based on wire diameter)

$$S_{\varrho} \approx S_{u} = S_{m}$$

where $m = \varrho U$ = mass flux. The theoretical analysis explores the mathematical consequences of these equations under various assumed flow conditions to derive equations for three different calibration methods.

The first two methods are based on the concept of "single high overheat": the wire is operated at such a high temperature that it is sensitive only to mass flux and not to fluctuations of temperature in the flow. In the first method (the centerline method), measurements are made at the center line of a wind tunnel, where the flow is relatively free of disturbances. The stagnation pressure, and consequently the mass flux (but not the mach number), is varied from run to run. The second method (the boundary-layer method), which is less vulnerable to certain calibration errors, involves measurements of the boundary-layer flow with mass flow estimated from pitot-static measurements by the standard equations of compressible flow. The third method is more complicated: through measurements at various wire temperatures (multiple overheats) and statistical analysis, it provides for the determination of both S_m and S_T.

The three methods were applied to a mach 2.1 flow of nitrogen in a blowdown wind tunnel and compared with LIF measurements. As a result, the following conclusions were drawn:

- The boundary-layer and centerline methods give the same measurements of mass flux. The boundary-layer method minimizes errors, but the centerline method may be easier and more reliable for the measurement of some complicated flows.
- A hot wire can be operated at a single high overheat or at multiple overheats to measure fluctuations in the mass flux.
- If a high overheat is used to measure only fluctuations in mass flux, then root-mean-square fluctuations of temperature and density cannot be determined accurately.
- If multiple-overheat measurements are taken of the mass flux, the total temperature, and the correlation between them, and if there are no unsteady shocks or other sources of pressure fluctuations, then the root-mean-square fluctuations of temperature and density can be determined accurately.

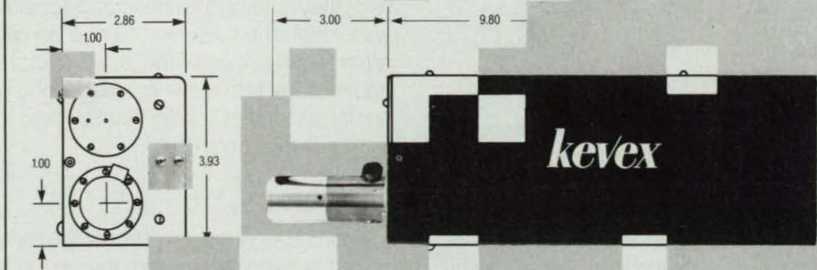
This work was done by Pamela Logan, Robert L. McKenzie, and Daniel Bershader of **Ames Research Center**. *To obtain a copy of the report, "Comparisons of Hot-Wire and Laser-Induced Fluorescence Measurements Obtained in Supersonic Turbulence," Circle 112 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11802.

Computing Geopotential Perturbations

An improved formulation reduces error and the number of computational steps.

A report describes a method for calculating the partial derivative of the geopotential perturbation with respect to time. This partial derivative is useful in computations



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of the orbit of a lightweight satellite in which the total orbital energy or a related parameter is one of the dependent variables.

In a total-orbital-energy formulation, the differential equation for the trajectory of the satellite is obtained by taking the total derivative, with respect to time, of the total orbital energy, h:

$$h = \tfrac{1}{2}\mathbf{r}\cdot\mathbf{P} + \frac{\partial V(r,t)}{\partial t}$$

where $\mathbf{r}$ is the instantaneous position vector from the center of the Earth to the satellite in an inertial reference frame, $r = |\mathbf{r}|$, $\mathbf{P}$ represents the perturbation forces derivable from the geopotential, $V(r,t)$ is the nonspherically-symmetrical perturbation in the geopotential, and t = time. The total derivative of the perturbation with respect to time experienced by the satellite is given by

$$\frac{dV}{dt} = \dot{\mathbf{r}}\cdot\frac{\partial V}{\partial \mathbf{r}} + \frac{\partial V}{\partial t}$$

where $\frac{\partial V}{\partial \mathbf{r}}$ represents the gradient operator usually denoted as ∇.

In a system of coordinates that rotates with the Earth or other geopotential source at a suitable angular velocity $\boldsymbol{\omega}$, the perturbation can be expressed as a function of position $\mathbf{r}_G$ only. With the help of this geocentric coordinate system, and taking $\mathbf{r} = \mathbf{r}_G$ instantaneously, the total derivative with respect to time experienced by the satellite and the partial derivative with respect to time in the inertial coordinate system are given by

$$\frac{dV}{dt} = \frac{\partial V}{\partial \mathbf{r}_G}\cdot(\dot{\mathbf{r}}_G + \boldsymbol{\omega}\times\mathbf{r}_G) + \frac{\partial V}{\partial t} \text{ and}$$

$$\frac{\partial V}{\partial t} = -\frac{\partial V}{\partial \mathbf{r}_G}\cdot(\boldsymbol{\omega}\times\mathbf{r}_G), \text{ respectively}$$

The perturbation is then decomposed into a zonal component V_Z that depends only on the radius and colatitude in the rotating coordinate system and into a component V_T that includes the sectorial and tesseral terms of the potential (terms that depend on the longitude or on longitude and colatitude in the rotating coordinate system). Because $\frac{\partial V_Z}{\partial \mathbf{r}_G}$ contains only terms perpendicular to $\boldsymbol{\omega}\times\mathbf{r}_G$, it does not contribute to the scalar product, and consequently

$$\frac{\partial V}{\partial t} = -\frac{\partial V_T}{\partial \mathbf{r}_G}\cdot(\boldsymbol{\omega}\times\mathbf{r}_G)$$

Two options are considered within this general formulation. While both are correct, they differ in the speed and accuracy with which the trajectory can be computed. In option A, all of the zonal, sectorial, and tesseral terms are included in the potential and, thereby, in the total energy: this makes $\mathbf{P} = \mathbf{0}$ and results in

$$h_A = \frac{\partial V}{\partial t} = -\frac{\partial V_T}{\partial \mathbf{r}}\cdot(\boldsymbol{\omega}\times\mathbf{r}_G)$$

In option B, only the zonal terms are included in the geopotential and, thereby, in the total energy: this makes $\frac{\partial V}{\partial t} = 0$ and places the sectorial and tesseral terms in $\mathbf{P}$, resulting in $h_B = \mathbf{r}\cdot\mathbf{P} = -\frac{\partial V_T}{\partial \mathbf{r}}\cdot\dot{\mathbf{r}}$.

For a satellite orbit near the Earth, the magnitude of the velocity $\boldsymbol{\omega}\times\mathbf{r}_G$ that arises from the rotation of the geocentric coordinate system is much less than the magnitude of the inertial velocity $\dot{\mathbf{r}}$. Thus $|\dot{h}_A| < |\dot{h}_B|$, and in practice $\dot{h}_A/\dot{h}_B < 1/16$. Because the total-orbital-energy formulation involves equations of perturbed harmonic oscillators, the frequencies of which depend on the total orbital energy, the smaller perturbation of option A results in oscillator frequencies that are more nearly constant.

Options A and B were compared by using them to propagate a nearly circular orbit for 10 days. Option B required an average of 59.4 variable steps per revolution, with a maximum error of 25 m. Option A required an average of 45.2 variable steps per revolution, with a maximum error of about 8 m. When both were implemented with 30 fixed steps per revolution, option B showed a rapidly growing error that reached 25 m after 4 days, while option A reached a maximum error of about 15 m after 10 days.

This work was done by Victor R. Bond and David D. Mulcihy of McDonnell Douglas Corp. for **Johnson Space Center**. *To obtain a copy of the report, "Computation of the Partial Derivative of a Potential Function With Respect to Time," Circle 73 on the TSP Request Card.*
MSC-21281

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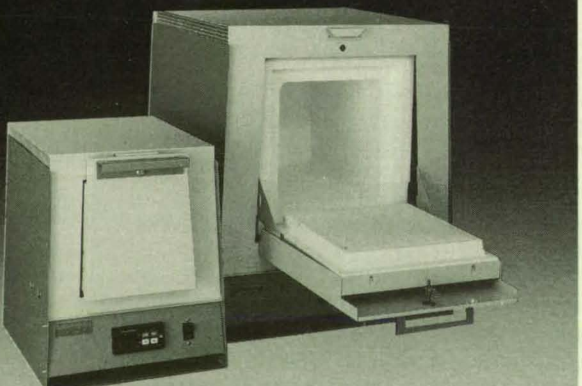

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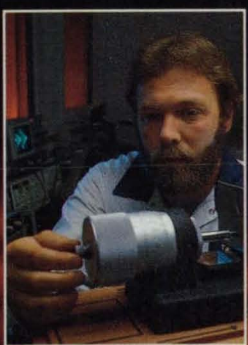

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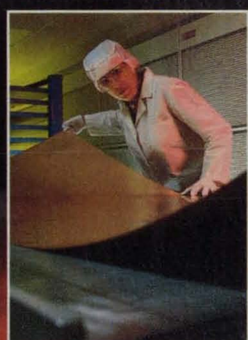

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Surface voids would be sealed from pressurizing gas.

Marshall Space Flight Center, Alabama

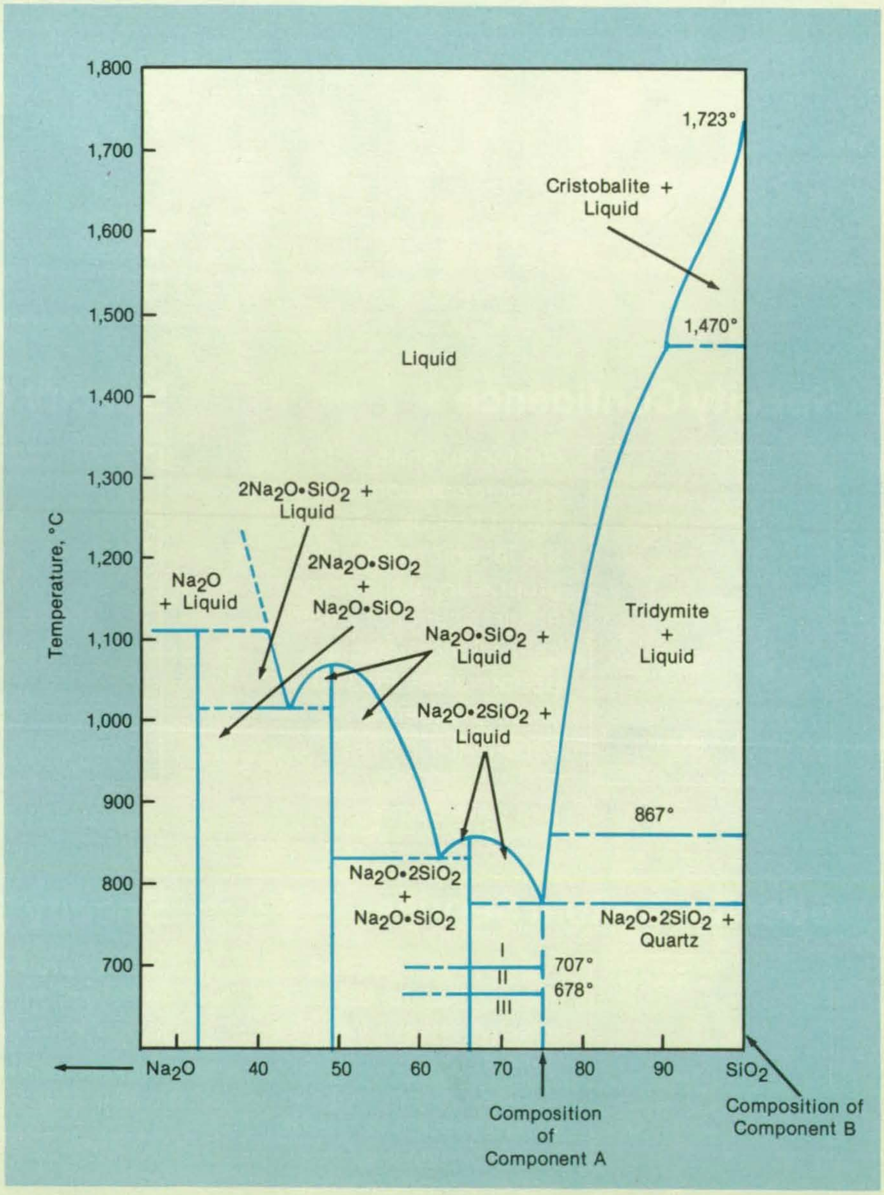
A proposed coating technique would enable the healing of surface defects by hot isostatic pressing (HIP). Internal pores are readily closed by HIP, but surface voids like cracks and pores that are in contact with the pressurizing gas are not healed. The proposed coat would be easy to apply, would separate the voids from the surrounding gas, would not react with the metal part under treatment, and would be easy to remove after pressing.

The coat would be applied to a casting or weldment as a thick slurry of two glass powders: one (component A), which melts at a temperature slightly lower than that used for HIP, and another (component B), which melts at a higher temperature. For example, powder A could be a glass of 75 percent SiO_2 and 25 percent Na_2O, while the other powder could be SiO_2 (see figure). The liquid component of the slurry could be a fugitive organic binder; for example, a mixture of cellulose acetate and acetone.

Most casting defects at surfaces occur in "hotspots" — areas where heat is not conducted away fast enough during solidification. Such areas are often inaccessible. The slurry should readily flow to them, however, after being brushed on a casting. The user does not have to worry about applying too much slurry — it should come off easily after HIP.

In the case of the Na_2O/SiO_2 material mentioned above, as the temperature is raised to about 825 °C during hot isostatic pressing, the lower-melting glass should first melt; but then the glasses should react, and the melting point should rise so that the glass mixture should harden. With the proper choice of the relative amounts of each glass, the mixture should form a coat stiff enough to protect against the gas pressures of 15,000 lb/in.^{2} (100 MPa) typically used in HIP.

When pressing is complete, the casting would be cooled to room temperature. The glass coat should shrink faster than the casting would. Therefore, the coat should spall from the casting, leaving no detectable effects on it.



The **Phase Diagram of Na_2O and SiO_2** indicates that a glass that has a melting temperature between ~780 and 1,723 °C can be made by mixing various proportions of 75-percent SiO_2/25-percent Na_2O glass with pure SiO_2. The numbers on the horizontal axis denote weight percentages of SiO_2.

This work was done by Gunes M. Ecer of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 115 on the TSP Request Card. MFS-29501*

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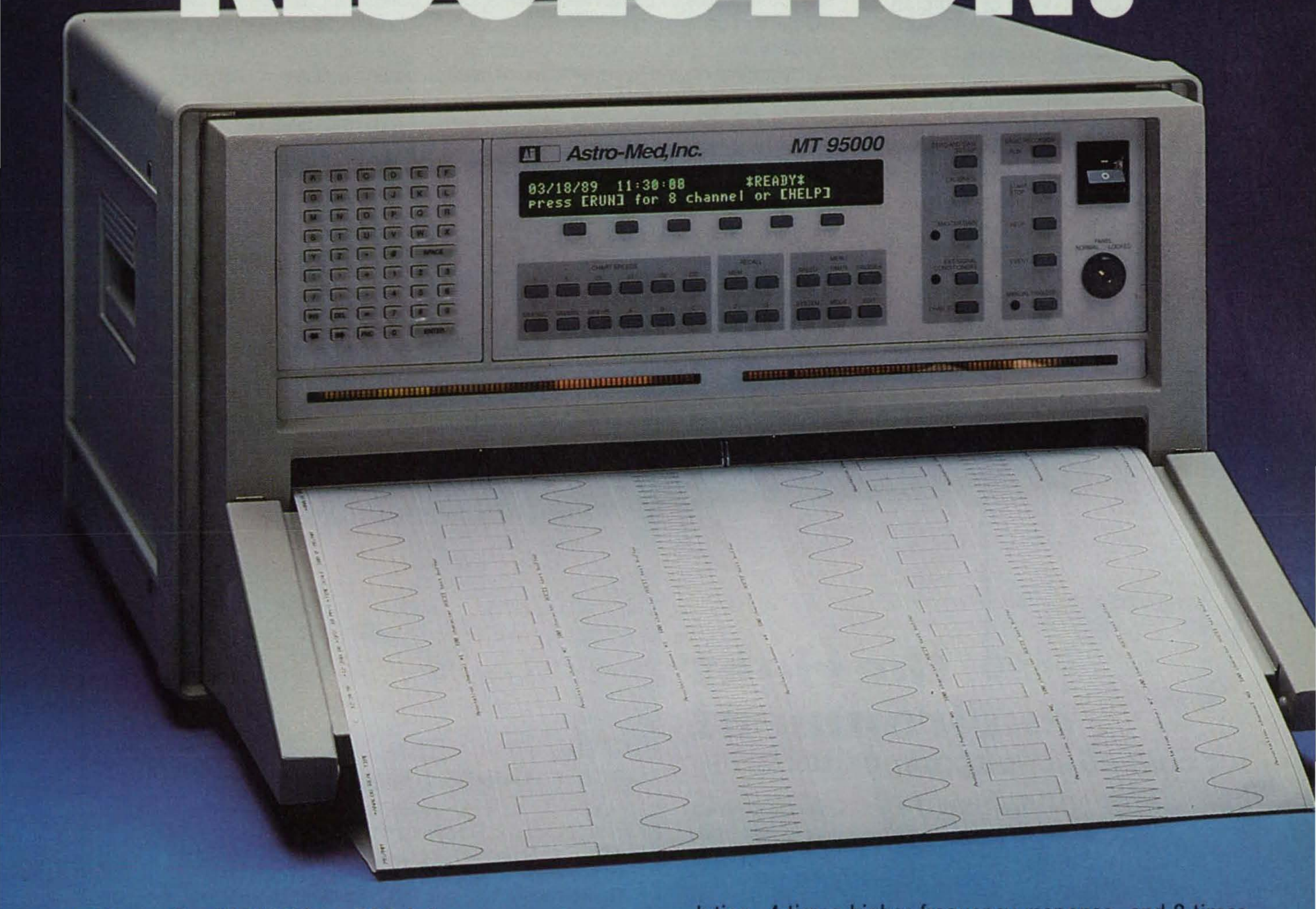

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Books and Reports

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.

Resistance to Delamination in Composite Materials

A fracture-mechanics approach is applied to delamination failures.

Delamination is the most-commonly-observed mode of failure in composite-material dynamic components of rotorcraft. Potential delamination sites in composite structures exist at discontinuities in load paths; for example, at straight edges, bonded joints, and bolted joints. These discontinuities give rise to interlaminar stresses even when the remote loading is in the plane of the laminations. Clearly, it would be useful to be able to model delamination mathematically and predict its onset for a given loading condition at a specified discontinuity.

A report presents a fracture-mechanics approach to analyzing, characterizing, and designing against delamination. In the study, examples of delamination problems are illustrated wherein the strain-energy-release rate associated with the growth of delamination has been found to be a useful generic parameter, independent of thickness, layup, and source of delamination, for the characterization of failure by delamination. Several techniques for the calculation of strain-energy-release rates for delaminations from a variety of sources are outlined. A technique for the quantification of durability due to cyclic loading is presented.

One example of this approach is the analysis of edge delamination. In this case, the strain-energy-release rate is related through an equation to the remotely applied strain, the thickness of the laminate, and the modulus of the laminate with and without the delamination. The strain-energy-release rate is independent of the size of the delamination and the orientation of the layup. A critical strain for delamination is identified, and this is used to calculate a critical strain-energy-release rate, which is then used to calculate the remotely applied strains required to propagate a delamination for a number of different fiber orientations. These predictions, for the case of edge delamination, closely approximate experimentally-determined strain values.

To model delaminations involving mixed-mode fracture, a finite-element approach is used to calculate the three components of the strain-energy-release rate: G_I (interlaminar tension), G_{II} (interlaminar sliding shear), and G_{III} (interlaminar scissoring shear). The total G is then determined by summing these components. This technique can be applied to different geometries, calculating the strain-energy-release rate components for several different sources of delamination.

This work was done by T. Kevin O'Brien of **Langley Research Center**. *To obtain a copy of the report, "Delamination Durability of Composite Materials for Rotorcraft," Circle 154 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, Langley Research Center [see page 14]. Refer to LAR-13753.

Unified System of Data on Materials and Processes

Wide-ranging sets of data for aerospace industry are described.

A document describes the Materials and Processes Technical Information System (MAPTIS), a computerized set of integrated data bases for use by NASA and the

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aerospace industry. MAPTIS stores information in a standard format for fast retrieval in searches and surveys of data. It helps engineers select materials and verify their properties. It promotes standardized nomenclature as well as standardized tests and presentation of data.

MAPTIS contains the following sets of data, among others:

- Nonmetallic materials — specifications, manufacturers, trade names, flammability, toxicity, and compatibility with hydrazine, hydraulic fluid, oxygen, and hydrogen.
- Metals — alloys, heat treatments, corrosion, stress corrosion cracking; and compatibility with oxygen, nitrogen tetroxide, hydrazine, hydrogen, and hydraulic oil.
- Atomic oxygen — effects on materials, guidelines for selection, and protective techniques.
- Thermal vacuum stability — data on outgassing, gathered from a variety of agencies.
- Verification and control of materials — information on where materials are used, ready reference for foreign alloys, and records of agreements on the uses of materials.
- Properties of materials, including mechanical, electrical, chemical, and thermal properties — particularly those related to processing, safety, and endurance in use.
- Lubricants — lubricity, viscosity, temperature range, formulation, flashpoint, chemical properties, processing, and thermal properties.
- Specifications and standards.

The format of the document is that of photographic projection slides used in lectures. The document presents examples of reports from the various data bases.

This work was done by Carlo F. Key of EER Systems for **Marshall Space Flight Center**. *To obtain a copy of the report, "Materials and Processes Information System," Circle 88 on the TSP Request Card. MFS-27212*

Effect of Solidification Speed on Fatigue Properties

Fast solidification increases fatigue life, but the failure distribution becomes less predictable.

A report describes the effects of the rate of solidification on the nickel-based superalloy MAR-M246(Hf) used in turbine blades. The report is based on experiments in which specimens were directionally solidified at 5 cm/h and 30 cm/h, then tested for high cycle fatigue. The specimens were also inspected by energy-dispersive x-ray (EDX) analysis and optical and electron microscopy.

The specimens solidified at the higher speed had higher volume fractions of carbide and interdendritic eutectic and lower volume fractions of the γ' phase. Correlated with these characteristics was the fatigue life — twice as high in the rapidly solidified specimens as in those solidified slowly.

However, the rapidly solidified specimens failed more randomly. These specimens exhibited more early failures than did the slowly solidified specimens, which followed a normal wearout pattern. The lesser predictability of failure in the rapidly solidified specimens can be related to the greater carbide and eutectic contents. Although heat treatment can diminish the segregation to some extent, it is still greater than in the specimens solidified more slowly.

This work was done by M. H. McCay, D. D. Schmidt, W. D. Hamilton, W. S. Alter, and R. A. Parr of **Marshall Space Flight Center**. *To obtain a copy of the report, "The Influence of Growth Rate on Fatigue Properties in a Directionally Solidified Superalloy," Circle 26 on the TSP Request Cards.*

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-27215

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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.

Electronic Components and Circuits

Computer-Aided Engineering of Cabling

This program generates data sheets, drawings, and other information on electrical connections.

DFACS is an interactive multiuser computer-aided-engineering tool for system-level electrical integration and cabling engineering. The purpose of the program is to provide the engineering community with a centralized data base for putting in, and gaining access to, the functional definition of a system as specified in terms of details of the pin connections of the end circuits of subsystems and instruments and data on harnessing. The primary objective is to provide an instantaneous single point of interchange of information, thus avoiding error-prone, time-consuming, and costly shuttling of data along multiple paths.

The DFACS program, which is centered around a single data base, has built-in menus that provide easy input of, and access to, data for all personnel involved in the system, subsystem, and cabling. The DFACS program enables the parallel design of circuit-data sheets and drawings of harnesses. It also recombines raw information to generate automatically various project documents and drawings, including the index of circuit-data sheets, the list of electrical-interface circuits, lists of assemblies and equipment, cabling trees, and drawings of cabling electrical interfaces and harnesses.

Real-time automatic production of harness drawings and circuit-data sheets from the same reservoir of data ensures instant harmony in the engineering design of the system and cabling. DFACS also contains automatic wire-routing procedures and extensive error-checking routines designed to minimize the possibility of engineering error.

The DFACS program was developed in 1987. It is designed to operate on a DEC

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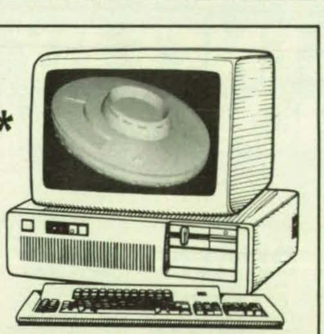
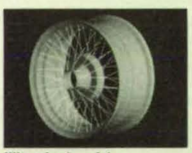
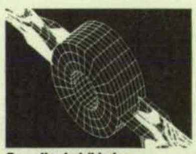
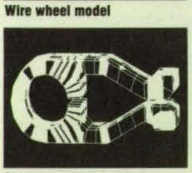




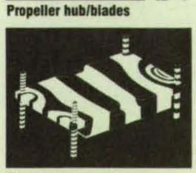
Wire wheel model



Propeller hub/blades



Stress contour on clip



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VAX minicomputer or microcomputer using INGRES Version 5.0/03 and VAX.VMS/04. INGRES is available through Relational Technology, Inc.

This program was written by Joseph W. Billitti of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 61 on the TSP Request Card.*
NPO-17391

Physical Sciences

Designing Corrector Optics

Image-spot radii can be reduced by factors ranging from 5 to 25.

Corrector Surface Design Software (CORFIG) calculates the optimum figure of a corrector surface for an optical system based on real ray traces. CORFIG generates the corrector figure in the form of a spline data-point table and/or a list of polynomial coefficients. The number of spline data points as well as the number of coefficients are specified by the user.

First, the parameters of the optical system (thicknesses, radii of curvature, and the like) are entered. CORFIG traces the outermost axial real ray through the uncorrected system to determine approximate radial limits for all rays. Then several real rays are traced backward through the system from the image to the surface that originally followed the object, within these radial limits. At this first surface, the local curvature is adjusted on a small scale to direct the rays toward the object, thus removing any accumulated aberrations.

For each ray traced, this adjustment is different, so that at the end of this process the resultant surface is made up of many local curvatures. The equations that describe these local surfaces, expressed as high-order polynomials, are then solved simultaneously to yield the final surface figure, from which data points are extracted. Finally, a spline table or list of polynomial coefficients is extracted from these data points.

CORFIG is intended to be used in the late stages of optical design. The design of the system must have at least a good paraxial foundation. Preferably, the design should be at a stage at which traditional methods of correction of Seidel aberrations do not bring the size of an image spot within specification.

CORFIG reads the system parameters of such a design and calculates the optimum figure for the first surface such that all of the original parameters remain unchanged. Depending upon the system, CORFIG can reduce the root-mean-square image-spot radius by a factor of 5 to 25. The original parameters (magnification, back focal length, and the like) are maintained because all rays upon which the corrector figure is based are traced within the bounds of the outermost ray of the original system. For this reason, the original system must have a certain degree of integrity.

CORFIG optimizes the figure of the corrector surface for on-axis images at a single wavelength only. However, it has been demonstrated many times that the method of CORFIG also significantly improves the quality of field images and images formed at wavelengths other than the design wavelength.

CORFIG is written completely in VAX FORTRAN. It has been implemented on a DEC VAX-series computer under VMS with a central-memory requirement of 55K bytes. The program was developed in 1986.

This program was written by A. Dantzler of **Goddard Space Flight Center**. *For further information, Circle 110 on the TSP Request Card.*
GSC-13120

Mathematics and Information Sciences

Data-Dictionary-Editing Program

Access to data-dictionary relations and attributes is made more convenient.

The Data Dictionary Editor (DDE) computer program was developed to give the developers of data bases more convenient access to the OMNIBASE VAX/IDM data-dictionary relations and attributes. Prior to the development of DDE, access to the descriptions table could be obtained via OMNIBASE IQL software. However, it was necessary to specify relations (tables) and attributes (fields) by numbers associated with their names. The DDE application program provides more convenient read/write access to the data-dictionary table ("descriptions table") via a data screen that uses SMARTQUERY function keys. (SMARTQUERY is an OMNIBASE software product that uses special function keys for the storage and retrieval of data records.)

DDE provides three main advantages: (1) The user works with the table names and field names rather than with table numbers and field numbers, (2) DDE provides online access to definitions of data-dictionary keys, and (3) DDE provides a displayed summary list that shows, for each datum, which data-dictionary entries currently exist for any specific relation or attribute.

The DDE data screen is an OMNIBASE SMARTDESIGN screen with two windows. The top window retrieves relation (table) descriptions and attribute (field) descriptions. The bottom window retrieves definitions of data-dictionary keys. DDE allows users to switch back and forth between the two windows without interfering with retrievals in progress in either window.

The DDE application program was developed for specific use: that of review and editing of records in the OMNIBASE "descriptions" relation (table). However, the routines that allow more than one retrieval sequence to be in progress at the same time can be adapted for use in other OMNIBASE applications.

DDE was developed on a DEC VAX 750 computer under VMS 3.6. Implementation of DDE requires a Brittain Lee data-base machine with IDM 500 and the OMNIBASE software package. OMNIBASE is available from Signal Technology, Inc. The DDE program was developed in 1987.

This program was written by A. P. Cumming of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information, Circle 135 on the TSP Request Card.* *MSC-21290*

AutoCAD-To-NASTRAN Translator Program

This program facilitates the creation of finite-element mathematical models from geometric entities.

The AutoCAD to NASTRAN translator (ACTON) computer program was developed to facilitate quick generation of small finite-element mathematical models for use with the NASTRAN finite-element modeling program. (NASTRAN is available from COSMIC.) ACTON reads the geometric data of a drawing from the Data Exchange File (DXF) used in AutoCAD and other PC-based drafting programs.

The geometric entities recognized by ACTON include POINT's, LINE's, SOLID's, 3DLINE's, and 3DFACE's. From this information, ACTON creates a NASTRAN bulk data deck, which can be used to create a finite-element model. The NASTRAN elements created include CBAR's, CTRIA's, CQUAD4's, CPENTA's, and CHEXA's. The bulk data deck can be used to create a full NASTRAN deck. It is assumed that the user has at least a working knowledge of AutoCAD and NASTRAN.

ACTON was written in Microsoft QuickBasic (Version 2.0). The program was developed for the IBM PC and has been implemented on an IBM PC-compatible under DOS 3.21. ACTON was developed in 1988.

This program was written by A. Jones of **Goddard Space Flight Center**. *For further information, Circle 136 on the TSP Request Card.* *GSC-13217*

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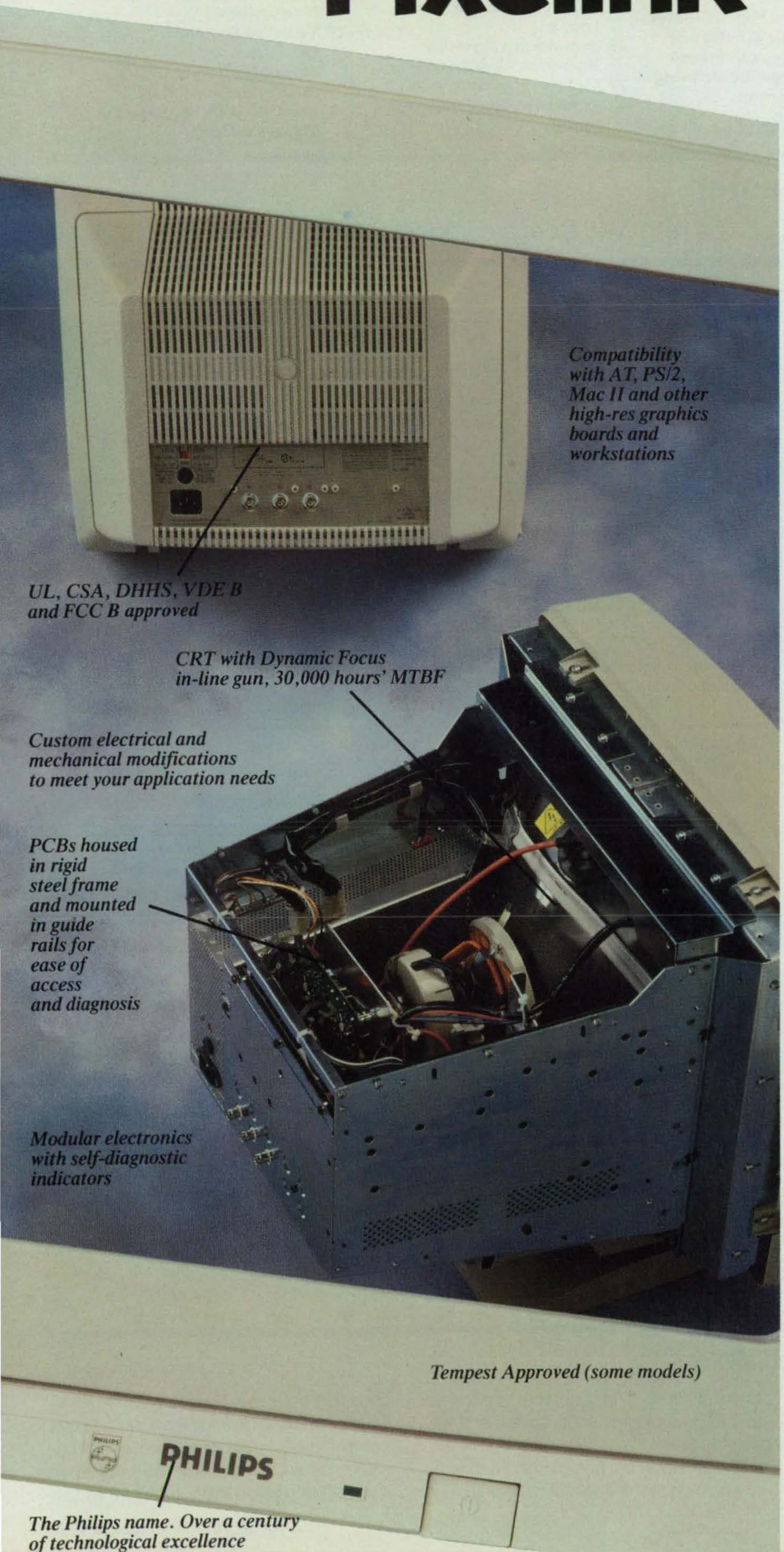

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Mechanics

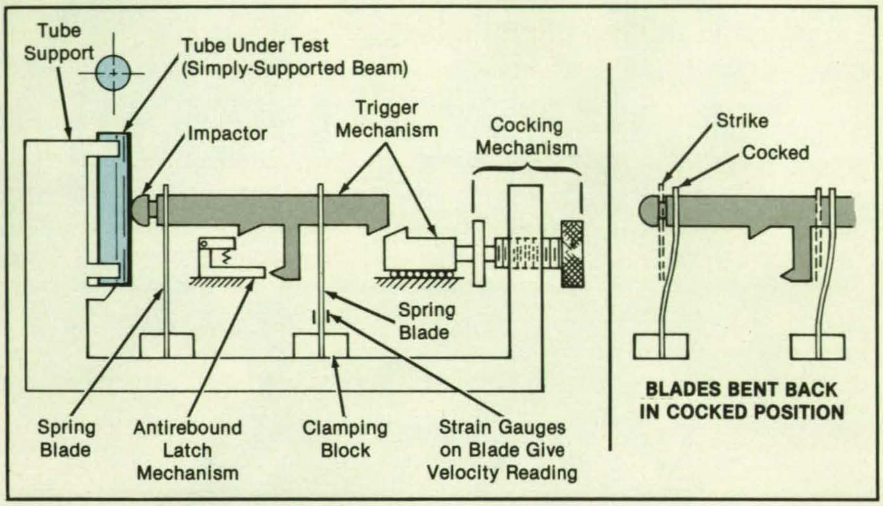
Spring-Blade Impact Tester

A record of energy relationships can be retrieved from a compact, portable tester.

Langley Research Center, Hampton, Virginia

The spring-blade impact tester was developed to support the evaluation of the tolerance to damage of struts under consideration for use in the Space Station. This approach offers the potential for determining damage as a function of the change in the relationship between applied and absorbed energies as the applied energy is successively increased with each impact. The concept also provides the potential for measuring behavior during impact, and the energy relationships are retrievable from oscilloscope traces of the impact.

The tester includes two identical flat spring blades set vertically and parallel to each other (see figure). The blades are clamped at the bottom to a massive plate that acts as a baseplate for the whole unit. At the upper ends, the blades are clamped to a single, rectangular-beam-like mass that spans the horizontal distance between them. When the mass is pulled horizontally in a direction that causes the blades to bend about their weak axis, the beam remains horizontal. Upon release of the pulling force, the mass travels back and forth horizontally with a decaying oscillatory motion.



The **Impactor Strikes the Specimen** at the moment of maximum kinetic energy after the spring blades are released from their cocked position.

Strain gauges installed on the blades measure the bending of the blades. A pair of back-to-back strain gauges mounted on each blade at a point other than at mid-height, where strain is always zero, provides a signal proportional to the displacement of the blade at the moment of release.

The maximum kinetic energy of the oscillating mass is proportional to the volume of the two blades, the elastic modulus of the blade material, and the square of any measurable static elastic bending strain at the moment of release, if damping is assumed to be zero. Damping is not zero, but its highly repeatable effect can be measured, calibrated, and taken into account so that the maximum kinetic energy can be predictably set by monitoring and adjusting the static bending strain at the instant of release. The specimen is placed so that a special anvil attached to the mass strikes it at midoscillation, the moment of maximum kinetic energy.

Other features include a hydraulic actuator to pull the mass to its release position; a special releasing latch that provides a clean, sharp release actuated by the tap of an ordinary hammer; and a special latch that allows the mass to pass through the location of maximum kinetic energy only once. This second latch prevents repeated, oscillatory blows to the specimen. Because the energy available is a function of the volume of the spring-blade material, a minimum of space is required for operation and storage. The impact tester is compact and portable and is both easy and safe to use.

This work was done by Alan M. Holmes and James W. Champagne of Lockheed Missiles & Space Co., Inc., for **Langley Research Center**. *For further information, Circle 22 on the TSP Request Card.*
LAR-13749

Algorithm for Solution of Navier-Stokes Equations

Advantages of two previous algorithms are combined.

Lewis Research Center, Cleveland, Ohio

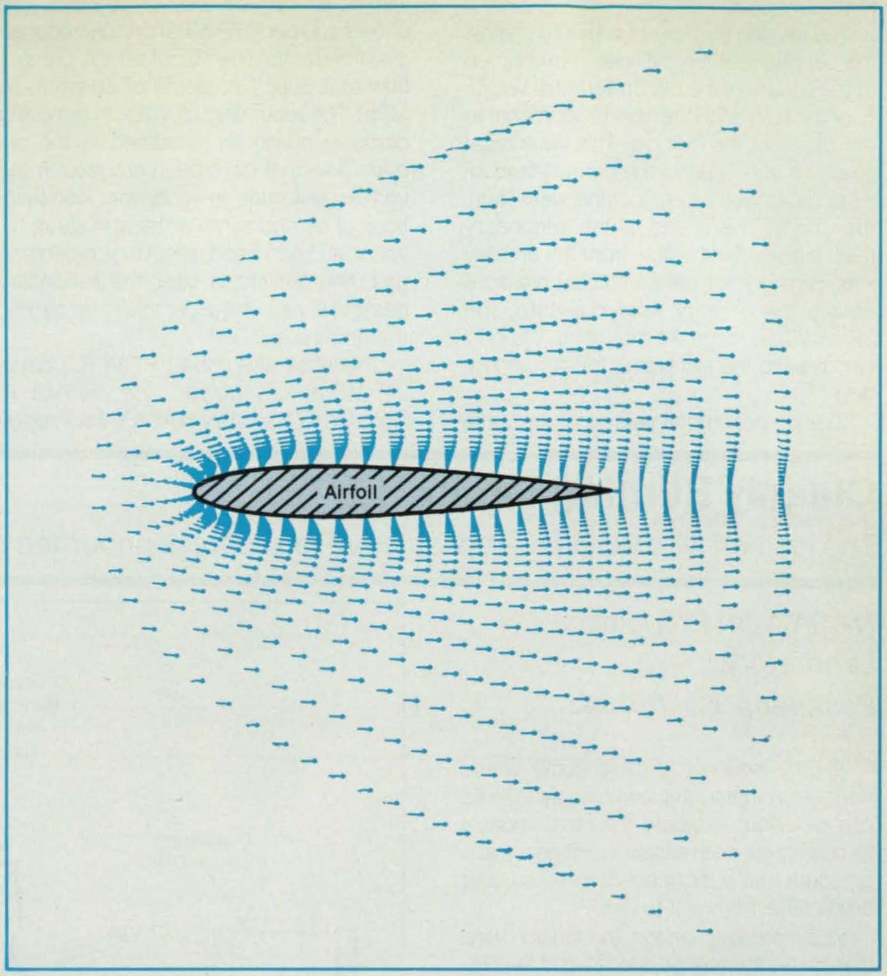
An algorithm for the solution of the two-dimensional, steady-state Navier-Stokes equations has been developed by combining the efficiency of the LU-SSOR scheme with the accuracy of the flux-limited dissipation scheme. The algorithm has been used to predict laminar, turbulent, and hypersonic flows.

The development begins with the classical equations for the two-dimensional, viscous flow of a gas in thermodynamic equilibrium. The flow is characterized by Cartesian components of velocity as functions of position and time. The dependent variables include the mass density, total energy per unit mass, pressure, and temperature. The pressure is obtained from an equation of state, as a function of the ratio of specific heats and the difference between the densities of total and kinetic energy. The Navier-Stokes equations are written in the form of conservation laws for the fluxes of mass, momentum, and energy, with source terms based on scalar coefficients of viscosity and thermal conductivity.

The steady-state Navier-Stokes equations are put in an implicit finite-difference form that can be solved by approximate Newton iteration. Because of the rapid growth in the number of arithmetical operations with the number of cells in the finite-difference mesh, such systems of equations have previously been solved indirectly by relaxation methods.

The LU-SSOR scheme is a new relaxation method that combines the advantanges of LU factorization with Gauss-Seidel relaxation. The vectorizable LU-SSOR scheme, which is based on central differences, requires scalar diagonal inversions. The application of the scheme to the approximate Newton iteration of the Navier-Stokes equations yields a set of equations that require no implicit smoothing on the left side. Only adaptive, total-variation-diminishing, flux-limited dissipation terms are added to the right side.

The algorithm was able to simulate a subsonic, viscous, laminar flow past an airfoil (see figure). It also performed well when applied to a subsonic, viscous, turbulent flow past an airfoil and to two hypersonic, inviscid flows past an inlet.



These **Velocity Vectors** mark the viscous flow past a National Advisory Committee for Aeronautics 0012 airfoil at mach 0.5, Reynolds number 5,000, and zero angle of attack.

This work was done by Seokkwan Yoon of Sverdrup Technology, Inc., for **Lewis Research Center**. *Further information may be found in NASA CR-179608 [N87-20243], "A Navier-Stokes Solver Using the LU-SSOR TVD Algorithm."*

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-14656*

Improved Flow-Controlling Vortex Generator

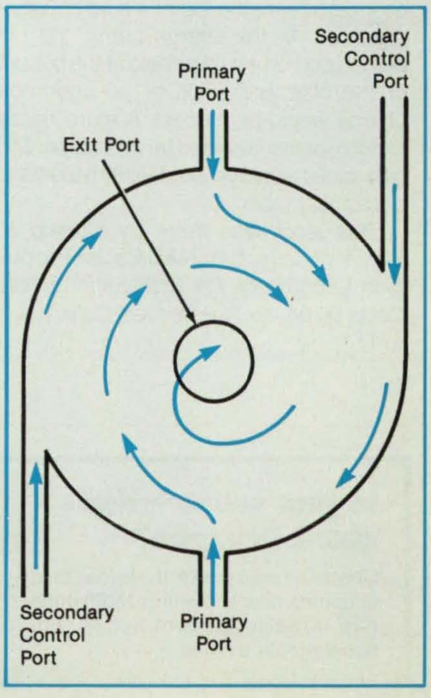
Symmetrical tangential streams control flow of radial primary streams.

NASA's Jet Propulsion Laboratory, Pasadena, California

A vortex generator uses a small secondary stream of fluid to control a normally-larger primary stream. The device is an improved version of the vortex generator described in "Variable Control Port for Fluidic Control Device," (NPO-16603), *NASA Tech Briefs*, Vol. 10, No. 2 (March/April 1986), pp. 114-115. Like a valve, the vortex generator can vary the rate of flow of the primary fluid from its maximum value down to zero. When properly designed, it requires a low pressure differential between the primary and secondary streams and expends a relatively small amount of secondary fluid.

The vortex generator consists of a disk-like short, hollow cylinder in which the primary fluid enters radially at two opposed points while two secondary streams enter tangentially at points 90° from the primary streams (see figure). An exit port is located at the center of one end of the cylinder.

The primary fluid enters through slots that extend the height of the cylinder. Without any secondary flow, the primary streams flow directly from their entrance ports to the central exit port. When the secondary streams are introduced (at a smaller volume and greater velocity), they set up a circular flow that gradually spirals inward



Secondary, or Control, Flows entering tangentially through diametrically opposite ports set up a swirling motion that restrains the primary flow. The pressure of the secondary fluid in relation to that of the primary fluid is the controlling factor.

to the exit port.

The rotating fluid exerts pressure against the periphery of the cylinder in proportion to the square of the circumferential velocity of the fluid and inversely proportional to the radius of the cylinder. This centrifugal pressure acts against the primary-fluid inlet ports as well as against the wall. Thus, the greater the speed of the secondary fluid, the smaller the flow from the primary inlet ports. When the centrifugal pressure equals the primary inlet pressure, the primary flow stops. At that point, the only fluid leaving the exit port is the secondary fluid.

In an experimental version of the valve with air as the fluid, a secondary pressure of only 100 psi (0.69 MPa) created enough circumferential flow to cut off the primary flow at a supply pressure of 80 psi (0.55 MPa). The secondary flow aids in removing particles previously entrained in the primary flow that have been dropped in the vortex generator. In tests with combinations of air and sand; water and sand; air, water, and sand; and diesel fuel, n-pentane gas, and pulverized coal; the secondary gas (air) swept up the particles and carried them to the exit port.

This work was done by Earl R. Collins, Jr., Wilbur J. Marner, and Naresh K. Rohatgi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 151 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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Refer to NPO-17277, volume and number of this NASA Tech Briefs *issue, and the page number.*

Cleanly Burning Squib

The ignition wire would be repositioned to suppress unburned particles.

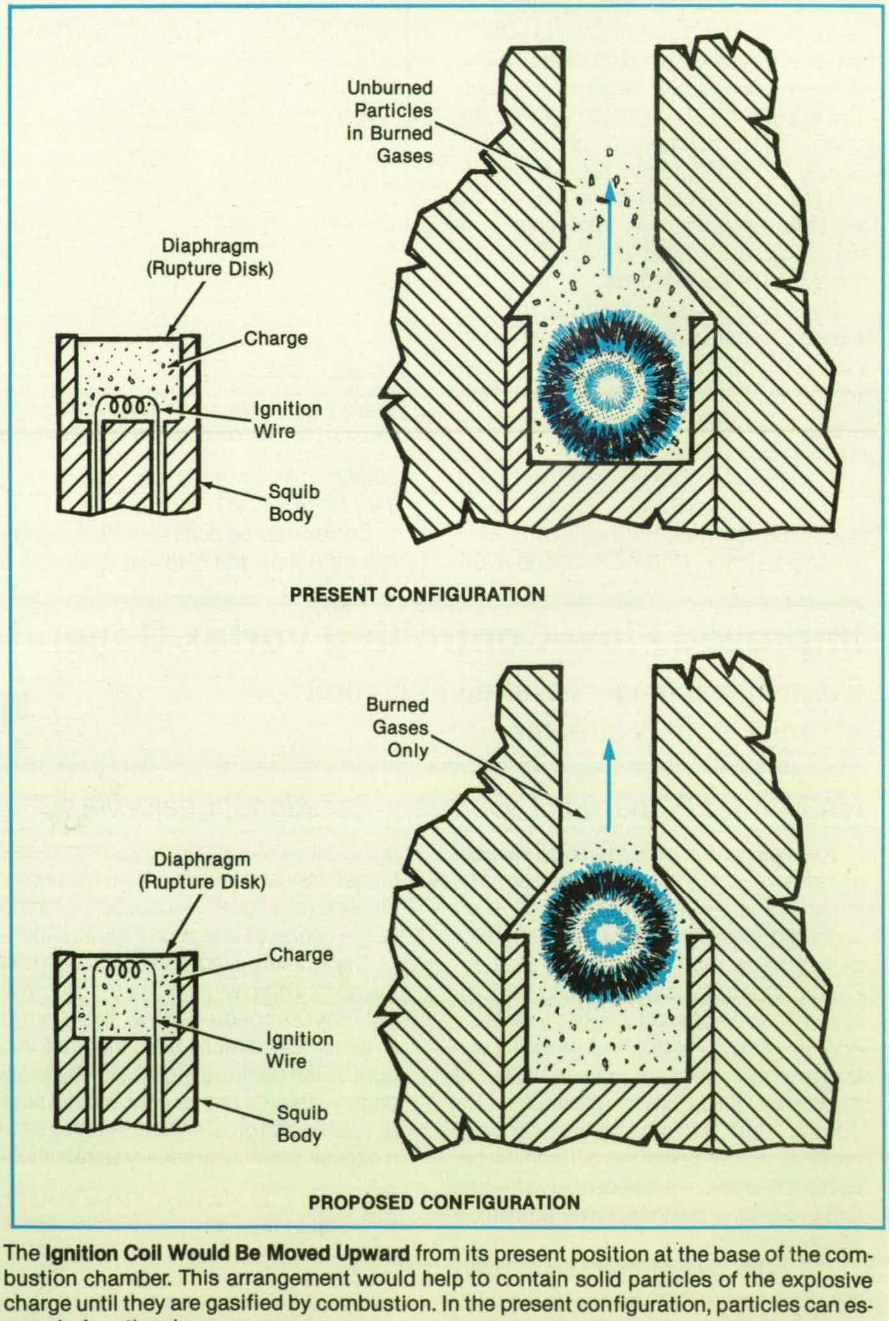
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed pyrotechnic squib would burn more thoroughly and cleanly than its predecessors. It would therefore rupture its diaphragm and release its hot gases at a pressure that is more nearly constant and predictable from unit to unit.

In the present version, the ignition wire that ignites the charge is located at the bottom of the combustion chamber (see figure). The charge thus burns upward and can expel unburned particles of the charge, creating localized and unpredictable variations in pressure that affect adversely the operation of the squib-actuated mechanism.

In the proposed new configuration, also shown in the figure, the ignition coil would be located near the top of the combustion chamber. As the charge burns, the unburned portion would be held at the bottom of the chamber. Little or no unburned charge would be ejected. A more nearly uniform pressure would be generated, and only gases would be ejected from the combustion chamber.

This work was done by Donald B. Bickler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 90 on the TSP Request Card.*
NPO-17112



The **Ignition Coil Would Be Moved Upward** from its present position at the base of the combustion chamber. This arrangement would help to contain solid particles of the explosive charge until they are gasified by combustion. In the present configuration, particles can escape before they burn.

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Capillary-Condenser-Pumped Heat-Transfer Loop

The heat being transferred supplies the operating power.

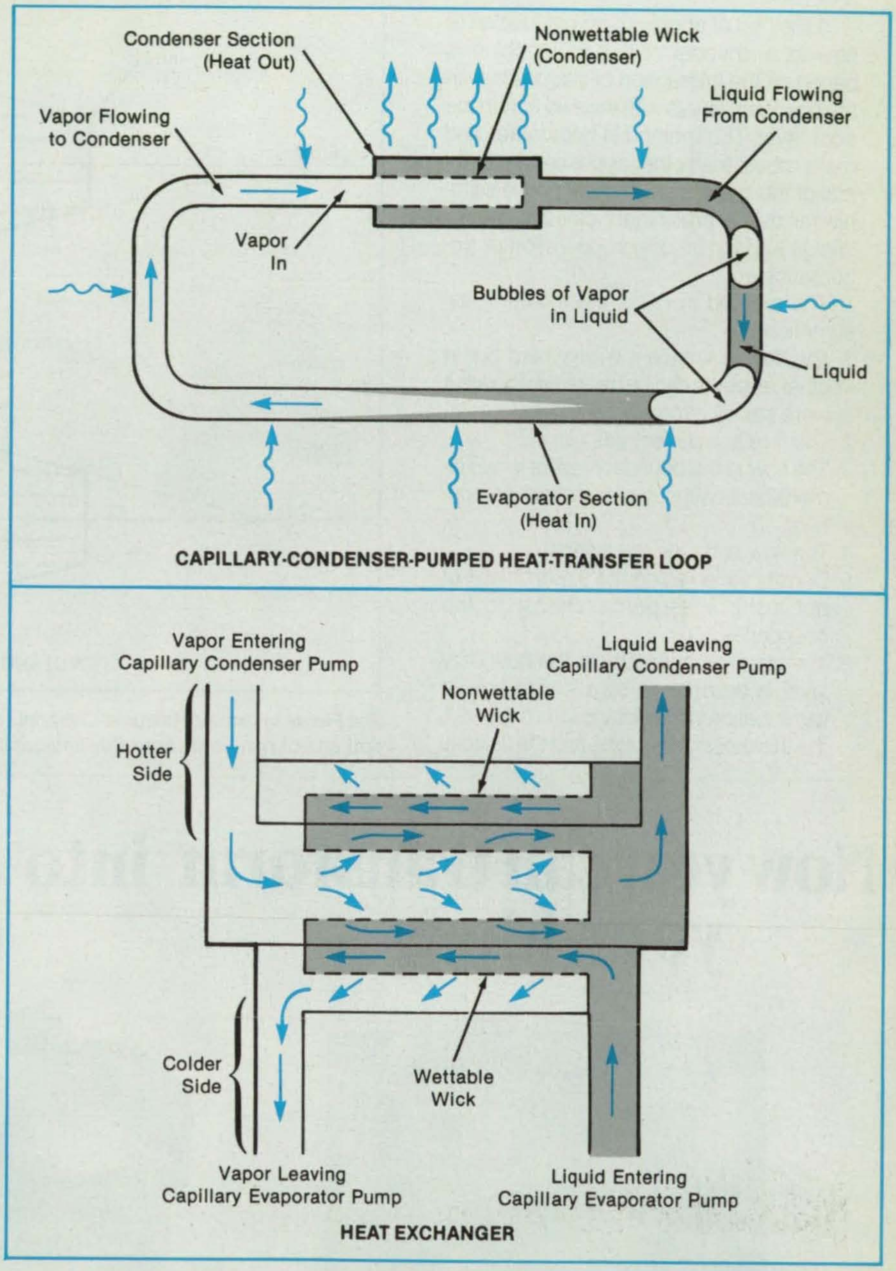
Marshall Space Flight Center, Alabama

The capillary-condenser-pumped loop is a closed-circuit, two-phase-fluid system for the transfer of heat through relatively long pipes. Like a heat pipe, this system requires no pump or externally supplied power to circulate the heat-transfer fluid, relying instead on the flow of heat in its evaporator and condenser sections to do the pumping. Unlike in a heat pipe, in which the liquid and vapor flow in opposite directions, the liquid and vapor in the capillary-condenser-pumped loop flow in the same direction.

In some respects, the capillary-condenser-pumped loop is essentially a capillary-evaporator-pumped loop operating in reverse. The loop (see figure) is filled with the fluid in both liquid and vapor phases. Heat is added to the liquid phase along the evaporator section (an ordinary pipe with no wick structure), causing the liquid to vaporize. Heat is removed in the relatively short condenser section, causing the vapor to condense.

The condenser section contains a nonwettable, porous wick structure in thermal contact with an external heat sink. (The corresponding section of a capillary evaporator pump would contain a porous, wettable wick.) The pressure is at a minimum in the vapor condensing in the wick and at a maximum in the liquid that has just condensed. The capillary pressure due to the surface tension of the liquid in the wick is the source of this difference in pressure and balances the pressure lost in pumping the fluid around the loop. The pressure in the condensed liquid pushes this liquid out of the condenser, causing the fluid to flow once again around the loop.

Whereas a capillary evaporator pump must be placed at a heat source, the capillary condenser pump can be placed at a heat sink. Thus, a capillary-condenser-pump heat-transfer loop is preferable where the heat-input (evaporator) length is greater than the available heat-rejection (condenser) length. This situation exists, for example, where the surface of a hypersonic airplane has to be cooled by transporting the aerodynamically generated heat to a central hydrogen-fuel heat sink.



The **Capillary-Condenser-Pumped Heat-Transfer Loop** is similar to a heat pipe and to a capillary-evaporator-pumped heat-transfer loop in that the heat-transfer fluid is pumped by the evaporation and condensation of the fluid at the heat source and sink, respectively. A capillary condenser pump can be combined with a capillary evaporator pump (below) to form a heat exchanger that circulates the heat-transfer fluids in both loops.

The capillary-condenser-pumped loop offers the following additional advantages:

- Because only a small fraction of the loop is filled with liquid, the weight is lower than that of a forced-convection loop, which must be filled completely.
- The internal pressure is limited to the saturation pressure of the heat-transfer fluid, whereas in an all-liquid forced-convection system, the internal pressure may be several times as high. The lower internal pressure may permit the use of thinner tubing, thus reducing weight even further.
- The transport of heat is more nearly isothermal than in older heat-transport systems of similar capacity. Thus, thermal stress in the loop is reduced, and less external surface area is needed in the condenser section for the rejection of heat to the heat sink.

This work was done by Calvin C. Silverstein of CCS Associates for **Marshall Space Flight Center**. *For further information, Circle 69 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-26046.

Calculating Flows in Turbomachine Channels

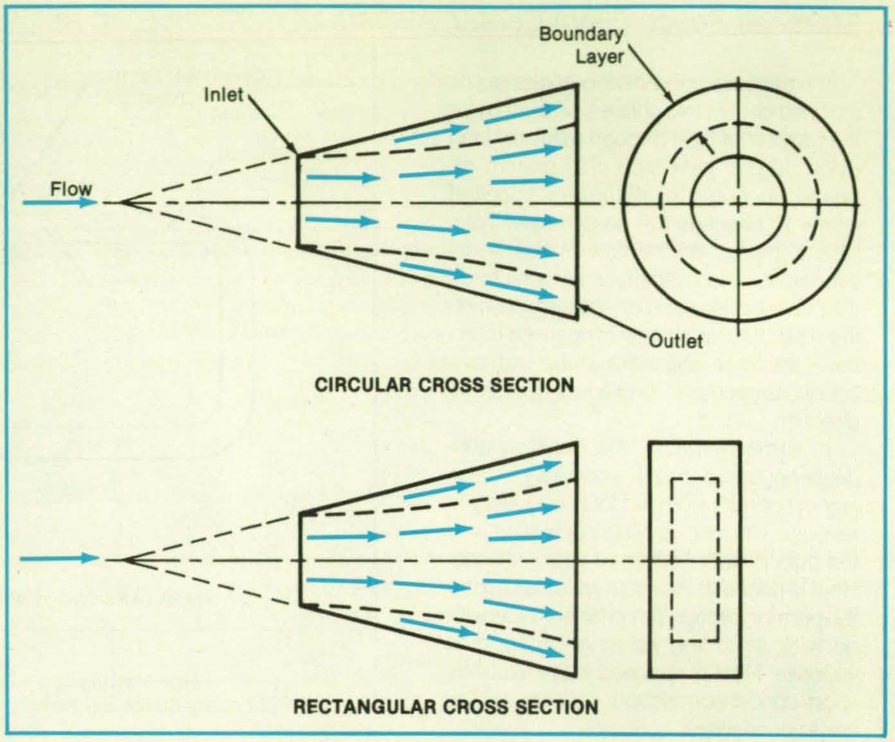
A noniterative integral-entrainment method yields good approximations.

Lewis Research Center, Cleveland, Ohio

A method of approximate calculation of flow in a channel of a turbomachine is based on the interaction of viscous flow in the boundary layers with inviscid flow in the core layer. The method is both faster and more robust than other approximate methods of the same type. The method is suitable for use in preliminary calculations for design and for off-design operation of turbomachinery.

The method involves the following assumptions:

1. The flow is turbulent everywhere but in other respects can be treated as though it were steady everywhere.
2. The fluid is a perfect gas.
3. The flow in the boundary layers is two-dimensional, without a crossflow component.
4. The flow surfaces are adiabatic.
5. Density varies along the streamlines but not along lines perpendicular to the boundaries.
6. The streamline velocity in the boundary layer is describable by a simple power-law equation in the distance from the wall, the thickness of the layer, and the velocity



The **Flows in Conical Diffuser Channels** are represented by two-dimensional boundary-layer and one-dimensional core flows described by the equations of the new method.

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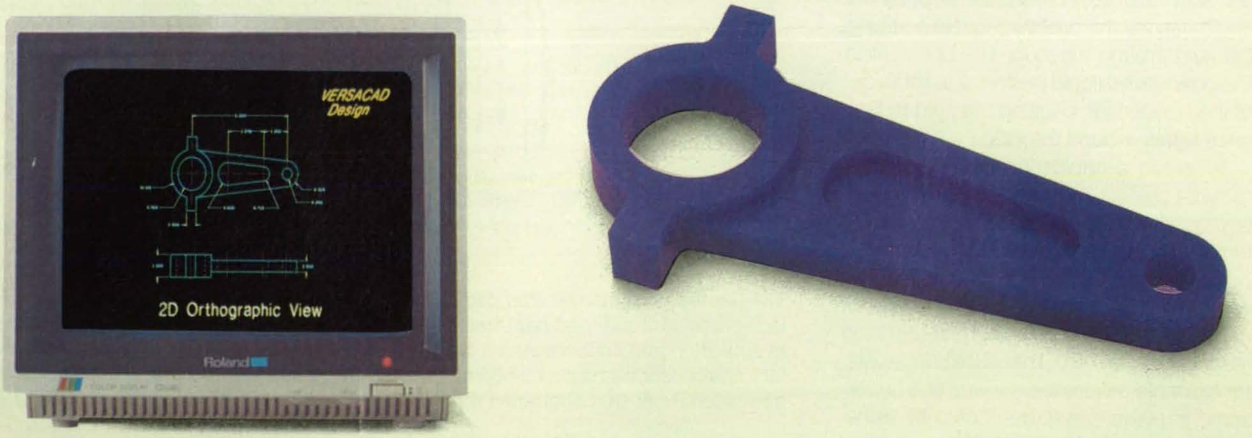

at the edge of the boundary layer, which is taken to be the free-stream velocity.

7. The flow in the core can be treated as though it were one-dimensional, in the sense that the two-dimensional equations of the conservation of momentum and mass can be reduced to one-dimensional equations in the coordinate along a streamline.

The equations of conservation of momentum and mass are integrated through the boundary layers, and some additional assumptions regarding the geometrical properties of the streamlines are invoked. Head's entrainment relation is introduced to find the perpendicular component of velocity at the edge of the boundary layer. The skin-friction coefficient is obtained from the Ludwig-Tillman relation. The variation of free-stream velocity is determined via the simple one-dimensional equation of continuity for the flow in the core. The set of equations is completed with the energy equation and the equation of state of the flow in the core, which are used to relate the static temperature, pressure, and density to the other quantities.

The foregoing constitute a set of simultaneous one-dimensional differential equations that are solved together to find the flow field. Because no iteration is involved, the solution is found rapidly — that is, the integration is performed in one pass along the channel. With some modifications and additional assumptions, the equations can also be solved for flow with merged boundary layers and no isentropic core ("fully developed" flow) and for separated flow.

The method has been applied to round and rectangular conical diffuser channels (see figure). The calculated pressure coefficients and other quantities of interest were in good agreement with experimental values in cases in which the analysis indicated no separation of flow. The pressure coefficients showed fair agreement in the separated regions.

This work was done by Lawrence F. Schumann of the U.S. Army Aviation Research and Technology Activity for **Lewis Research Center**. *Further information may be found in NASA TM-88928 [N87-15944], "A Method for Calculating Turbulent Boundary Layers and Losses in the Flow Channels of Turbomachines."*

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LEW-14705

Structurally-Tailorable, Nonlinear, Snap-Through Spring

An abrupt change in load/deflection response is controllable and predictable.

Langley Research Center, Hampton, Virginia

A structurally-tailorable, nonlinear, snap-through spring (STNSTS) exhibits a controllable and predictable abrupt change in load/deflection response and is based upon a known phenomenon of snap-through structural response. The STNSTS is composed of a pin-connected two-bar linkage as shown in Figure 1, which depicts combined tension/compression springs. As load is applied to the STNSTS, the stiffness is a function of the internal spring and the bending stiffness of the pin-connected bars. As the load increases, the bars deform laterally until they collapse and snap through (Figure 2).

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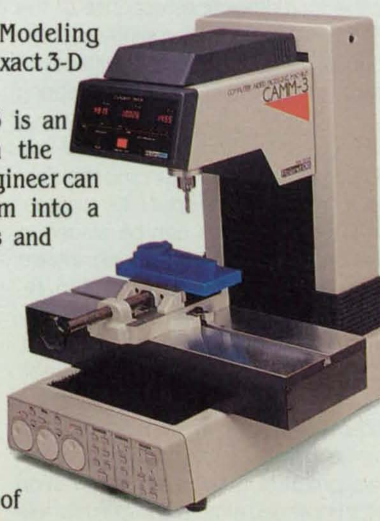

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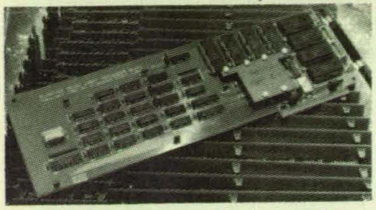

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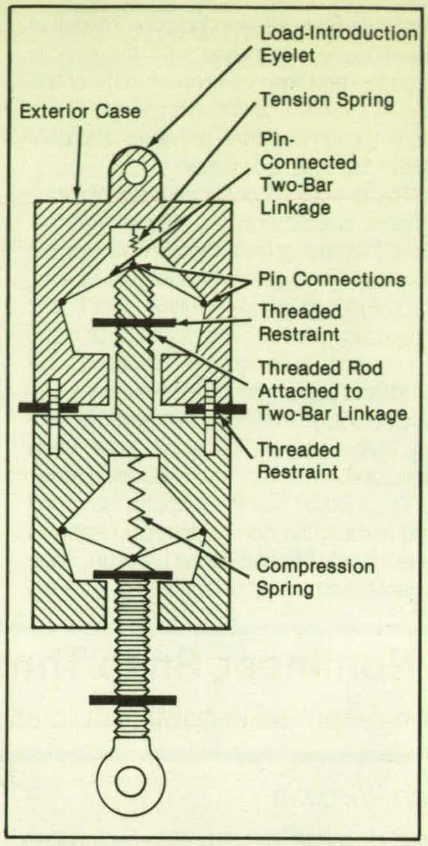

Figure 1. The **STNSTS Can Be Structurally Tailored** in both tension and compression configurations.

When the snap through occurs, a large deformation occurs as a result of a small increment of the applied load. After the snap through, the load/deflection response becomes a function of stiffness of the internal spring and the membrane stiffness of the bars. Additional stiffness can be provided by restraints in contact with the spring case. The restraints limit the deflection of the internal spring/two-bar linkage. Once the restraints make contact with the spring case, the load/deflection response of the STNSTS is a function of the stiffness of the internal spring, the membrane stiffness of the bars, and the stiffness of the spring case.

The load/deflection response of the STNSTS is tailorable by changing the size, stiffness, and orientation of its components. Multiple devices can be placed in parallel or series to produce an infinite number of different load/deflection responses. The STNSTS has potential application in passively-tailored rotor-blade flap, pitch, and lag response, to improve the aerodynamic performance and stability characteristics of rotors; in aerodynamically- and aeroelastically-tailored wing spars and ribs, to produce a tailored deformation state for improved effectiveness in maneuvering, aerodynamic performance, and stability characteristics; and in energy absorbers for automobile bumpers and aircraft landing gear.

This work was done by James H. Starnes, Jr., of **Langley Research Center** *and Gary L. Farley and Wayne R. Mantay of the U.S. Army Aerostructures Directorate. No further documentation is available.*

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, Langley Research Center [see page 14]. Refer to LAR-13729.

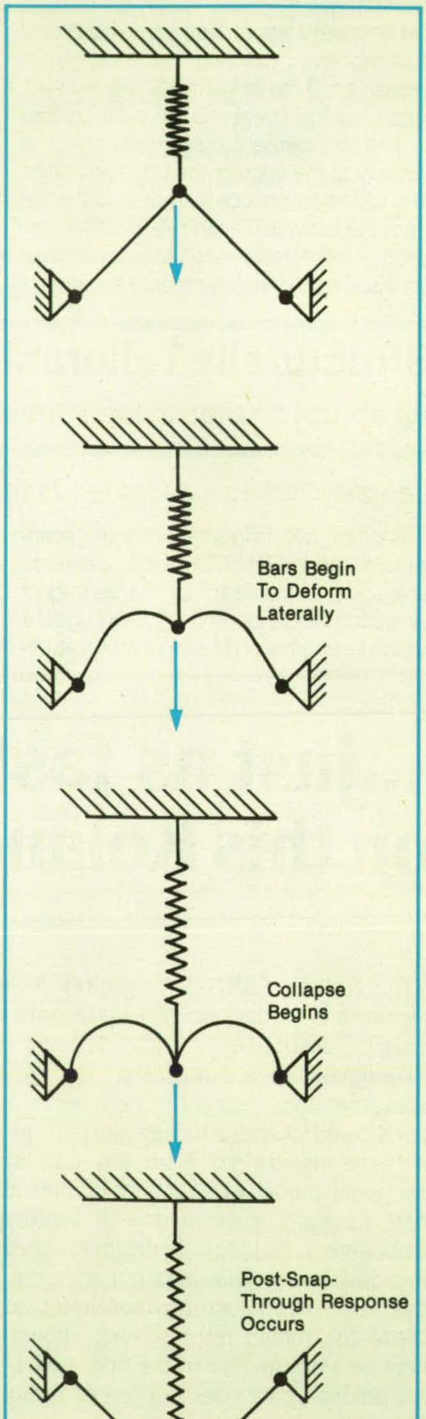

Figure 2. **Bars Deform and Collapse** to produce snap-through spring response.

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.

Thermal Stresses in Space-Shuttle Wing

Combined thermal deformations of wing-skin panel and the TPS would not tear the SIP layer.

A report presents an analysis of thermal stresses induced in the skin panel, the thermal-protection system (TPS), and the strain-isolation pad (SIP) of the Space Shuttle orbiter. The purpose of the analysis was to determine whether any part of the abovementioned structures would be overstressed and overdeformed under the reentry heating, assuming one TPS tile had been lost at the end of the reentry heating.

The wing-skin panel, which is reinforced by spanwise stringers of hat-shaped cross section, was represented with an equivalent plate of uniform effective thickness. The temperature distribution in the wing-skin panel was chosen to represent the likely cooling effect of the loss of one tile at the center of the panel at the end of the reentry heating. The temperature of the central square-shaped region of the panel was assumed to be 180 ° (82 °C), while the rest of the panel was assumed to be at 320 °F (160 °C).

The first problem was to determine whether the compressive stresses induced in the panel immediately outside the cooled region would be sufficient to cause skin buckling. The stresses in the panel were calculated by use of the NASA structural analysis (NASTRAN) computer program. The peak chordwise compressive stresses predicted by NASTRAN were 4960 lb/in.^{2} (34.2 MPa) and 2650 lb/in.^{2} (18.3 MPa), respectively, under free-edge and fixed-edge conditions. The critical buckling stress in the chordwise direction calculated from the classical buckling theory was 3612 lb/in.^{2} (24.9 MPa). Thus, if the actual edge condition is close to the free-edge condition, then the skin panel immediately outside the cool region may reach the elastic instability in the chordwise direction.

The next problem was to determine whether the thermal deflection of the skin panel could tear the SIP. The maximum chordwise compressive stress in the skin panel calculated by NASTRAN could produce a maximum deflection of 0.0246 in. (0.63 mm), which could induce peak tensile stress of 18.14 lb/in.^{2} (125 kPa) in the SIP. This stress level is considerably less than the tensile strength [40 lb/in.^{2} (276 kPa)] of the SIP. Thus, the SIP is unlikely to be torn.

Finally, thermal-stress analysis was performed on the TPS tile that was subject to the most severe temperature gradient during the reentry heating. The tensile stress induced in the TPS was found to be much less than the tensile strength of the TPS tile. For the worst case, that in which the skin-panel and the TPS tile deform in opposite directions, the combined deflections of the skin panel and the TPS tile could induce 33.72 lb/in.^{2} (232.5 kPa) tensile stress in the SIP. This is about 84 percent of the tensile strength of the SIP. Thus, the combined deformations of the TPS tile and the skin panel are unlikely to tear the SIP.

This work was done by William L. Ko and Jerald M. Jenkins of **Ames Research Center**. *Further information may be found in NASA TM-88276 [N87-23994], "Thermal Stress Analysis of Space Shuttle Orbiter Wing Skin Panel and Thermal Protection System."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-12139.

Reduced-Dynamic Technique for Determination of Orbits

Orbits are determined more accurately than in the dynamic or geometric method.

A report discusses the reduced-dynamic technique for the use of signals from satellites in the Global Positioning System (GPS) to determine the orbit of a satellite in a low orbit around the Earth. The reduced-dynamic technique is formed from a combination of the dynamic and geometric (nondynamic) tracking techniques, and it combines the advantages of both to increase the accuracy of the estimated orbit under conditions in which neither is clearly superior.

The simplest technique is geometric tracking by use of instantaneous measurements to four or more GPS satellites. This technique is completely free of errors in the assumed dynamics but is vulnerable to measurement noise, ephemeris error, and a factor called position dilution of precision,

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which magnifies the error where the observing geometry is poor. At best, the tracking accuracy approaches a few meters.

In dynamic tracking, the dynamics of the satellite are constrained, and noisy instantaneous measurements of the state (position or velocity or both) of the satellite taken during an interval of time are combined to reduce the measurement noise and to yield greater information concerning the state at a single instant of time. At the same time, the estimates of the orbits of the GPS satellites are also improved to reduce their contributions to the error of the estimated state of the satellite in question. The transition from the states of the satellites at the times of the measurements to the states at the time of interest is furnished by integration of the equations of motion, which are governed by the forces (dynamics) acting upon the satellites during the interval. Any mismodeling of these dynamics results in systematic errors in the state. These errors tend to grow as the data arc length increases.

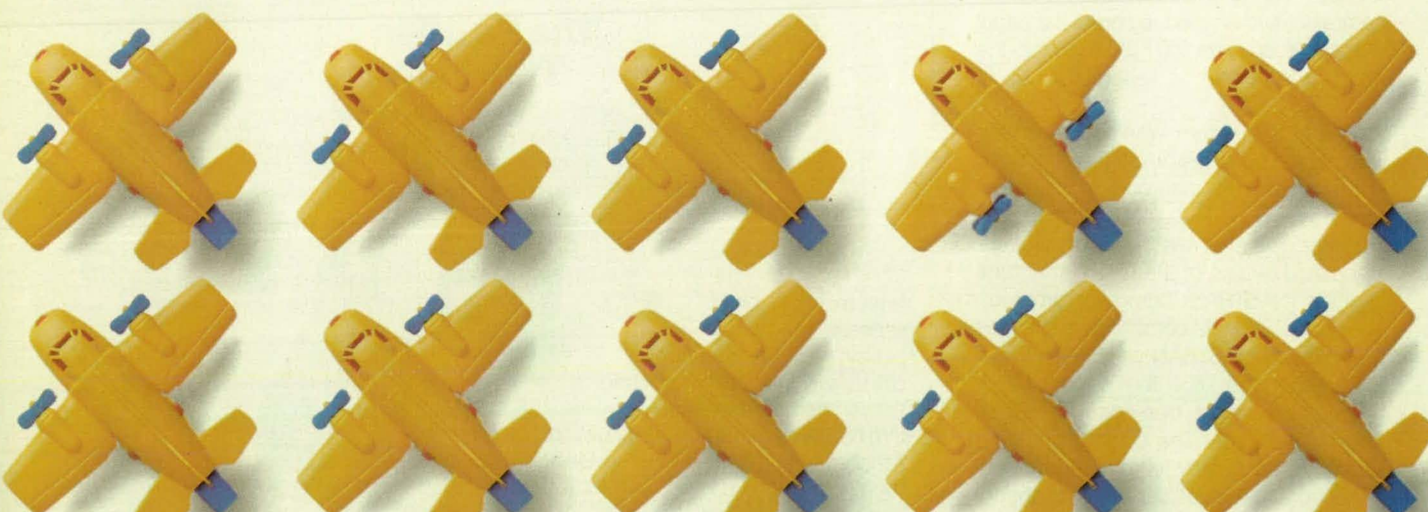
In nondynamic tracking, the instantaneous user satellite positions are still determined by differential GPS pseudorange measurements; however, the transition between positions at different times is furnished by the satellite positional change inferred from continuous differential GPS carrier phase measurements. Because carrier phase can be tracked with extremely high accuracy, very accurate state transition can be inferred from carrier phase. This approach is completely free from satellite dynamic errors. In exchange, however, it is highly sensitive to weak observing geometry.

Nondynamic tracking discards orbit dynamic models and the associated information entirely. This is one of the principal attractions of the nondynamic technique. Not only is sensitivity to model errors eliminated, but the complexity of the solution process is greatly reduced. Nevertheless, it is reasonable that if dynamic and nondynamic tracking are good separately, then an optimal combination of the two should be even better. In situations in which the geometry is good and the dynamics are poorly known, the small additional improvement to be expected by adding in dynamics might not justify the greatly increased complexity. However, where the geometry is poor and the dynamic models are reasonably good, the added dynamic information could lead to a substantial improvement. In the new technique, both dynamic and geometric information is used to propagate the state, with appropriate weight given to each method.

The reduced-dynamic technique can be described mathematically in terms of a Kalman sequential-filter formulation. This involves two steps: a time update, which makes use of a state-transition model to propagate the estimate of the state and the covariance of the state of the satellite from one batch of data to the next, and a measurement update, which incorporates a new batch of measurements. These two steps alternate until all batches of data are incorporated.

The weight on the dynamic information is controlled by adjusting a set of three process-noise parameters that represent a fictitious three-dimensional force on the satellite in question. The relative weight of the dynamics is varied by selecting different values for the a priori uncertainty σ_o, the steady-state uncertainty σ, and the correlation time τ for these process-noise parameters. An increase in τ and a decrease in σ_o and σ increases the weight on the dynamic information. When $\tau \to \infty$, $\sigma \to 0$, and $\sigma_o \to 0$, the technique reduces to conventional dynamic tracking; when $\tau \to 0$, $\sigma \to \infty$, and $\sigma_o \to \infty$, it becomes nondynamic tracking. It follows that an optimally-tuned reduced-dynamic solution must always be as good as or better than both the purely dynamic and the purely nondynamic solutions.

To derive the full benefit of the reduced-dynamic technique, it is necessary to give the optimum weight to the dynamic model. The weight can be predetermined through



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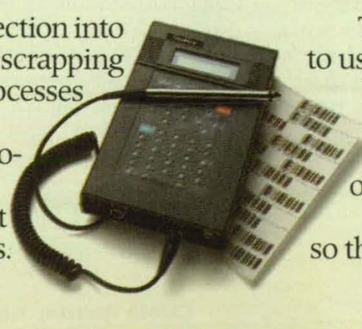

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a covariance analysis that uses a realistic model of the dynamic error. However, the performance appears to be insensitive to the relative weighting between the two types of information as long as it is not far from optimum. When the actual level of dynamic-model error is uncertain, an additional deweighting of the dynamic model is recommended. Such biased weighting would prevent an inordinately large error from arising due to misjudgment of the error in the dynamic model.

This work was done by Sien-Chong Wu, Thomas P. Yunck, and Catherine L. Thornton of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Reduced-Dynamic Technique for Precise Orbit Determination of Low Earth Satellites," Circle 126 on the TSP Request Card.*
NPO-17386

Quality Evaluation by Acousto-Ultrasonic Testing of Composites

This promising nondestructive-testing method is based on ultrasonic simulation of stress waves.

A report reviews acousto-ultrasonic technology for nondestructive testing. The report discusses principles, suggests advanced signal-analysis schemes for development, and presents potential applications.

Acousto-ultrasonics has been applied principally to assess defects in laminated and filament-wound fiber-reinforced composite materials. The technique can be used to determine variations in such properties as tensile, shear, and flexural strengths and reductions in strength and toughness caused by defects. It can be used to evaluate states of cure, porosities, orientation of fibers, volume fractions of fibers, bonding between fibers and matrices, and qualities of interlaminar bonds.

The term "acousto-ultrasonics" is a contraction for "acoustic-emission simulation with ultrasonic sources." Conventional acoustic-emission testing depends on loading a part to excite spontaneous stress waves like those that accompany plastic deformations and the growth of cracks. Acousto-ultrasonics differs mainly in that the ultrasonic waves are benign and are generated externally by pulsed sources (usually piezotransducers).

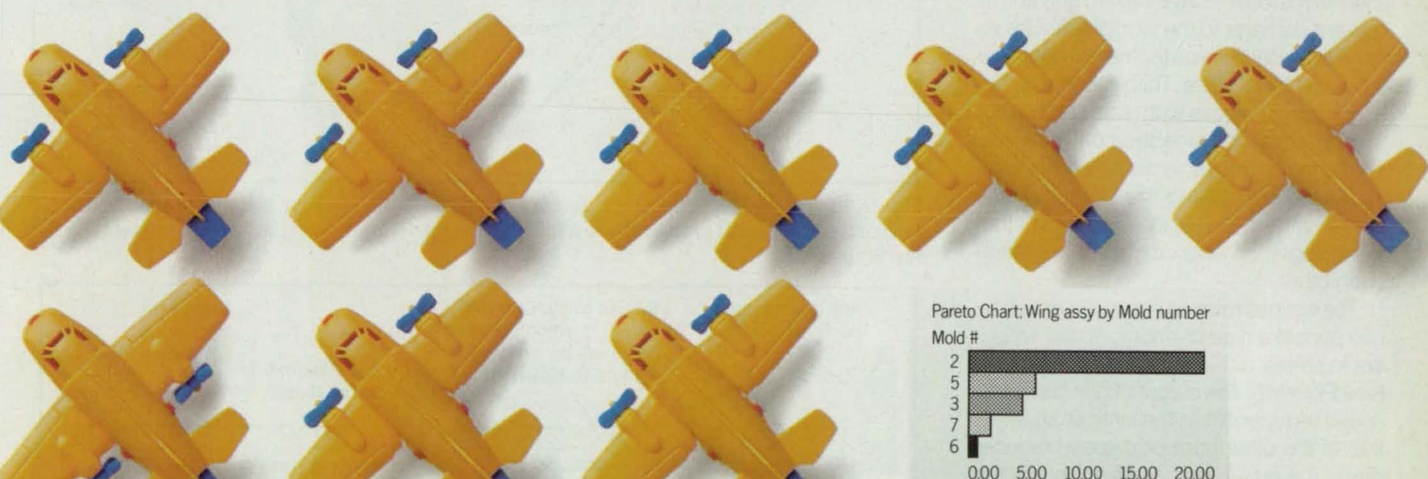
In a typical apparatus, a transmitting probe and a receiving probe are placed a specified distance apart on the same side of the part under test. The sending-and-receiving pair can be moved about as a unit to scan the part. Signal-processing instrumentation analyzes the received sound to generate a map of variations in the properties of the material.

The sensitivity of acousto-ultrasonics has already been demonstrated experimentally. The technology has been used to detect and quantify subtle but significant variations in strength and resistance to fracture of fiber-reinforced composites. This achievement is remarkable because it was accomplished with relatively-unsophisticated signal-processing and signal-analysis procedures.

Although acousto-ultrasonic technology has been used on polymer-matrix composites, it is applicable to such other composite materials as metals reinforced by fibers and ceramic-matrix composites. The use of acousto-ultrasonics should be considered whenever it is necessary to quantify damage or degradation of properties after composites have been exposed to hostile environments.

This work was done by Alex Vary of **Lewis Research Center**. *Further information may be found in NASA TM-89843 [N87-20562], "The Acousto-Ultrasonic Approach."*

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-14709



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Machinery

Robot Hand Grips Cylinders Securely

Jaws and linkage accommodate various sizes.

Lyndon B. Johnson Space Center, Houston, Texas

A robot hand includes two pairs of parallel jaws that can grasp rods, pipes, tubes, struts, and other long, heavy cylindrical objects. The hand features a compact rotary drive and a butterfly configuration that simplify the approach and gripping maneuvers of the robot.

Parallelogram linkages maintain the alignment of each jaw with the other jaws. One bar of each linkage is connected to one of two concentric, counterrotating shafts; the rotation of these shafts moves the jaws in each pair toward or away from each other to grasp or release the workpiece (see Figure 1).

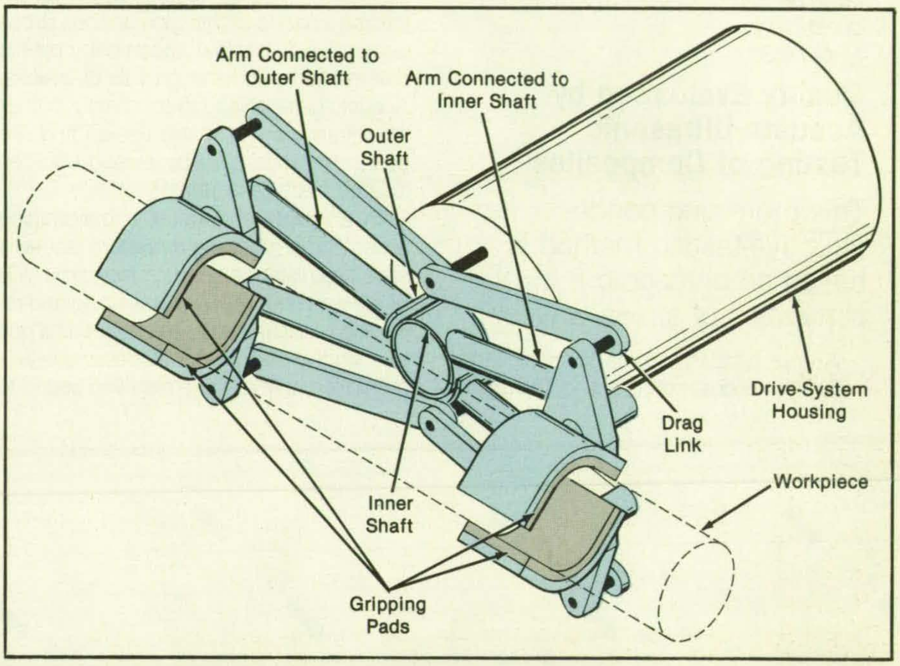


Figure 1. **Pairs of Jaws on Parallelogram Linkages** are actuated by counterrotating shafts. Part of the outer shaft is cut away to allow movement of the arms of the linkage connected to the inner shaft.

Each jaw includes a rigid gripping pad lined with rubber to give it a firm grip and to prevent damage to the workpiece. The inner cylindrical surface (corner) of each jaw tapers off to flat sides. This enables the jaw to grasp workpieces with diameters larger than or equal to twice the corner radius. The range of graspable diameters could be increased by making the corner radius very small and the flat sides as fingers that mesh together when the jaws approach each other.

The counterrotating shafts are driven by two pancake-type harmonic speed reducers in series, actuated by the same motor (see Figure 2). The output of one harmonic speed reducer drives the inner shaft, while that of the other harmonic speed reducer drives the outer shaft. Slots are cut in the outer shaft so that the stationary portions of the harmonic speed reducers can be fixed to the housing. It is possible to do this because the outer shaft does not have to rotate more than 50°.

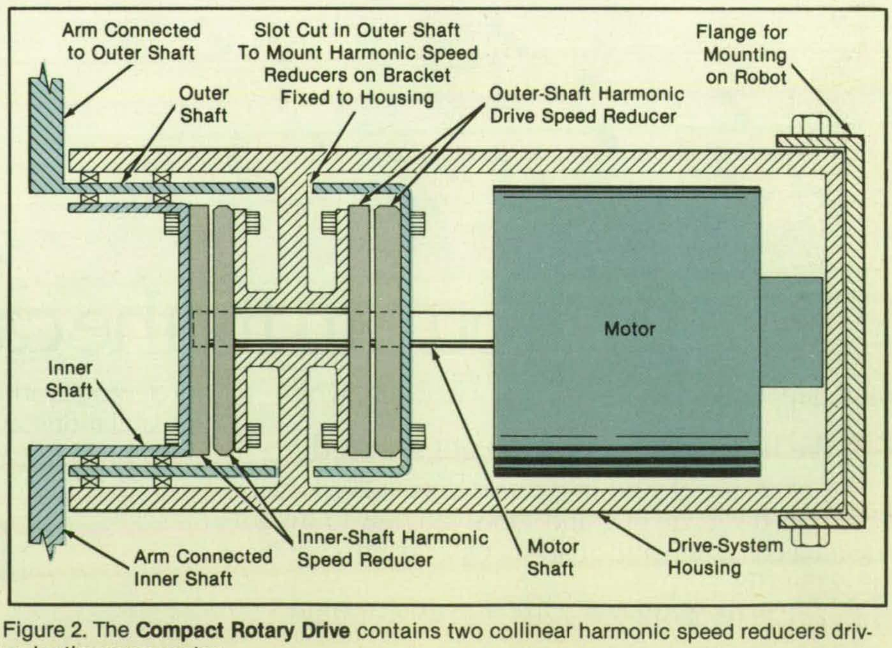


Figure 2. The **Compact Rotary Drive** contains two collinear harmonic speed reducers driven by the same motor.

This work was done by George F. Parma of **Johnson Space Center**. *For further information, Circle 82 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-21365.

Energy-Efficient, Continuous-Flow Ash Lockhopper

Pressure balance in the control gas prevents the loss of reactor gas.

NASA's Jet Propulsion Laboratory, Pasadena, California

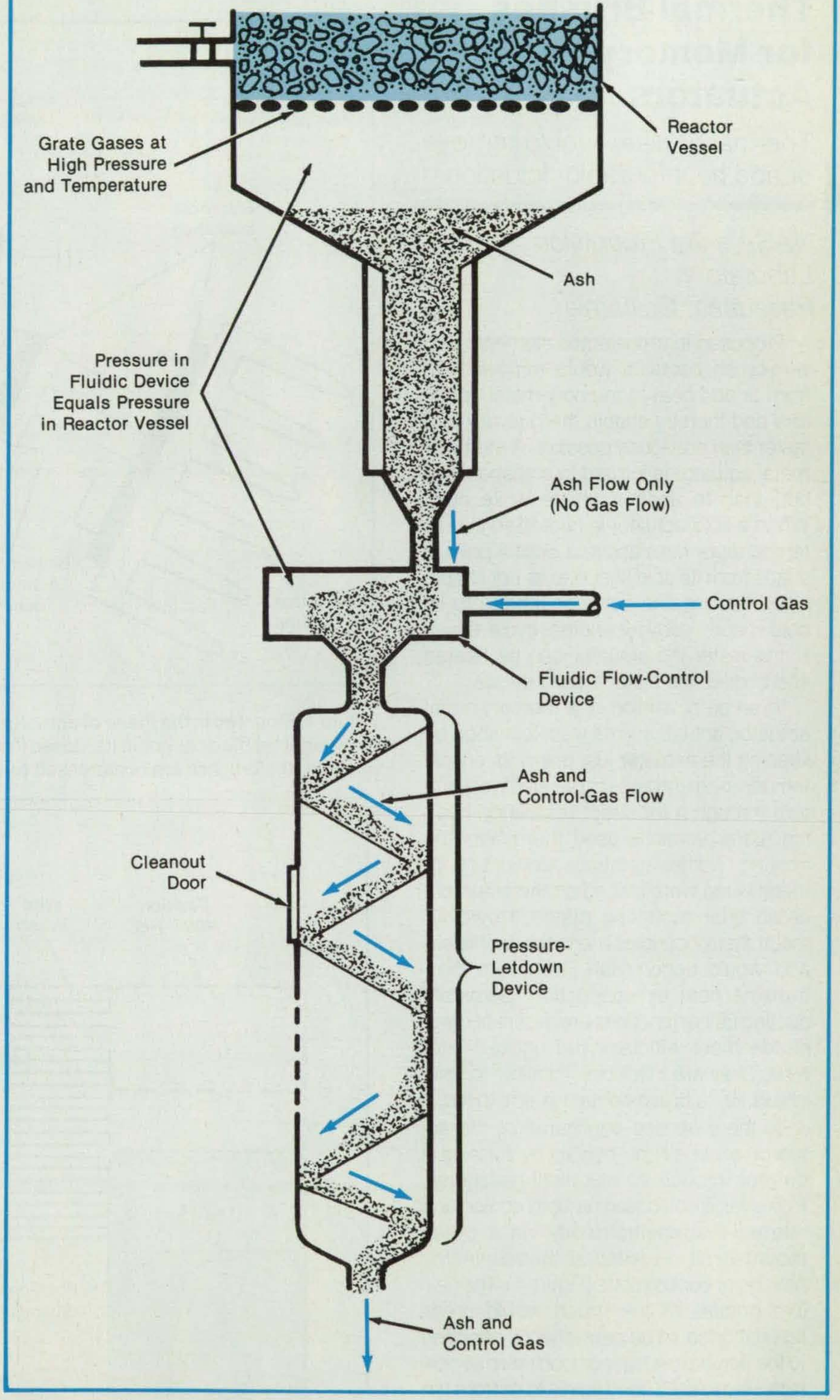
The energy efficiency of a continuous-flow ash lockhopper (see figure) has been increased by preventing hot gases from flowing out of a reactor vessel through the ash-hopper outlet and carrying away heat energy. Stopping the loss of reactor gases can also be important for reasons other than energy efficiency: the desired reaction product may be a gas, or the gases produced may be toxic or may need to be contained to prevent pollution. The improved lockhopper should also enable the reactor to attain the highest possible product yield with continuous processing while permitting a controllable, continuous flow of ash.

The principal components of the lockhopper have been discussed in the following NASA Tech Briefs: "Pressure-Letdown Plates for Coal Gasifiers" (NPO-15965), page 355, Vol. 8, No. 3 and "Variable Control Part for Fluidic Control Device" (NPO-16603), page 114, Vol. 10, No. 2. The lockhopper was designed to convert reactor solids removal from batch to continuous flow; it should also be applicable in fluidized-bed reactor systems and in the separation of dust or other solids from gases.

In the improved lockhopper, the loss of the reactor gas is prevented by equalization of the pressure of the control gas injected into the fluidic flow-control device with the pressure in the reactor vessel. This eliminates the pressure gradient at the ash outlet of the reactor. However, the flow of ash continues because of gravity. In scale-model tests that used sand to simulate ash, the continuous flow of the sand was obtained without loss of reactor pressure.

In the original lockhopper, a quasi-porous-plug pressure-letdown device greatly reduced, but did not eliminate, the loss of gas and the concomitant loss of heat from the reactor vessel. In the improved lockhopper, the pressure-letdown device serves to reduce the flow of control gas required to achieve the equalization of pressures.

The original lockhopper used steam as the control gas, but in some processes the introduction of steam into the reactor vessel is not permissible or not desirable. The steam was generated by injecting water into the ash-hopper outlet of the reactor. This quench water also caused large cinders to disintegrate into fine ash that could pass through the fluidic control and pressure-letdown devices. With the improved lockhopper, moving grates or other conventional mechanical methods would be used to break up cinders when necessary.



In the **Improved Continuous-Flow Ash Lockhopper**, the pressure-driven loss of hot gas from the reactor vessel through the ash-hopper outlet is prevented by using the control gas in the fluidic flow-control device to equalize the pressure in the reactor vesel.

In many applications the control gas may be compressed air; in others, inert gases or other specific gases may be required. The control gas eventually leaves the system along with the ash, but a collecting chamber with scavenging compressor pumps can be used to recover it for recirculation.

This work was done by Earl R. Collins, Jr. and Jerry W. Suitor of Caltech **NASA's Jet Propulsion Laboratory** *and David Dubis of the Morgantown Energy Technology Center of the Department of Energy. For further information, Circle 92 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's Resident Office-JPL [see page 14]. Refer to NPO-16985.

Thermal Brushes for Memory-Metal Actuators

Thermal brushes would remove or add heat for rapid actuation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Proposed thermoelectric elements with wire-brush contacts would remove heat from or add heat to memory-metal actuators and thereby enable them to respond faster than previously possible. A memory-metal actuator is formed to a shape while hot, then to another shape while cold. When a cold actuator is heated so that its temperature rises above a critical point, it snaps from its cold shape to its hot shape. Upon cooling, the actuator returns to its cold shape, ready for another cycle. Clearly, the faster the actuator can be heated and cooled, the faster it can operate.

In an early version of a memory-metal actuator, actuation time was kept short by keeping the actuator just below its critical temperature and passing an electrical current through it for direct resistance heating. Later versions used thermoelectric cooling. Peltier junctions consisting of metal wires were placed on the actuators or on their mounting plates. However, metal thermocouples are highly inefficient and would accomplish little more than transmit heat by conduction. Semiconducting Peltier junctions are orders of magnitude more efficient, but unlike metal wires, they are inflexible. To allow for this inflexibility, a brush contact is employed.

In the proposed configuration, the actuator could still be heated by passing a current through an electrical resistance. However, it could also be both cooled and heated thermoelectrically via a brush mounted on an external thermoelectric heating or cooling plate (Figure 1). The flexible bristles of the brush would press against or could be permanently attached to the actuator, ensuring good thermal contact. Heat would flow rapidly to or from the actuator metal, through the bristles and heating/cooling plate, from or to a heat sink.

Depending on the heating and cooling needs of the device, additional brushes and cooling elements could be placed along the circumference of the actuator.

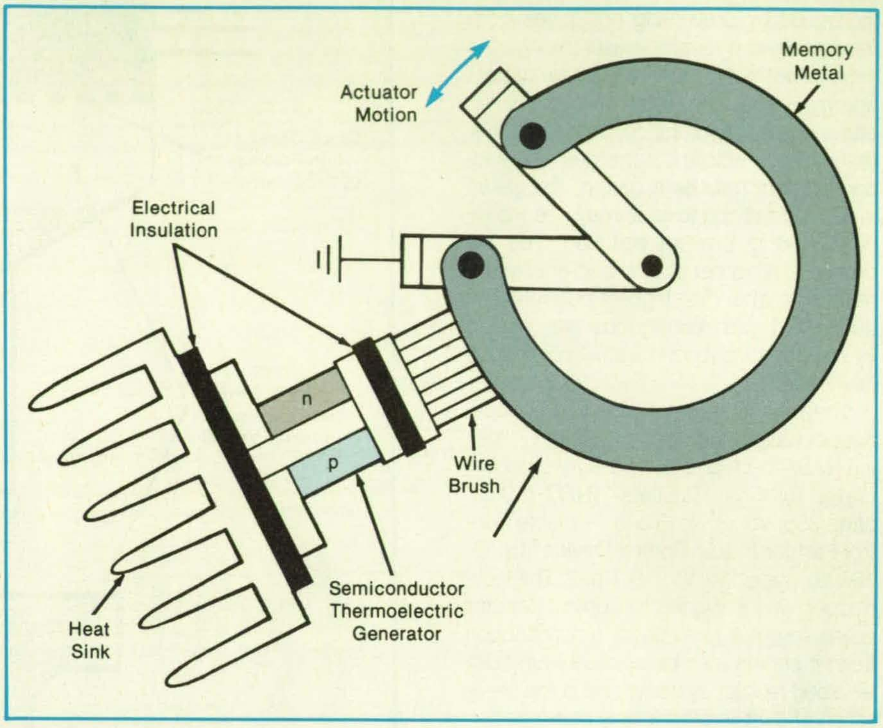


Figure 1. **Mounted in the Plane** of actuator motion, bristles of a metal brush press lightly but firmly against the actuator in its closed (hot) position. When the actuator expands to its cold position, the brushes are compressed further.

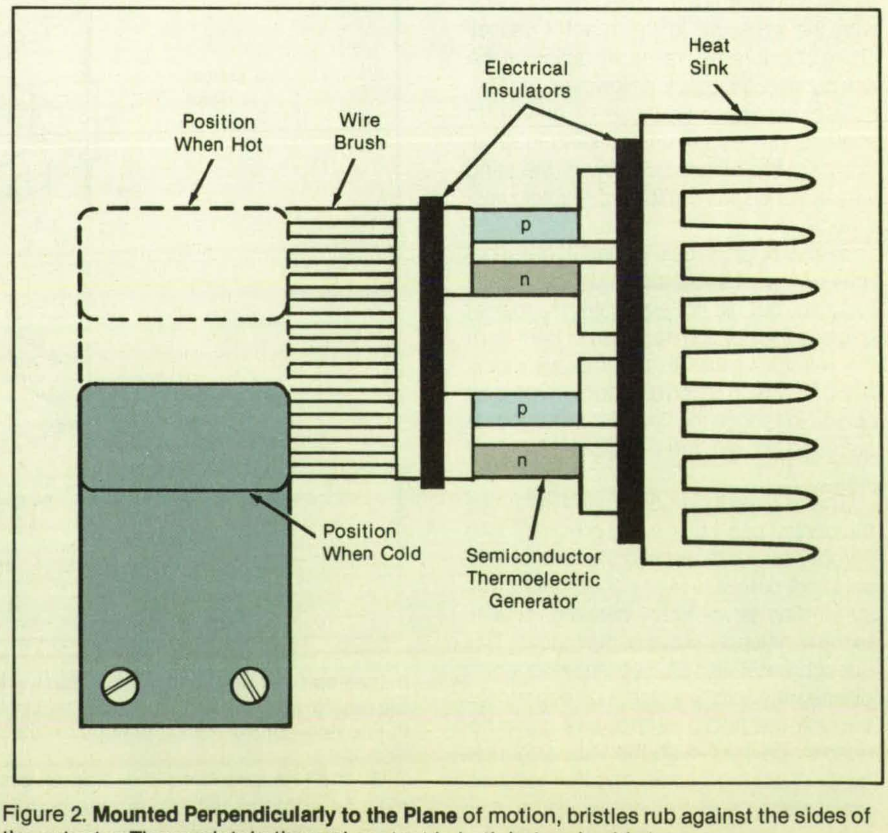


Figure 2. **Mounted Perpendicularly to the Plane** of motion, bristles rub against the sides of the actuator. They maintain thermal contact in both hot and cold states.

The bristles should bend slightly when they are in contact with the contracted (hot) actuator; they can then easily bend further when the actuator expands. The elements should not be placed near the moving end of the actuator, where they would interfere with the displacement.

The bristles must not be too long or else their thermal resistance will be excessive. Therefore, if they must accommodate a large swing of the actuator, another brush orientation should be considered. The brushes can be mounted perpendicularly to the plane of motion so that they wipe the sides of the actuators as they expand and contract (see Figure 2). In this position, the brushes add frictional resistance to the motion of the actuator; whereas in the in-plane position, they add bending resistance. In either case, the resistance is small compared with the density of the force generated by the memory metal — about 6×10^4 psi (400 MPa) for Nitinol (or equivalent) alloy.

This work was done by Charles Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 102 on the TSP Request Card.*
NPO-17068

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.

Ceramic Bearings for Gas-Turbine Engines

Materials and methods of design have improved over the years.

A report reviews data from three decades of research on bearings that contain rolling elements and possibly other components made of ceramics. Ceramic bearings are attractive for use in gas-turbine engines because ceramics generally retain their strengths and resistances to corrosion over a range of temperatures much greater than that of typical steels used in rolling-element bearings. Furthermore, because ceramics have mass densities lower than those of steels, they might be used to reduce centrifugally induced stresses in the outer races of high-speed bearings.

The text begins with a brief description of historical developments in the field. This is followed by a discussion of the effect of contact stress on the fatigue life of a rolling element. The discussion is supplemented by figures and a table that give data on the fatigue lives of rolling elements made of various materials.

The next topic is the effect of elastic and thermal properties. Equations for stresses, contact radii, and fatigue lives are presented. A table gives typical physical properties of ceramic and steel bearing materials. Another table gives the lives and dynamic-load capacities, relative to those of all-steel bearings, of bearings made with steel races and rolling elements of crystallized-glass ceramic, alumina, silicon carbide, titanium carbide bonded with nickel, silicon nitride, or steel.

The report then analyzes data on the effects of temperature and speed on fatigue lives for several materials and operating conditions. This is followed by a discussion of the related topic of the generation of heat in bearings, with consideration of the effects of bearing materials, lubrication, speeds, and loads.

Preliminary research on unlubricated bearings and bearings lubricated by solid films is reported. There is a brief description of the advantages and disadvantages of several schemes for mounting ceramic-rolling-element bearings. Recent developments in the manufacture of silicon nitride rolling elements are recounted.

The report presents several conclusions, including the following:

- Of the ceramic materials studied, silicon nitride yields the rolling elements with the longest fatigue lives. However, the dynamic-load capacity of an all-silicon nitride bearing is only 5 to 12 percent that of an all-steel bearing of the same size and shape.
- A bearing made of ceramic rolling elements and a steel race cannot be expected to last as long as does an all-steel bearing if the modulus of elasticity of the ceramic exceeds that of the steel (as it usually does).
- Lubrication of ceramic rolling elements appears to be necessary to prevent failure at high temperatures.
- The contemplated use of all-ceramic bearings in turbomachinery will impose special requirements on design and mounting. Optimum designs have yet to be developed.

This work was done by Erwin V. Zaretsky of **Lewis Research Center**. *Further information may be found in NASA TM-100288 [N88-18007], "Ceramic Bearings for Use in Gas Turbine Engines."*

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.
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Fabrication Technology

Strong, Low-Resistance Bonds for AMTEC Electrodes

The heat of an operating cell helps form the contacts.

NASA's Jet Propulsion Laboratory, Pasadena, California

Strong, low-electrical-resistance contacts between the elements of a current-collection grid in an alkali-metal thermoelectric converter (AMTEC) cell are obtained by simple in-place thermocompression bonding. The bonds are formed between the porous electrode of molybdenum film, the nickel or cobalt strips that overlie the film, and the molybdenum tie wires that run at right angles to the strips.

The elements are assembled on a sodium β'' alumina ceramic substrate. When the assembly is exposed to the temperature of an operating AMTEC cell, typically in excess of 1,000 K, the elements diffuse and bond together at their junctions under the combination of heat and pressure created by the differing coefficients of thermal expansions of the materials. The contact between the nickel grid and the molybdenum current lead is strong but contributes resistance of less than 10 milliohms for a 1-cm^2 electrode. The contact between the nickel grid and the porous electrode is also quite strong but contributes a higher resistance, approximately 100 milliohms for a 1-cm^2 electrode, depending on the composition and morphology of the electrode. The bonding method also works on films of tungsten or tungsten/platinum.

This work was done by Roger M. Williams, Bob L. Wheeler, Barbara Jeffries-Nakamura, C. Perry Bankston, Terry Cole, and Maria Loveland of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 5 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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Refer to NPO-17161, volume and number of this NASA Tech Briefs issue, and the page number.

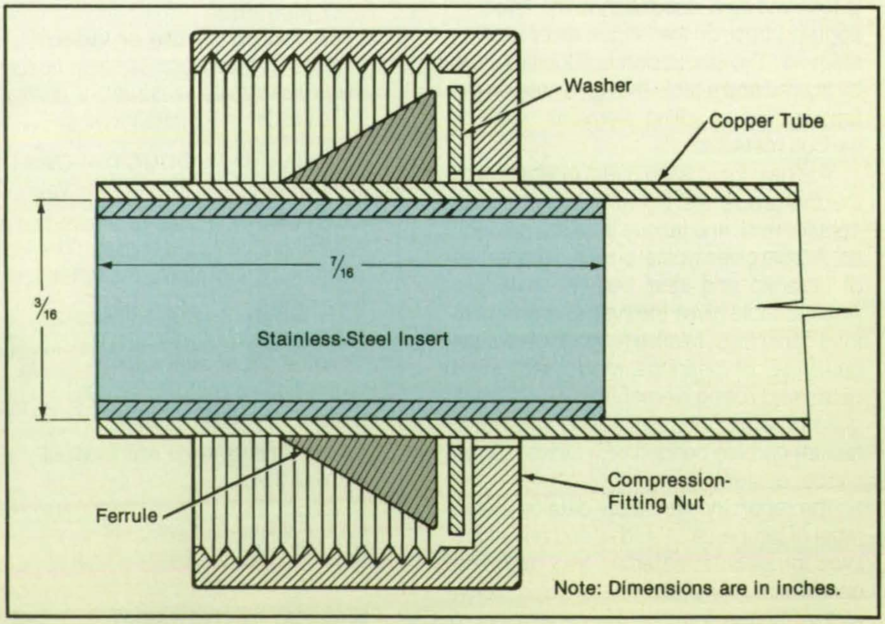
Improved Vacuum-Tight Connector

A simple reinforcing tube increases service life and improves the seal.

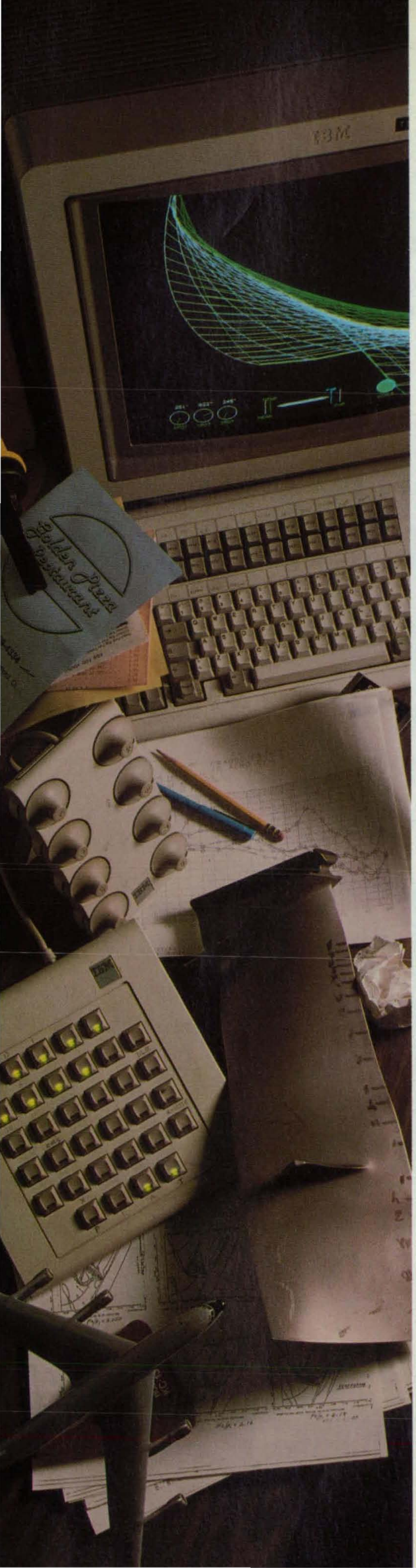
Lewis Research Center, Cleveland, Ohio

Copper cooling lines used in a vacuum must be connected with fittings that not only are easily installed or replaced but also remain vacuum tight at pressures in the range of 1×10^{-9} torr (about 10^{-7} Pa) and temperatures in excess of 250 °C. Standard stainless-steel Swagelok (or equivalent) fittings have been used to make these connections, but the high temperatures to which they were subjected invariably caused leaks, which necessitated the shutdown of the system for maintenance. The repair of a fitting involved the replacement and installation of a new sealing ferrule along with a corresponding shortening of the copper line. Several such repairs would eventually make it necessary to replace a line with a new one of sufficient length.

One method to eliminate this problem, as shown in the figure, is to place a special stainless-steel tube insert within the copper line where the fitting is attached. This insert provides a nondeformable backup wall that supports the copper material



The **Short Stainless-Steel Tube** is inserted in the copper tube to reinforce it against compression, thereby preventing leaks due to thermal distortion or to collapse under the squeeze of the ferrule in the compression fitting.



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against the ferrule. This insert not only prevents the copper from moving inward under the squeeze of the ferrule but also prevents thermal distortion of the copper from opening a leak. The insert enables the sealing ferrule to bite more deeply into the copper and thereby produces a vacuum seal similar in principle to the commonly-used Conflat (or equivalent) flange seal.

Several test specimens of this improved connector have been constructed, tested, and evaluated. The fittings have not only operated successfully at the required operating conditions of vacuum and temperature but have also consistently demonstrated high reliability after having been loosened and tightened many times.

This work was done by Frank Rudin of **Lewis Research Center**. *No further documentation is available.*
LEW-14720

Electrostatic Spraying With Conductive Liquids

Thin, uniform polymer coatings can be applied in a water base normally impossible to charge.

Lyndon B. Johnson Space Center, Houston, Texas

An electrostatic sprayer has been modified so that it can apply coatings suspended or dissolved in electrically conductive liquids. The sprayer was developed to apply a water-base polyurethane coating to a woven, shaped polyester fabric. The coating provides a pressure seal for the fabric, which is part of a spacesuit. The sprayer may also be useful for applying waterproof, decorative, or protective coatings to fabrics for use on Earth.

Ordinarily, such a sprayer cannot handle water or other conductive liquids because the tip of the nozzle electrode tends to short-circuit; it cannot then impart a charge to the particles in the atomized liquid. In the modified sprayer, the nozzle and gun are constructed of nonconductive molded plastic. The liquid passageway is made long enough that electrical leakage through it is low. The coaxial hose for the liquid is built of a polytetrafluoroethylene tube, an insulating sleeve, and a polyurethane jacket.

In addition, the sprayer is provided with an insulated seal at the gun-to-hose connection, a nonconductive airhose, a pressure tank electrically isolated from ground, and a special nozzle electrode. The supply of atomizing air is reduced so that particle momentum will be controlled by the electrostatic field more effectively.

A high-voltage cable is connected to the nozzle electrode in the spray head. The polyurethane/water mixture passes from a pressurized pot through the coaxial hose to the nozzle. There it is atomized by the air supply and charged by the negative nozzle electrode so that it emerges from the gun as a spray of uniformly dispersed negative particles. A nozzle voltage of more than 30 kV is needed.

The fabric is not conductive enough to act as a positive electrode. It is therefore placed on a metal plate shaped to conform with the fabric. The electrostatic field passes directly through the thin fabric, setting up a force field perpendicular to the surface of the grounded plate. The fabric interstices thus become thoroughly filled, since the charged particles try to penetrate the fabric. Even irregularly shaped surfaces become smoothly and uniformly coated.

As a precaution, the fabric surface should be made thoroughly clean, as should the atmosphere in which the spraying process is carried out. Otherwise, dirt particles on the fabric will align with the force field and stand upright, creating a flocked surface.

This work was done by Joseph J. Kosmo and Frederic S. Dawn of **Johnson Space Center** *and Robert E. Erlandson and Loren E. Atkins of Albany International Research Co. For further information, Circle 85 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the Albany International Research Co. Inquiries concerning licenses for its commercial development should be addressed to

Albany International Research Co.
1000 Providence Highway
Dedham MA 02026

Refer to MSC-21067, volume and number of this NASA Tech Briefs *issue, and the page number.*

Differential Curing in Fiber/Resin Laminates

A modified layup schedule should counteract the tendency toward delamination.

Lyndon B. Johnson Space Center, Houston, Texas

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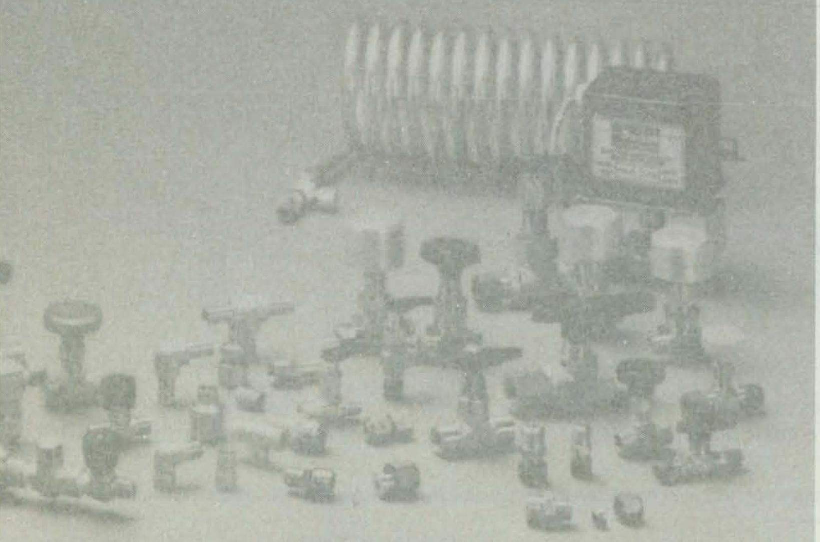

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FluidConnectors

A proposed differential-curing technique should help to prevent the entrapment of volatile materials during the manufacturing of fiber/resin laminates. The volatiles are released during the cure of the resin. It is necessary to remove them because they give rise to voids and delaminations.

In the conventional (non-differential-curing) manufacturing process, layers of woven fibers, all impregnated by the same thermosetting resin (prepregs), are stacked on a mold, then covered with a release material and a bleeder cloth. The entire layup is then enclosed in a vacuum bag and heated in an oven or autoclave to cure the resin. The vacuum removes the volatiles that diffuse out to the surface of the laminate.

The rate of curing of the resin increases with the temperature. Because the heat of the oven or autoclave is conducted into the curing laminate through the bag and the mold, the outer plies of the laminate are initially hotter, and therefore, can cure before the middle plies do. If the outer plies on the bag side cure first, they can trap the volatiles inside.

The improved manufacturing process would resemble the conventional process, except that prepregs that have been partially cured would be laid on the mold in a sequence in which the degree of partial cure decreases from the mold side to the bag side. The degree of partial cure of each layer at the time of layup can be selected by controlling the storage and partial-curing temperatures of the prepreg according to an Arrhenius equation for the rate of gel of the resin as a function of temperature and time from the moment of mixing. The differential advancement of the cure in the layers would be made large enough to offset the effect of advance bag-side heating in the oven or autoclave. Thus, the inner layers would cure before the outer layers, allowing the volatiles to escape.

In an alternative version of the process, the prepregs would be uncured or partially cured to the same degree and kept in cold storage. One prepreg would be taken from storage, placed on the mold, and heated to a moderate temperature for a short time to obtain a partial cure. Another prepreg

Circle Reader Action No. 558

would then be taken from storage, placed on the first prepreg, and the resulting layup heated again to cure the first layer further and begin the cure of the second layer. This process would be repeated until all the layers are in place. The laminate would then be vacuum-bagged and autoclaved to complete the cure.

This work was done by Charles N. Webster of LTV Missles and Electronics Group for **Johnson Space Center**. *For further information, Circle 109 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 14]. Refer to MSC-21376.

Attaching Precise Mirrors to Lightweight Supports

Mirrors would be formed on optical masters and glued in place.

NASA's Jet Propulsion Laboratory, Pasadena, California

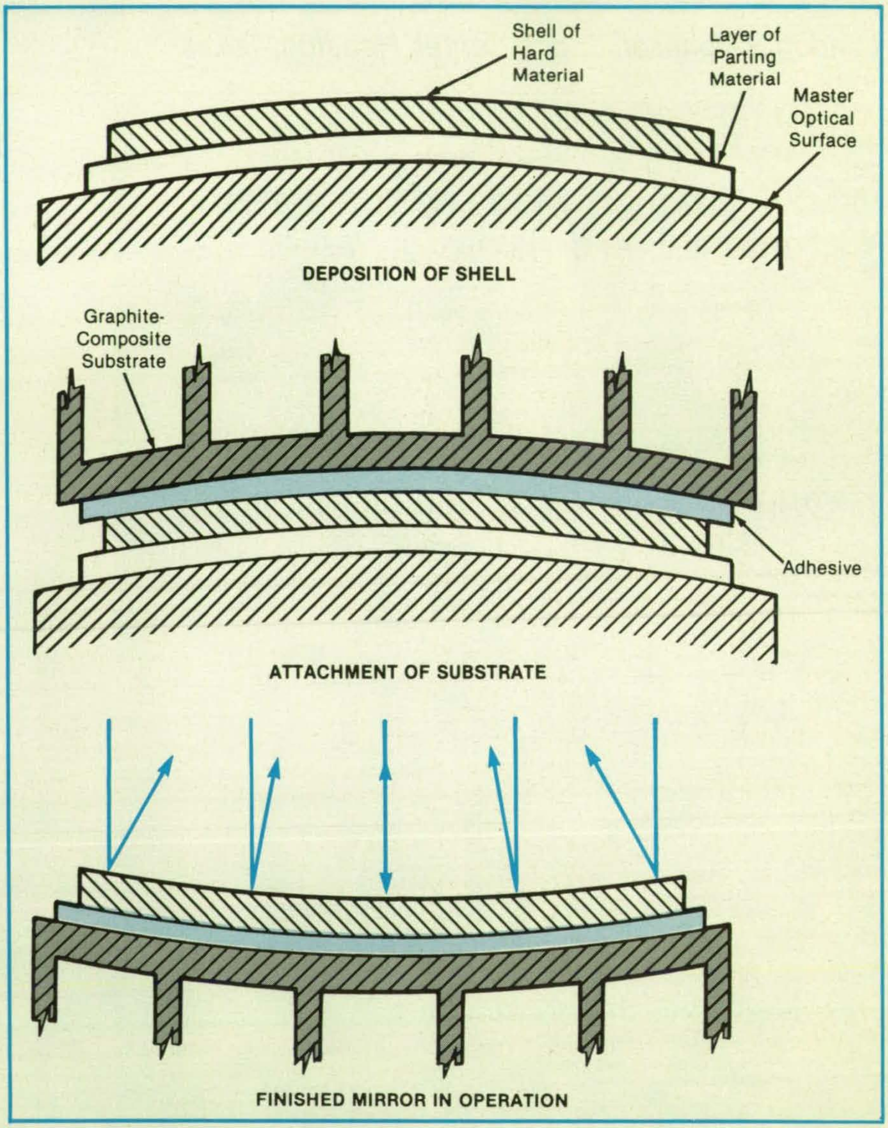
A technique has been proposed to form precise mirror surfaces on lightweight, rigid, imprecise graphite-composite substrates. The technique should enable the fabrication of lightweight mirrors of high surface finish suitable for use at short wavelengths: Heretofore, the irreducible small-scale roughness of the surfaces due to the structures of composite materials inhibited the use of composite mirrors at short wavelengths.

The technique (see figure) resembles that used to make lightweight replica mirrors and gratings. A layer of parting material is deposited on a master optical surface of the precise desired shape. This parting layer must be very thin to minimize degradation of the replica.

By ion-assisted evaporation or another established method, a shell of mirror or mirror-supporting material is deposited on the parting layer. The shell could be made of SiO_2, SiN, HfN, or other hard material. The thickness of the shell is made large enough — typically between a few microns and 1 mm — to give the shell significant rigidity of its own and to withstand handling and abrasion.

Next, a layer of adhesive much thinner than the shell is used to attach the mirror shell to a graphite-composite substrate, the surface of which approximates the desired mirror surface. When the adhesive has cured, the substrate and shell are separated from the master at the parting layer. The resulting mirror has nearly the high optical quality of the master.

This work was done by Aden B. Meinel and Marjorie P. Meinel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 142 on the TSP Request Card.* *NPO-17164*



A **Mirror Would Be Attached** to an imprecise substrate in a procedure similar to that used to make replica mirrors and gratings.

Making a Superconductive Thin Film

A sharp transition is obtained at 93 K.

Marshall Space Flight Center, Alabama

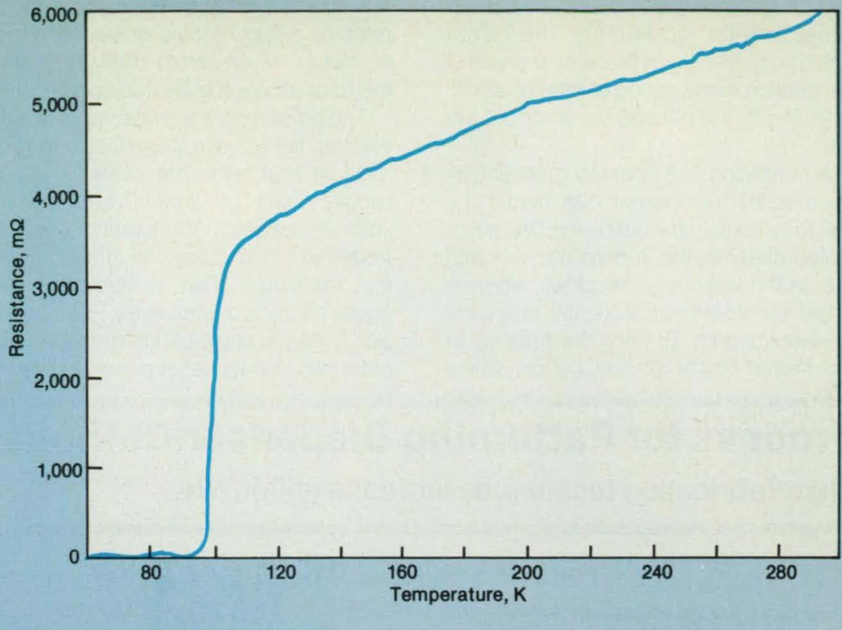
An experimental fabrication process results in a superconductive thin film of $YBa_2Cu_3O_7$ (the "123" phase of Y/Ba/Cu/O) on a substrate of green semiconducting Y_2BaCuO_5 (the "211" phase). The film becomes superconductive below a transition temperature (T_c) of 93 K.

Previous experiments had shown that after specimens of Y/Ba/Cu/O were reacted at temperatures greater than 950 °C but for relatively short times, they had sharper T_c transitions. This observation gave rise to the hypothesis that an extremely careful heat treatment is necessary because the formation of the semiconducting "211" phase is thermodynamically favored over the formation of the superconducting "123" phase. The new fabrication process takes account of this hypothesis by incorporating suitable heat treatments.

In the experiment, preparation of the semiconducting substrate material was begun by grinding appropriate amounts of metal oxides, pressing them into pellets, then heating them to 950 °C for 12 h to form the "211" phase. To assure complete reaction, the pellets were reground, pressed into pellets again, and reheated.

The superconducting material to be deposited on the substrate was prepared by mixing the appropriate amounts of metal oxides to form $YBa_2Cu_3O_7$, pressing them into pellets, heating at 950 °C for 12 h, then quenching to room temperature. The material was then annealed in oxygen at 950 °C for 6 h, followed by slow cooling in the furnace. At this point, the material had a T_c of 96 K.

The superconducting material was deposited on the substrate by radio-frequency sputtering at room temperature. Initially, the deposited film was 1 mm thick and was insulating. After it was annealed in oxygen at 900 °C for 30 min, then cooled in the furnace, it had become superconducting. As shown in the figure, the transition to superconductivity at 93 K is very sharp. The estimated critical current density is 350 A/cm^2.



The **Resistance of the Film** deposited by the experimental fabrication process decreases with decreasing temperature down to 93 K, where it exhibits a sharp transition to zero.

This work was done by Maw-kuen Wu of the University of Alabama for **Marshall Space Flight Center**. *For further information, Circle 29 on the TSP Request Card. MFS-26093*

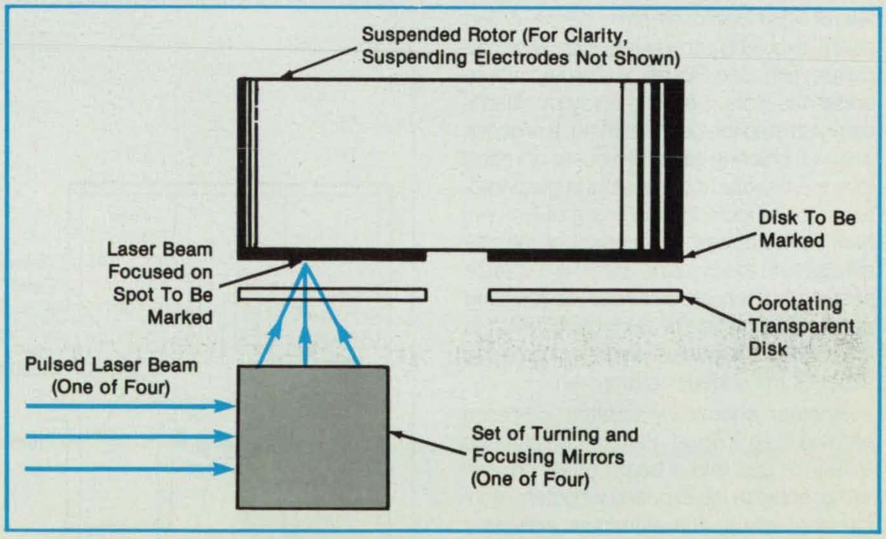
Advanced Engraving of Angle-Encoder Disks

Precision would be increased over that of mechanical engravers.

Marshall Space Flight Center, Alabama

A proposed optical/mechanical/electronic system would engrave the angular-interval marks on angle-encoder disks. The system was conceived to meet the need for increased precision of angular measurements in advanced scientific instruments.

At present, the most-precise angular-encoder disks are made on mechanical angle-dividing machines. Small increases in the precision of such machines are expensive and consume much time. The proposed system would abandon the traditional mechanical-precision approach, relying instead on a combination of the high precision of electronic time division and digital synthesis of frequency with the almost-friction-free motion of a rotor suspended in a high vacuum by electrostatic forces.



Laser Pulses Timed According to the Rotational Speed of a rotor electrostatically suspended in a vacuum would mark an angular-encoder disk mounted on the lower end of the rotor. The precision of the timing circuitry and the low rotational damping (damping time about 700 years in a high vacuum) would result in highly-precise angular intervals.

As shown schematically in the figure, the disk to be engraved would be mounted on the lower end of a short cylindrical rotor suspended electrostatically and would serve as the lower-end rotor electrode. Voltages applied to all the electrodes of the electrostatic suspension system would be determined by a feedback control subsystem that would sense the various capacitances between the end and side rotor and stator electrodes. Because these capacitances depend on the position and orientation of the rotor relative to the stator, the subsystem could process the capacitance signals to compensate for asymmetry in the rotor, seismicity, and other perturbations in such a way as to keep the axis of the rotor vertical and at the desired position.

The surface of the disk to be engraved would be coated with a noble metal. Focused laser beams would mark this surface by evaporating the metal at the designated spots. There would be two pairs of laser beams, arranged orthogonally to enable cancellation of the effects of deviations of the lateral position of the rotor. For equal angular increments, the lasers would be pulsed periodically, at intervals of the fraction of the period of rotation corresponding to the desired increment of angle.

A corotating (but normally mechanically-separate) transparent disk below the disk to be engraved would collect the evaporated metal so that it does not accumulate on the laser-beam windows, where it would otherwise subsequently attenuate the laser beams. To bring the rotor up to the desired rate of rotation, the corotating disk would initially be connected to the rotor via a piezoelectric or electromagnetic clutch, which would disengage when the rotor attains the desired speed.

The pressure of the metal vapor and the electric field in the interelectrode gaps must be kept below the levels that would trigger electrical arcs. Preferably, the voltages applied to the top and side electrodes would be balanced in such a way that the electric field at the bottom disk could be zero. Alternatively, the suspension voltages could be interrupted in synchronism with the laser pulses to prevent arcing, but this would necessitate the careful avoidance of harmonics to prevent excessive vibrations.

This work was done by Walter K. Polstorff of **Marshall Space Flight Center**. *For further information, Circle 119 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-28294

Process for Patterning Dispenser-Cathode Surfaces

Microfabrication techniques increase uniformity.

NASA's Jet Propulsion Laboratory, Pasadena, California

Several microfabrication techniques have been combined into a process that cuts slots 100 μm long and 1 to 5 μm wide into tungsten dispenser cathodes for traveling-wave tubes. The slots enable a more-uniform low-work function coating to be dispensed to the electron-emitting surface. The emission of electrons therefore becomes more uniform over the cathode surface.

A molybdenum mandrel is coated by chemical-vapor deposition with a layer of tungsten 25 μm thick, followed by a layer of aluminum 5 μm thick. A layer of photoresist 1 μm thick is applied over the aluminum. Slots are cut in the photoresist by writing with a laser beam, electron beam, or ion beam, exposing parts of the underlying aluminum film (see Figure 1). The aluminum under the slots is etched away by chemically-assisted ion-beam etching, a process in which chlorine gas and a beam of xenon ions are directed into the slots in the photoresist (see Figure 2). The beam of ions enhances the chemical reactivity of the aluminum with the chlorine, forming a volatile product that is pumped away. The resulting pattern of slots in the aluminum, which is identical to the pattern in the photoresist, exposes the underlying tungsten.

Another chemically-assisted ion-beam etching step follows. Fluorine or chlorine trifluoride gas and a beam of xenon ions are directed at the exposed tungsten, etching slots into it. The aluminum acts as a mask because it reacts only slightly with either gas. If slots narrower than 1 μm are needed, the patterned cathode can be coated with more tungsten by chemical-vapor deposition to close partially the gaps between the walls of the slots.

This work was done by Charles E. Garner and William D. Deininger of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 137 on the TSP Request Card.*
NPO-17183

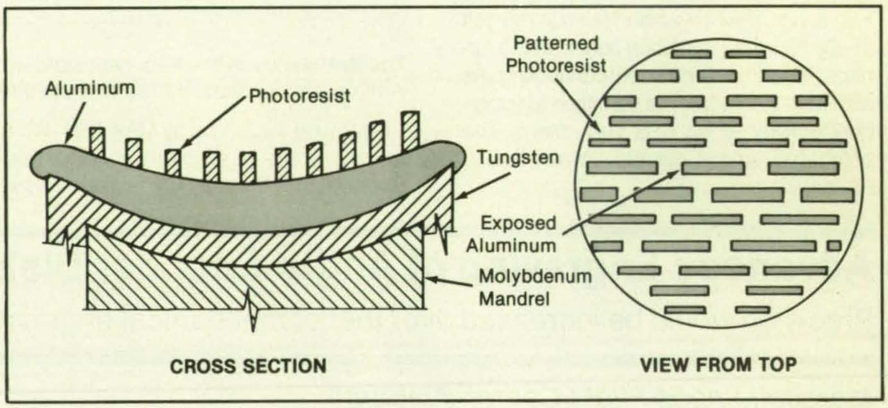


Figure 1. The **Patterned Photoresist** serves as a mask for etching the underlying aluminum.

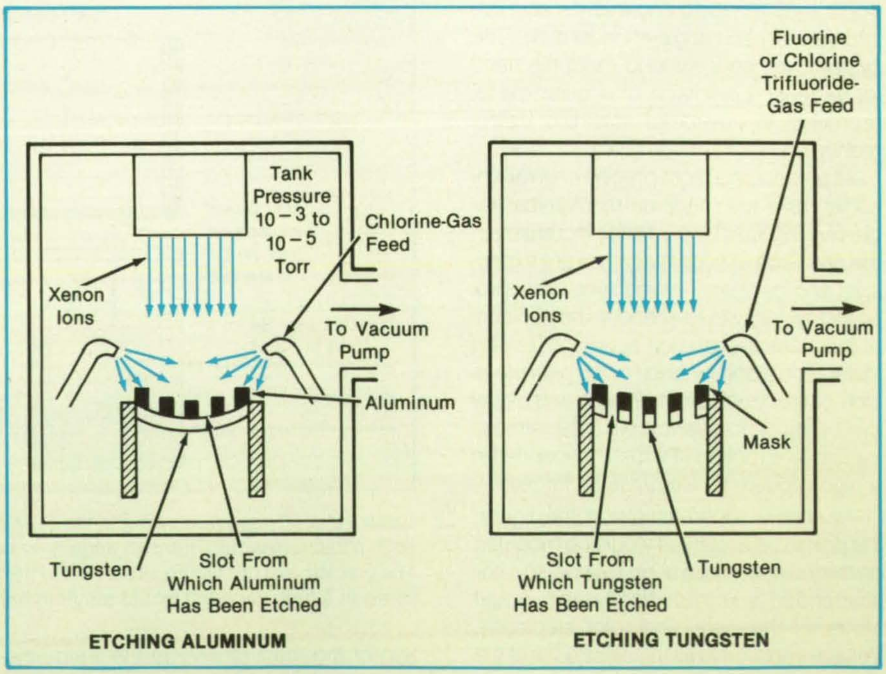


Figure 2. **Chemically-Assisted Ion-Beam Etching** with chlorine removes exposed parts of the aluminum layer (left). Chemically-assisted ion-beam etching with fluorine or chlorine trifluoride removes the tungsten not masked by the aluminum layer (right).

Deposition of Pinhole-Free $CoSi_2$ Film

A stoichiometric combination of cobalt and silicon is overlaid with silicon.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new fabrication method produces a pinhole-free film of cobalt silicide on a silicon substrate. Earlier methods resulted in as many as 10^7 pinholes per square centimeter. The absence of pinholes is critical to the operation of multilayer devices employing $CoSi_2$ layers, such as the metal base transistor.

In the new method, cobalt and silicon are evaporated from electron-beam sources onto a substrate of silicon having a <111> crystal orientation. The materials are deposited in the stoichiometric ratio of two silicon atoms to one of cobalt, yielding a single-crystal $CoSi_2$ film 5 to 10 nm thick. A layer of amorphous silicon 1 to 2 nm thick is deposited on the $CoSi_2$. The specimen is then annealed at 550 °C for 10 min.

The amorphous-silicon cap prevents pinholes from forming during annealing. In the absence of this cap, apparently the high surface energy of $CoSi_2$ relative to Si causes the formation of pinholes, which expose the underlying Si surface and thereby reduce the total energy of the epitaxial system at temperatures above 500 °C. The silicon cap appears to reduce the total surface energy without the formation of pinholes. In fact, the temperature can be raised as high as 600 °C with the cap.

Because the $CoSi_2$ layer is stoichiometric, it does not consume the cap during annealing. Thus, the cap remains during the entire annealing process and is available to serve as a template for further deposits of silicon during later processing.

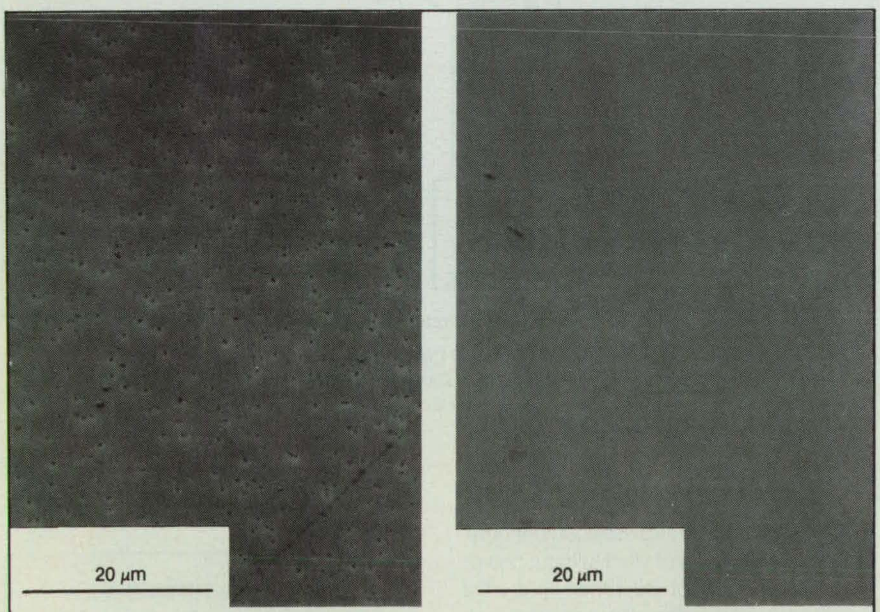
Scanning electron microscopy and other techniques were used to evaluate the quality of the $CoSi_2$ films on both silicon-capped and uncapped substrates. The films were etched with carbon tetrafluoride plasma to enlarge pinholes for greater visibility; where a silicon cap layer covered a pinhole, it, too, was removed by the plasma. This procedure improved the detection resolution to 1,000 pinholes per square centimeter. No pinholes could be found on the capped film, whereas the uncapped film was riddled with pinholes (see figure).

This work was done by True-Lon Lin, Robert N. Fathauer, and Paula J. Grunthaner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 42 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

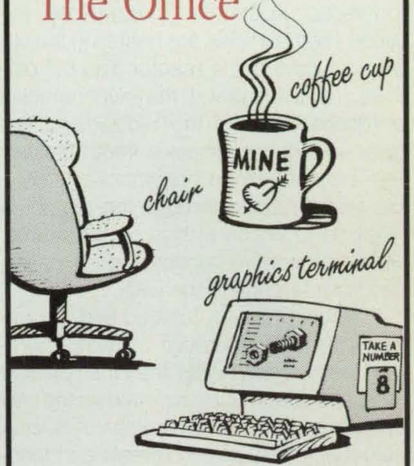
Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17447, volume and number of this NASA Tech Briefs *issue, and the page number.*



The **Scanning Electron Micrograph** of a silicon-capped $CoSi_2$ film shows no pinholes, whereas that of an uncapped film shows many. The density of pinholes in the micrograph of the uncapped specimen is 2×10^7 cm^{-2}. Both the capped and uncapped specimens have been etched by CF_4 plasma to enhance the visibility of the pinholes.

Three Things You Shouldn't Have To Share At The Office



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Fluidized-Bed Reactor With Zone Heating

Deposition of silicon on the wall is suppressed.

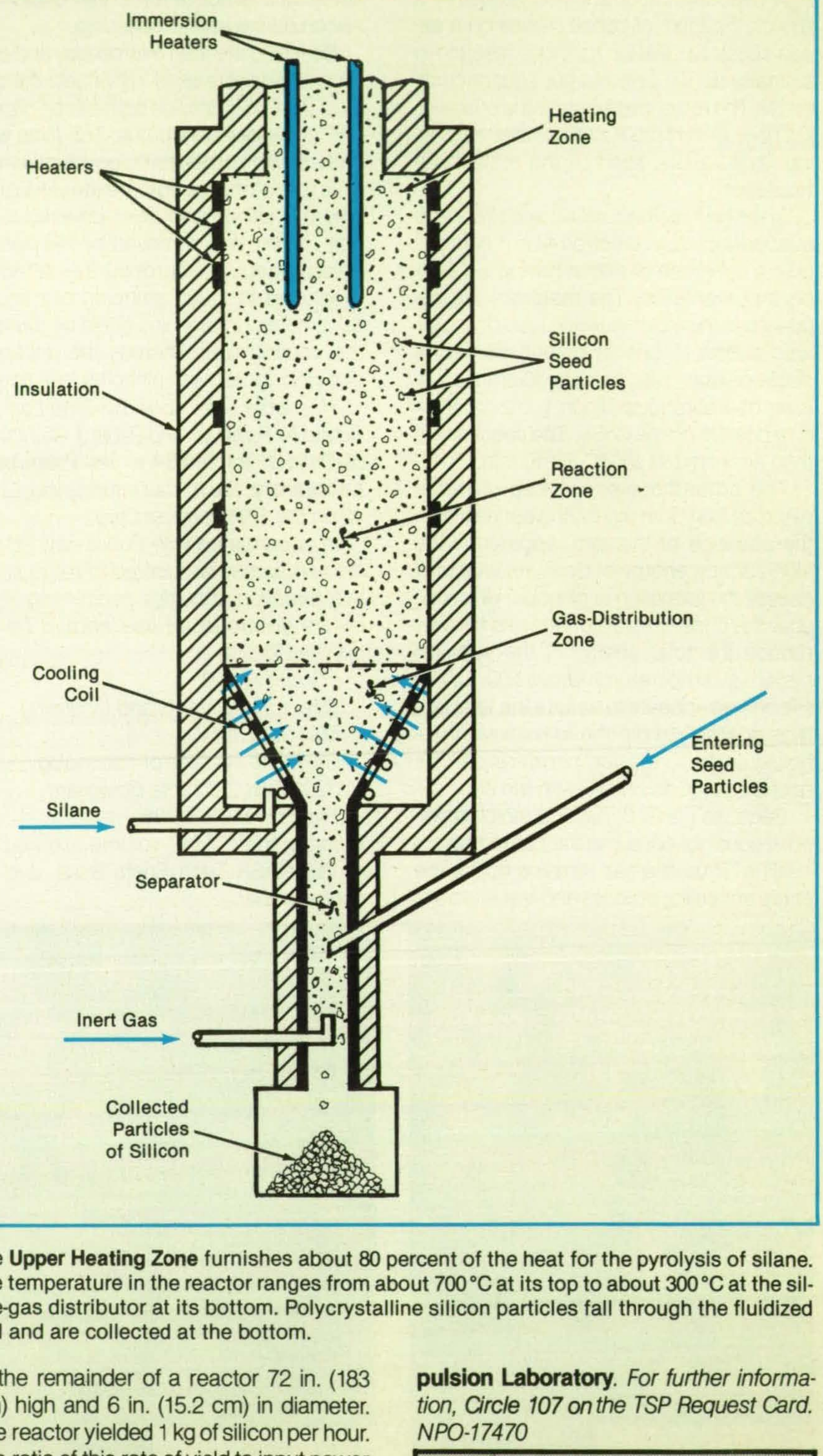
NASA's Jet Propulsion Laboratory, Pasadena, California

The design of a fluidized bed for production of silicon greatly reduces the tendency of silicon to deposit on the wall of the reaction vessel. In the new fluidized bed, the silicon seed particles are heated in the uppermost zone of the reactor. The hot particles gradually mix with the lower particles and descend through the fluidized bed. The lower wall of the vessel is kept relatively cool. Because silane that enters at the bottom and circulates through the reactor is pyrolized to silicon at high temperatures, silicon is therefore deposited on the particles in preference to the wall.

A typical previous fluidized bed, in contrast, was heated through the wall. Therefore, the wall was hotter than the reaction zone, and silicon was deposited on the wall as well as on the bed particles, reducing the net yield of silicon and creating a cleanup problem. Moreover, the high temperature in the lower layers of the bed favored the formation of fine silicon dust that had to be separated from the product particles and recovered.

In the new process, silicon seed particles are introduced into the base of the reactor vessel (see figure), where a stream of inert gas creates a fluidized bed of the particles extending almost to the top of the vessel. At the top of the bed, immersion heaters encased in quartz and wall heaters maintain a temperature of 650 to 800 °C. The turbulence of the bed mixes hot seed particles from the heating zone with particles in lower layers, the net result being a vertical gradient of temperature ranging down to 450 to 650 °C at the bottom of the bed. Wall heaters add only enough heat to make up for losses.

Silane flowing up from the base of the vessel decomposes in the reaction zone just below the heating zone, depositing silicon on the silicon seed particles but not on the wall. Essentially all the silane reacts in the reaction zone; it does not flow into the heating zone. Once a particle has grown to a size of 400 to 1,500 μm, the particle descends from the reaction zone through a separator to a collector.



The **Upper Heating Zone** furnishes about 80 percent of the heat for the pyrolysis of silane. The temperature in the reactor ranges from about 700 °C at its top to about 300 °C at the silane-gas distributor at its bottom. Polycrystalline silicon particles fall through the fluidized bed and are collected at the bottom.

Silane enters the vessel through a perforated distributor cone at the bottom. Water circulating in a coil around the distributor cone keeps it at a temperature of about 300 °C — low enough to suppress the deposition of silicon dust even though the silane is highly concentrated at this point in the reactor.

In a demonstration of the process, about 8 kW of power were supplied to the top 15 in. (38 cm), and 2 kW were supplied to the remainder of a reactor 72 in. (183 cm) high and 6 in. (15.2 cm) in diameter. The reactor yielded 1 kg of silicon per hour. The ratio of this rate of yield to input power (0.1 g/Wh) is about 30 times that of a commonly-used batch process and may be higher than that of other fluidized-bed processes as well.

This work was done by Sridhar K. Iya of Union Carbide Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 107 on the TSP Request Card. NPO-17470*

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Molecular-Beam Epitaxy of $CrSi_2$ on Si(111)

Crystalline layers have been grown in a commercial apparatus.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that $CrSi_2$ can be grown on the (111) face of a single-crystal Si substrate by molecular-beam epitaxy. The epitaxial $CrSi_2$ produced thus far is not in the desired single-crystal form. However, because $CrSi_2$ is a semiconductor with a band gap of 0.3 eV, the experimental process has potential for the monolithic integration of microelectronic devices based on $CrSi_2$ (e.g., infrared detectors) with signal-processing circuitry based on Si.

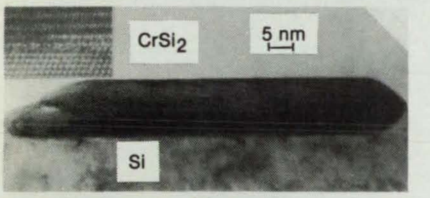
In the experiments, Si(111) wafers were first cleaned chemically by a process that leaves a protective oxide on the surface. The wafers were then placed in a commercial molecular-beam epitaxy (MBE) apparatus, where the oxide was removed by a beam of Si in some cases or by thermal desorption in other cases.

The apparatus was equipped with separate electron-beam evaporators, one for Si and one for Cr. Each $CrSi_2$ specimen was grown by one of four techniques, each of which is a special case of generic MBE. In the first technique, called "solid-phase reactive epitaxy" (SRE), Cr was deposited on a subtrate of Si held at room temperature; the substrate and deposit were then annealed at a temperature of 580, 650, or 720 °C. In the second technique, called "reactive-deposition epitaxy" (RDE), Cr was deposited on a hot Si substrate. The third technique, called "solid-phase epitaxy" (SPE), involved the stoichiometric deposition of Cr and Si at room temperature, followed by annealing at higher temperature. In the fourth technique, denoted by the generic term "MBE," Cr and Si were codeposited stoichiometrically on a hot Si substrate.

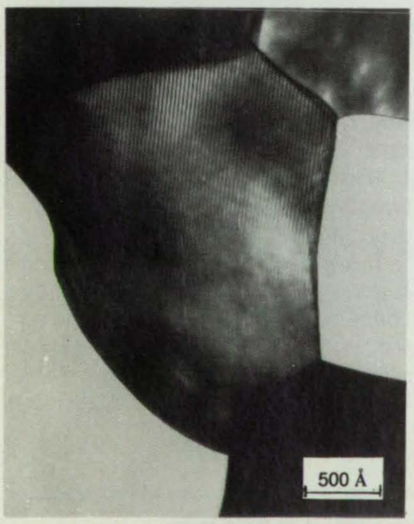
$CrSi_2$ layers were grown to thicknesses of 10 and 210 nm (see figures). The specimens were monitored during growth by reflection high-energy electron diffraction (RHEED). After removal from the MBE apparatus, the specimens were analyzed by scanning electron microscopy (SEM), transmission electron microscopy (TEM), and Rutherford backscattering spectroscopy (RBS).

The analyses showed that the $CrSi_2$ layers tended to form islands, within each of which one of several crystalline orientations prevailed. The two most common orientations observed were $CrSi_2(0001)//Si(111)$ with $CrSi_2[10\bar{1}0]/Si[10\bar{1}]$ and $CrSi_2(0001)/Si(111)$ with $CrSi_2[11\bar{2}0]/Si[10\bar{1}]$. The two orientations differ in that the $CrSi_2$ layers are rotated about 30° with respect to each other about the perpendicular to the surface. For the thick layers, the MBE technique yielded the largest grains and best RHEED pattern. The sizes of the grains were found to increase with temperature: grains 1 to 2 μm across were observed in a layer deposited at 825 °C.

This work was done by Robert W. Fathauer, Paula J. Grunthaner, True-Lon Lin, and David N. Jamieson of Caltech and Jurek H. Mazur of USC for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 37 on the TSP Request Card.* *NPO-17438*



(a)



(b)

Micrographs of $CrSi_2$ Layers show (a) cross-sectional TEM image of an island of $CrSi_2$ for a 10-nm layer grown by SRE. The insert shows the latice image of a portion of the $CrSi_2/Si$ interface. Part (b) is a planar TEM image of a 210-mm layer grown by MBE.

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Mathematics and Information Sciences

Continuously-Variable Vernier Scale

An easily fabricated device increases precision in reading graphical data.

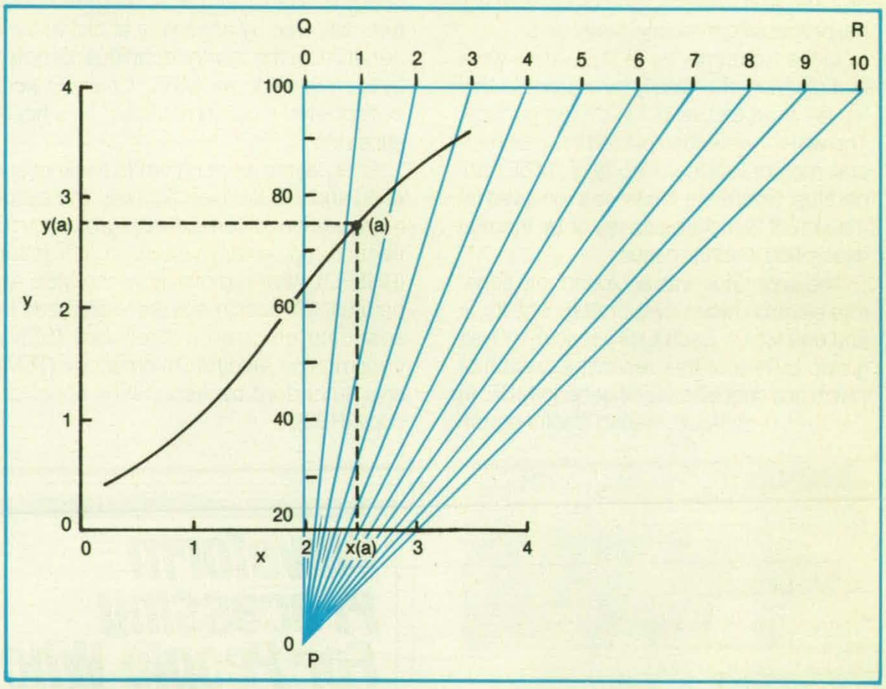
Langley Research Center, Hampton, Virginia

The continuously-variable vernier scale (CVVS) is designed to provide greater accuracy to scientists and technologists in reading numerical values from graphical data. It is placed on the graph and used to interpolate the coordinate value of a point on a curve or a plotted point on a figure within a division on each coordinate axis.

A typical construction and use of the CVVS are shown in the figure. A baseline PQ is constructed of arbitrary length, but it should be about 10 times the distance to be interpolated. Next, the scale line QR is constructed perpendicular to PQ. For convenience, QR may be equal in length to PQ. Then, 10 equally spaced divisions are marked off on the scale line QR, and straight lines are drawn from P.

The CVVS is overlaid on a plotted curve as shown so that the two legs of the triangle, PQ and PR, span the division on the *x* axis that includes the projected intercept *x*(*a*) of point (*a*). Note that this intercept falls between lines 4 and 5 of the geometric overlay. Therefore, *x*(*a*) can be more closely estimated as 2.49 instead of 2.5. If the scale is then rotated by 90° and the above procedure is repeated for the appropriate division on the *y* axis, the *y* coordinate, *y*(*a*), is more closely estimated as 2.76 instead of 2.8. To make it easier to line up the baseline with a coordinate axis and with the line that projects the point to one of the axes, faint lines can be drawn parallel to both axes.

The CVVS can also be used to interpolate a logarithmic scale if a logarithmic scale is constructed on the scale line. It can also be used to change the scale of a figure by changing the scale of the coordinate axes on that figure.



The **CVVS in This Case** is used to read the *x* and *y* coordinates of point (*a*) more precisely as 2.49 and 2.76, respectively.

For durability and clarity, the CVVS can be constructed on thin, clear, plastic material. It is a simple, inexpensive device that can readily meet the needs of scientists and technologists in making better estimates of points on plotted figures that are published in the literature. The CVVS requires neither the measurement of line segments where the projection of the point intersects a division nor a calculation to quantify the projected value. It is a very flexible device that can be constructed with any kind of scale. It is very easy to use, requiring no special equipment of any kind, and can save a considerable amount of time if numerous points are to be evaluated.

This work was done by Irvin M. Miller of **Langley Research Center**. *No further documentation is available.*

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, Langley Research Center [see page 14]. Refer to LAR-13721.

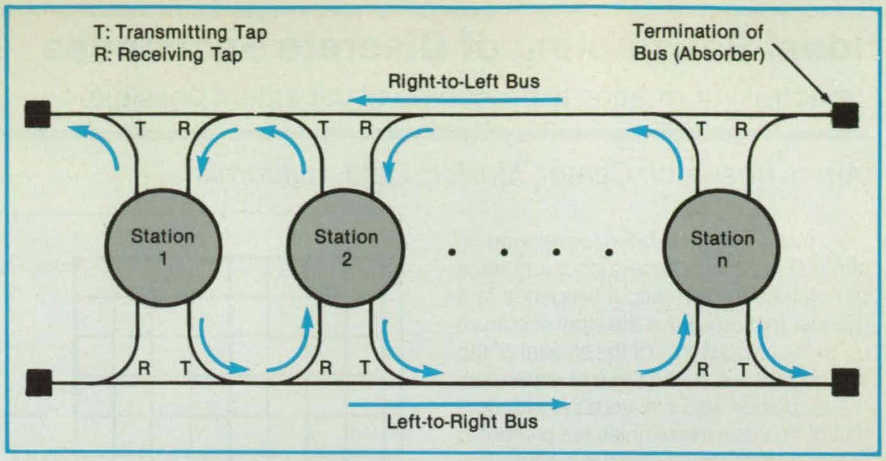
Some Protocols for Optical-Fiber Digital Communications

One works best in heavy traffic; another, in light traffic.

NASA's Jet Propulsion Laboratory, Pasadena, California

Three protocols have been proposed for digital communications among stations connected by passive taps to a pair of unidirectional optical-fiber buses. The protocols mediate round-robin, bounded-delay access to the buses by all stations and are particularly suited to fast transmission. Partly because the transmission medium is passive (there are no relay stations) and partly because the protocols distribute the control of the network among all stations with provision for the addition and deletion of stations (there are no control stations), the communication network should be able to resist and recover from failures.

The signals on the two buses travel in opposite directions. Each station includes a transmitter and receiver connected to both buses (see figure). When the receiver detects a carrier signal, it attempts to synchronize itself to the bits in the preamble of the incoming signal and to copy the signal into the memory of the station. Provided that the receiver detects no signal coming from upstream and/or has been granted access by the protocol, the transmitter sends a preamble followed by a packet of data. There is a delay between the time a station senses the end of a carrier on a bus and the time when it can start transmitting on the same bus. There is an equal delay between the sensing of a carrier coming from upstream and the interruption of a transmission. These functions are common to all unidirectional-bus systems but are managed in different ways by different protocols.



Traffic on the Twin Unidirectional Buses is managed by any of three protocols described in the text. Each has advantages and disadvantages, depending on the level of traffic and the number of stations attempting to transmit.

The first of these three protocols, called "U-Net," defines a procedure to determine which two stations are at the right and left ends of the bus and which should transmit a special sequence of bits called the "token." The network then operates in cycles that are initiated when the left-end or right-end station transmits the token. Each station downstream from the initiating end station waits for the token and any appended packets of data to pass by, then transmits its own packet (if any). Thus, each station has an opportunity to add a packet of data to a train of packets headed by the token.

When traffic is light or only one station has data to send, the U-Net protocol wastes time by forcing the transmitting station to wait for the token and then to transmit only one packet at each pass. This disadvantage is overcome by a hybrid protocol that enforces a random-access mode when traffic is light or a single station is transmitting and reverts to an implicit-token mode when multiple-source traffic builds up. This protocol is called "Buzz-Net" because of a buzzing signal that any station transmits to synchronize the network and drive it to the token mode under certain conditions of increasing traffic.

While the Buzz-Net protocol is efficient at low traffic, it is less efficient than the U-Net protocol is at high traffic, where it wastes time by repeatedly switching between the two modes. The "Token-less" protocol was introduced to obtain efficiency at high traffic, to reduce waiting at low traffic, and to eliminate special token-initialization procedures. As the name implies, this protocol does not involve an explicit token. Instead, it supports a round-robin access mode like that of U-Net, and the synchronizing event (implicit token) is the cessation of activity on one of the buses. The implicit token propagates in one direction on one bus and in the opposite direction on the other bus, thus minimizing the interval of silence between the end of one round and the beginning of the next.

This work was done by Cavour Yeh and Mario Gerla of the University of California for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 133 on the TSP Request Card.*
NPO-17333

Algorithm for Optimal Control of Large Structures

The cost of computation appears competitive with that of other methods.

NASA's Jet Propulsion Laboratory, Pasadena, California

An iterative algorithm has been derived for the numerical computation of optimal control of a linear system (e.g., a large, vibrating structure) of many degrees of freedom. The cost of the algorithm, as measured in terms of the number of computations required, is of the order of, or less than, the cost of prior algorithms applied to similar problems.

The problem is to compute the optimal control of forced response of a structure with n degrees of freedom that is identified in terms of a smaller number, r, of vibrational modes. The article begins with the Hamilton-Jacobi formulation of mechanics and the use of a quadratic cost functional. While the Hamilton-Jacobi approach has previously resulted in computational complexity that increased almost exponentially with n, the complexity can be reduced by an alternative approach in which the quadratic cost functional is expressed in terms of the control variables only. This leads to the iterative solution of a second-order time-integral matrix Volterra equation of the second kind that contains the optimal control vector.

At each iteration, the matrix Volterra equation is integrated numerically by use of a trapezoidal integration scheme in which the control interval is discretized into s equally spaced intervals of time. The particular structure of the matrices can be exploited to reduce the number of computations and to enable the use of a Jacobi-type iterative solution. Some steps are common to all iterations and thus need to be executed only once.

Overall, the total number of computations required is of the order of

$$[4r(q_{max}+r)ms+n^2]$$

where m is the number of control variables and q_{max} is the number of iterations required for convergence. Although q_{max} is not known a priori, the dominance of diagonal terms in one of the matrices at an intermediate step of the derivation suggests that q_{max} should be of the order of 10. As a result, the algorithm appears to be competitive with other methods based on solutions to matrix Riccati equations, especially at large n.

This work was done by Moktar A. Salama and John A. Garba of Caltech and Senol Utku of Duke University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 28 on the TSP Request Card.* *NPO-16983*

Ideal Resampling of Discrete Sequences

Spectral information is preserved to the extent possible.

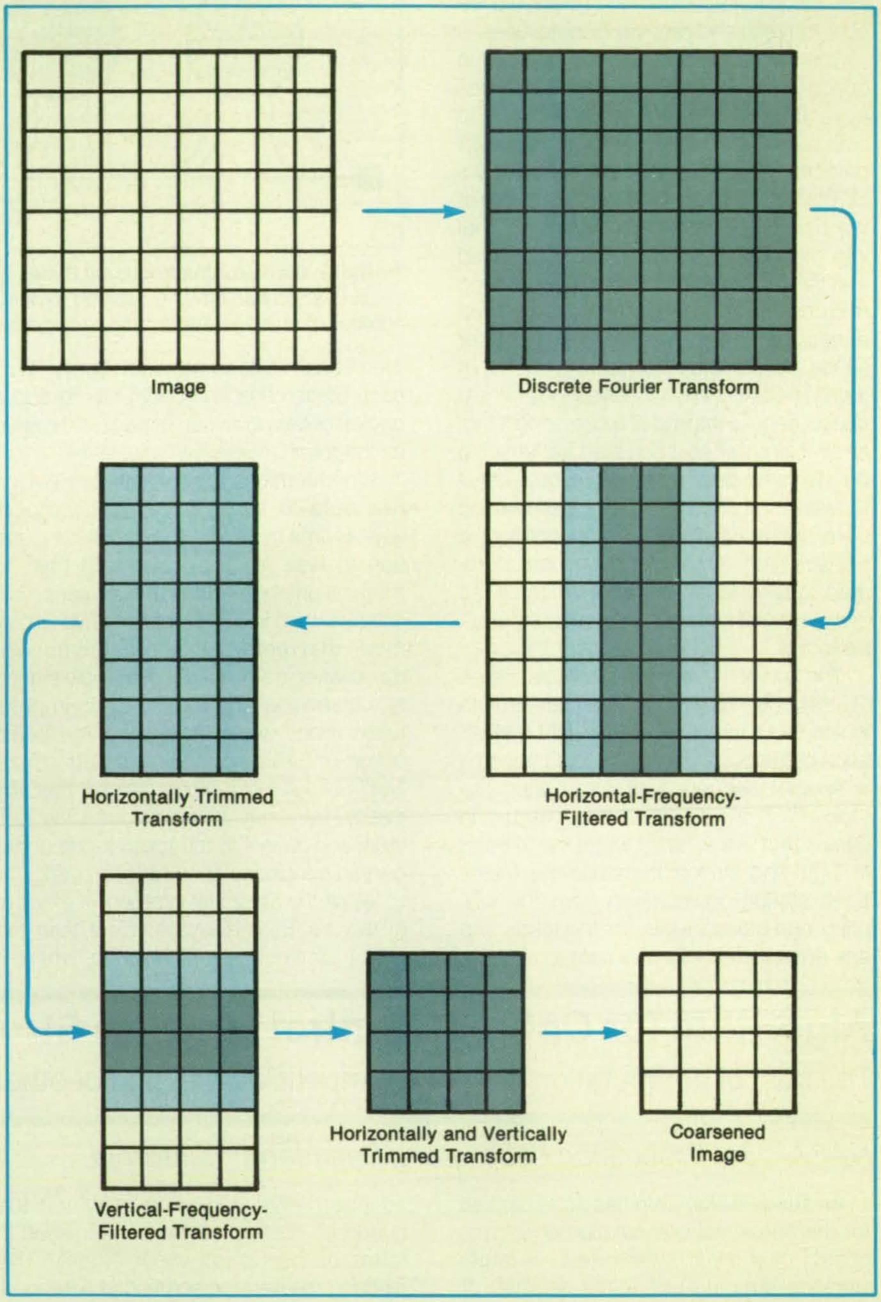
Ames Research Center, Moffett Field, California

A technique has been developed to shrink or expand a discrete input sequence of numbers into an output sequence in a manner that preserves the input spectrum up to the Nyquist limit of the smaller of the two sequences. In the case of expansion, the technique also prevents the introduction of spurious frequencies not present in the input. While the technique is applicable to many kinds of data sampled at regular intervals, it is particularly useful in the processing and enhancement of images, where the discrete sequences are spatially ordered sets of picture-element brightness values.

The problem is to change the input sequence of N numbers to an output sequence of M numbers. The first step of the solution is to take the discrete Fourier transform (DFT) of the input. The DFT is used to reconstruct a continuous, band-limited function containing the same spectrum as that of the input sequence. This is the function that one would observe upon low-pass filtering an input signal below the Nyquist frequency of the sequence (and taking half the amplitude at the Nyquist frequency) and is the function that yields the input sequence when sampled at the input times or positions.

The continuous function is low-pass filtered to eliminate frequencies (if any) above the Nyquist rate of an M-sample sequence. This can be done in the frequency domain by taking the product of the DFT and the filter frequency dependence, or in the time or space domain by convolution with a sinc function of frequency M. In the time or space domain, the filtered signal can be converted to the output sequence by sampling it at intervals of 1/M. Alternatively, the filtered DFT can be convolved with a pulse-train DFT, then inverted to the time or space domain to yield the output sequence.

A two-dimensional array of numbers (e.g., image data) is treated by applying the technique to the two-dimensional DFT's of the rows and columns of picture elements. Similarly, third-order and higher-order arrays are treated via the applicable multidimensional DFT's. The technique might be used, for example, to expand an image array, increasing the number of picture elements to smooth out the grainy appearance of a few large picture elements. Alternatively, it might be used to decrease the number of picture elements (see figure).



An **Image Is Coarsened** by resampling to reduce the number of picture elements while preserving as much as possible of the original image information.

If the third dimension of a three-dimensional array is time, the technique could be applied to create a slow-motion image sequence without the difficulty of recording rapidly, then playing back at low speed. The image would be recorded at the normal frame rate and played back at the lower frame rate. The technique would be used to generate intermediate images at small intervals between frames, thereby suppressing the appearance of jerky motion caused by the sudden jumps between frames at the low frame rate.

This work was done by Andrew B. Watson of **Ames Research Center**. *Further information may be found in NASA TM-88202 [N88-19100], "Ideal Shrinking and Expansion of Discrete Sequences."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11719.

Design of Combined Stochastic Feedforward/Feedback Control

Methodology accommodates a variety of control structures and design techniques.

Langley Research Center, Hampton, Virginia

A methodology for the design of combined stochastic feedforward/feedback control has been developed, and a digital automatic landing system has been designed by use of this approach. The main objective of a control law is to enable a plant to track a desired or commanded trajectory selected from a given class of trajectories as closely as possible in the presence of random and deterministic disturbances and despite uncertainties about the plant. The feedforward controller tries to track the desired or commanded trajectory, whereas the feedback controller tries to maintain the state of the plant near the desired trajectory. Modern control theory has concentrated more attention on the important feedback control problem, while the feedforward control problem has received less attention.

In the methodology for combined stochastic feedforward/feedback control, the main objectives of the feedforward and feedback control laws are seen clearly. The inclusion of error-integral feedback, dynamic compensation, rate-command control structure, and the like is an integral element of the methodology. Another advantage of the methodology is the flexibility to develop a variety of techniques for the design of feedback control with arbitrary structures to obtain the feedback controller: These include stochastic output feedback, multiconfiguration control, decentralized control, or frequency and classical control methods.

A specific incremental implementation is recommended for the combined feedforward/feedback controller. Some advantages of this digital implementation are simplicity, elimination of the need for trim values, and avoidance of such problems as integrator windup. The closed-loop eigenvalues obtained in this implementation contain the designed closed-loop eigenvalues that would result if an incremental implementation were not used. It has been shown that when using an incremental implementation, it is advantageous to design the controller with as many integrators as the number of controls. The use of fewer integrators results in marginally stable eigenvalues of unity, while the use of more integrators constrains the placement of eigenvalues.

A digital automatic landing system for the Advanced Transportation Operating System (ATOPS) research vehicle, a Boeing 737-100, has been designed by use of the stochastic-feedforward-controller and stochastic-output-feedback methodology. The control modes of the system include the capture and tracking of the localizer and glideslope, crab, decrab, and flare. By use of the recommended incremental implementation, the control laws have been simulated on a digital computer and connected with a nonlinear digital simulation of the aircraft and its systems.

This work was done by Nesim Halyo of Information and Control Systems, Inc., for **Langley Research Center**. *Further information may be found in NASA CR-4078 [N87-25806], "A Combined Stochastic Feedforward and Feedback Control Design Methodology with Application to Autoland Design."*

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.
LAR-13795

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.

Commercial Expert-System-Building Software Tools

Computer programing tools are described and compared according to their knowledge-representation approach, inference methods, user interfaces, functional applicability, and other criteria.

A report evaluates commercially-available expert-system-building tools in terms of their structures, representations of knowledge, inference mechanisms, interfaces with developers and end users, and capabilities of performing such functions as diagnosis and design. These software tools are the commercialized derivatives of artificial-intelligence systems developed by researchers at universities and research organizations. Reportedly, they reduce the time to develop an expert system by an order of magnitude compared to that required with such traditional artificial development languages as LISP.

The core of an expert system consists of a knowledge base and an inference engine that operates on the knowledge base to develop a solution or response. In addition, the system needs an interface to the end user or to an array of sensors and effectors to communicate with the outside world. A tool to develop an expert system must also include a developer interface so that the requisite knowledge base can be developed, the end-user interface can be built, and special instructions can be given to the inference engine. Other important tool attributes include the computers on which they will run and their interfaces with other software and data bases.

A table lists 20 such tools, rating their attributes as strong, fair, programmable by the user, or having no capability in the various criteria. The following tools are rated: ART, KEE, Knowledge Craft, S.1, PICON, ENVISAGE, ES ENVIRONMENT/VM, PERSONAL CONSULTANT+, KES, NEXPERT, EXSYS 3.0, INSIGHT 2+, M.1, RULEMASTER 3.0, KDS, TIMM, ES/P, EXPERT EDGE, 1st Class, and OPS5. The report also briefly describes each of the tools, pointing out their distinctive features.

This work was done by William B. Gevarter of **Ames Research Center**. *Further information may be found in NASA TM-88331 [N87-28281/NSP], "The Nature and Evaluation of Commercial Expert System Building Tools: Revision 1."*

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.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 14]. Refer to ARC-11757.

Application of Artificial Intelligence to Wind Tunnels

Goals include data of better quality, increased productivity, and retention of expertise.

A report discusses the potential use of artificial-intelligence systems to manage the wind-tunnel test facilities at Ames Research Center. One of the goals of this program is to obtain experimental data of better quality and otherwise generally increase the productivity of the facilities. Another goal is to increase the efficiency

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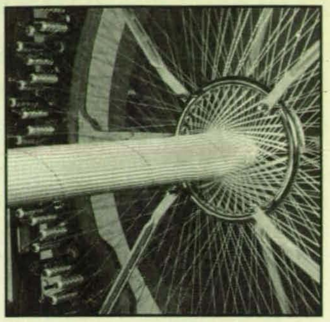

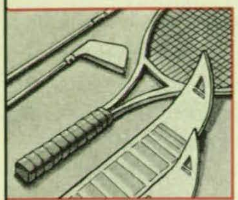

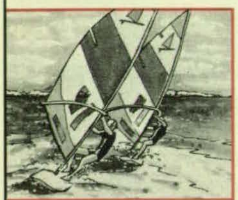

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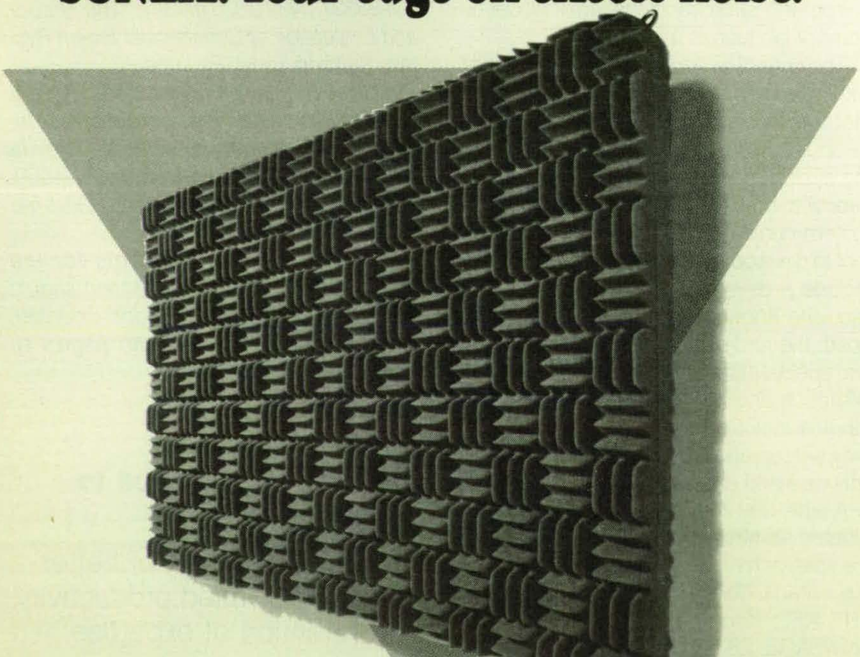

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and expertise of current personnel and to retain the expertise of former personnel. The third goal is to increase the effectiveness of management through the more efficient use of accumulated data.

The authors recommend the development of three major artificial-intelligence systems to achieve these goals. One would include expert subsystems that could be used in planning and conducting wind-tunnel tests; for advice and training in the understanding of the characteristics of wind tunnels, measuring instruments, and ancillary equipment; and to assist in setting up tests to meet various objectives and requirements.

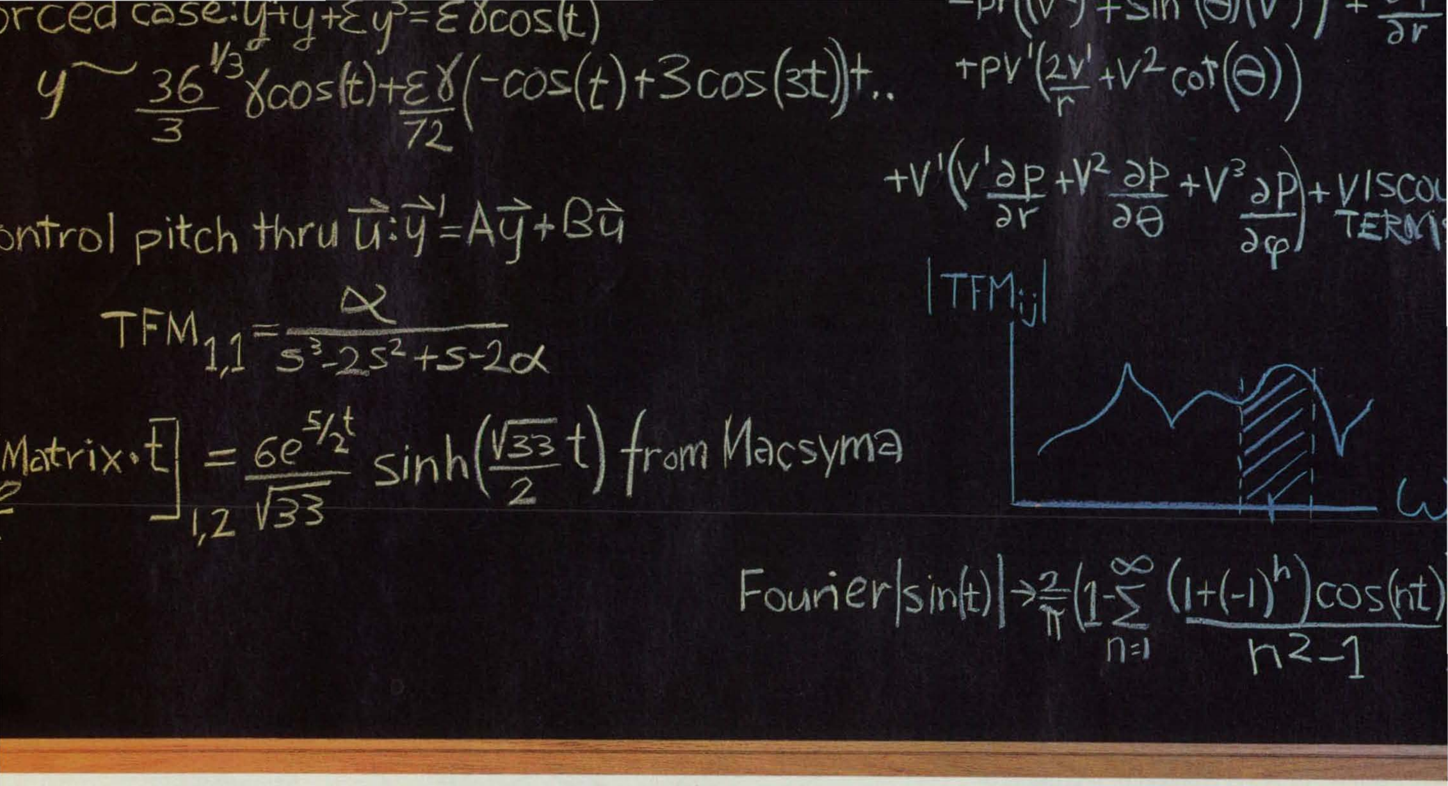
This system would include what amounts to an interactive electronic instruction manual similar to some textual-information systems that are already commercially available. A pretest-intelligent-assistant subsystem would help engineers in the design of models and selection of instrumentation. A prototype subsystem to aid in the selection of strain-gauge balances to be inserted in models is described in an appendix. One subsystem would incorporate computational fluid dynamics to help in planning tests. Other subsystems include one to assess the quality of data during and after tests, one to correct for the effects of the walls of wind tunnels on experimental data, and one for training.

The second major artificial-intelligence system would guide the diagnosis, monitoring, and repair of equipment. By duplicating established techniques used by experienced technicians, one subsystem could spot emerging trouble early, thereby increasing productivity by preventing unnecessary damage and unnecessary repetition of tests. One subsystem would monitor sensors during tests for signs of malfunctions. Another subsystem would monitor wind-tunnel machinery.

The third major artificial-intelligence system would be an interactive system for the management of the data base of multiyear test statistics. This system would be used to improve schedules of operation and maintenance of tunnels and other equipment, the assignment of personnel, the distribution of electrical power, and the analysis of costs and productivity. Several commercial artificial-intelligence computer programs are discussed as possible candidates for this use.

This work was done by Ching F. Lo and Frank W. Steinle, Jr., of **Ames Research Center**. *Further information may be found in AIAA paper 88-22141, "Application of Intelligence Systems to Wind Tunnel Test Facilities."*

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.
ARC-12229



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Automatic Sprout Grower

A compact unit nurtures growing seeds.

Lyndon B. Johnson Space Center, Houston, Texas

A self-contained seed-sprouting system provides an environment for sprouting seeds quickly and easily. Developed as a source of fresh vegetable material on short Space Shuttle flights, the kit offers advantages to home gardeners too. Apartment dwellers could use it for steady production of homegrown sprouts even though they have no garden space.

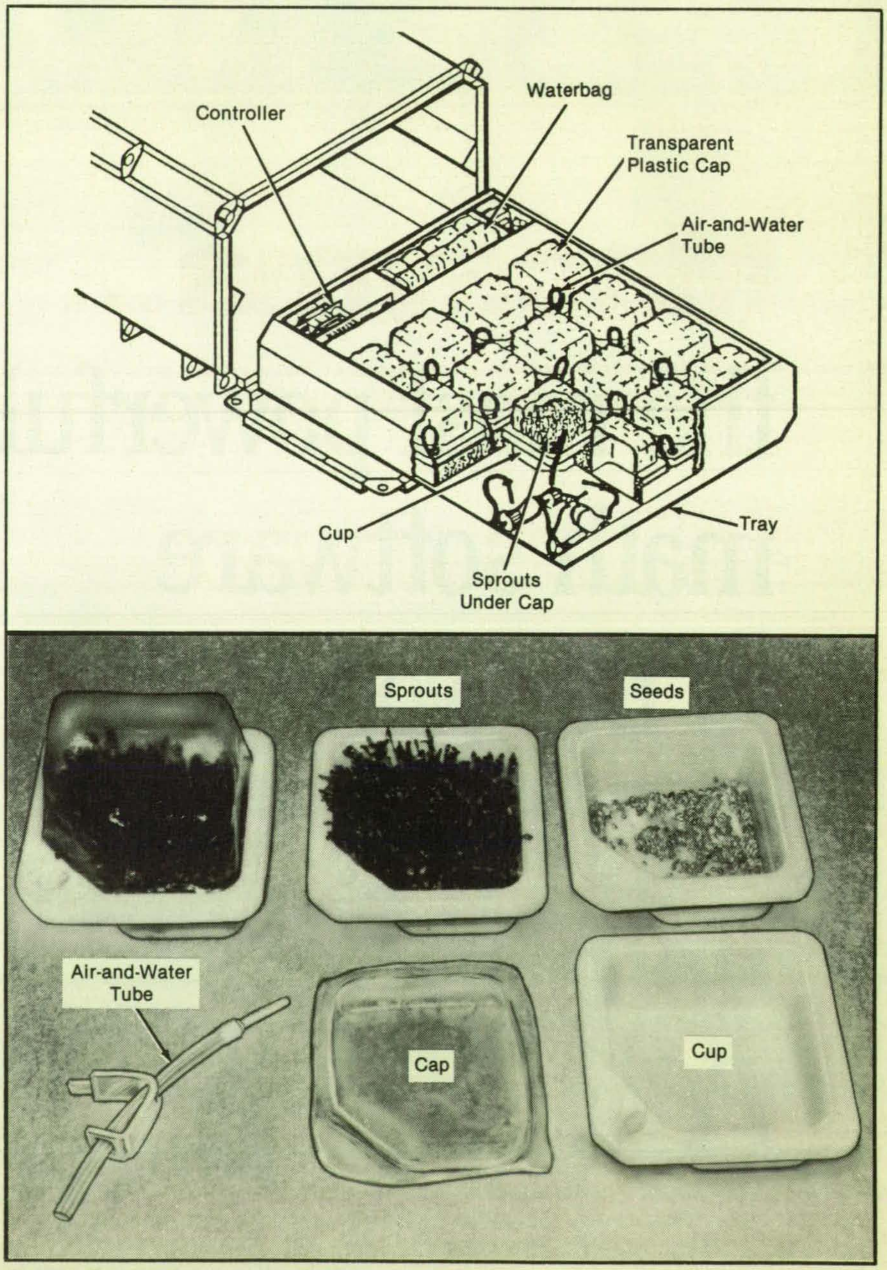
The system gives seeds all they need to sprout: water, good drainage, and plenty of air. Light, soil, and the containers for cultivating whole plants are unnecessary.

Seeds of various vegetables and field crops can be stored dry indefinitely, then placed in the system when needed. The seeds quickly grow five to seven times in weight and turn into what are essentially green vegetables. The vitamin contents increase dramatically, as do fiber contents. Fat and carbohydrate contents drop, while little protein is lost. Many of the inhibitors and toxicants of raw seeds are eliminated or reduced significantly.

The sprouting container is the standard 6-oz (0.18-L) package for dehydrated food and drink mixes in the Space Shuttle. About 4 g of dry alfalfa or radish seeds are vacuum-sealed in each cup, like freeze-dried foods. Sixteen cups are suspended in a tray (see figure). An air-and-water inlet tube links each cup to a system of tubes and solenoid valves that alternately furnish air and water and remove stale air. A peristaltic pump supplies water from a vinyl medical-fluid bag. A small diaphragm pump supplies and exhausts air. A small circuit board times the movements of the air and water.

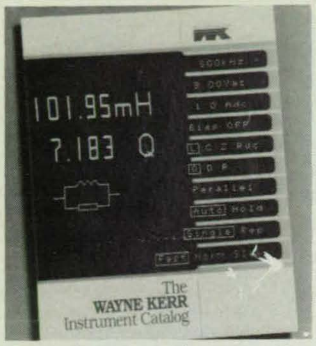
The proper growth of sprouts, both on Earth and in the microgravity of outer space, depends on adequate aeration and just the right amount of water. In microgravity, the effect of excess water is magnified in that water clings to the germinating seeds through surface tension, impeding movement of oxygen to the seeds. To prevent the sprouts from drowning in this way, the system adds water at frequent intervals, providing only the moisture needed for immediate uptake and for the expansion of the sprouts during each interval. The kit also periodically deflates and reinflates the sealed cups to remove gaseous metabolic products and to supply fresh oxygen.

This work was done by Richard L. Sauer of **Johnson Space Center** *and H. W. Scheld and J. W. Magnuson of PhytoResource Research, Inc. For further information, Circle 108 on the TSP Request Card. MSC-21266*



Sprouts Grow in Cups in a tray. Growth proceeds at room temperature with ordinary room air. The photograph shows details of the growth cup and newly sprouted seeds.

New Literature

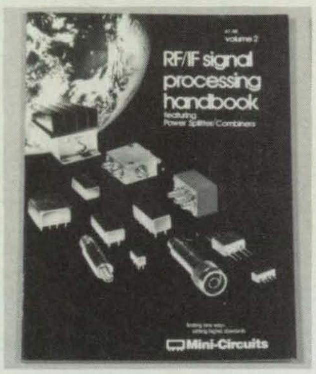


Five LCR meters, three precision analyzers, and a 1 MHz part tester are spotlighted in a new **instrument catalog** from Wayne Kerr Inc., Woburn, MA. The free catalog features product specifications, a selection guide, and a "Terms and Techniques" section that illustrates methods used to test capacitors, resistors, and inductors.
Circle Reader Action Number 724.

The Inventor's Notebook offers an organized way to document an invention's progress from first glimmer to the marketplace. Published by Nolo Press, Berkeley, CA, the softcover book features an extensive work diary and covers legal, financial, and marketing issues. Each chapter contains pages for record keeping, explanations of business concepts, and a bibliography of pertinent books.
Circle Reader Action Number 706.

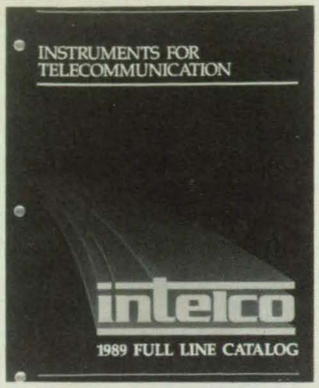
Newport Electronics Inc., Santa Ana, CA, has produced a 12-page brochure highlighting the new 500 Series of **isolated, two-wire 4-20 mA transmitters.** The publication presents 12 transmitter models for RTD, thermocouple, millivolt, milliamp, and volts input. Included are specifications, ordering information, and applications data — which covers the fundamentals of two-wire 4-20 mA transmitters and the combination of a transmitter with digital panel meters in the same loop. The brochure also describes 13 complementary digital process meters.
Circle Reader Action Number 726.

DAIR Computer Systems, Palo Alto, CA, is offering a free **artificial intelligence software and services catalog.** Product highlights include: Chaos Manner, the first chaos exploration program for personal computers; Netwurkz, a neural network tutorial that illustrates an associative memory's operation; PL/D, a system language that combines the speed and control of assembly language with the ease of expression of a compiler; and Neurotape, a 16-hour video course in neural net methodology.
Circle Reader Action Number 722.

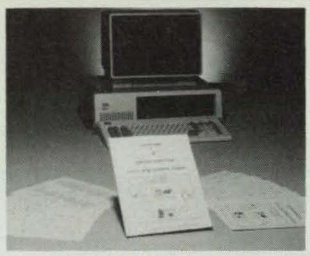


RF/IF/Microwave signal processing components from DC to 6 GHz are featured in a new 132-page handbook from Mini-Circuits, Brooklyn, NY. The handbook includes specifications and performance curves for power splitter/combiners, and also describes wideband products such as amplifiers, frequency mixers, high- and low-pass filters, frequency doublers, phase detectors, GaAs switches and drivers, RF transformers, and directional couplers.
Circle Reader Action Number 730

"The Strategic Difference in Advanced Electronics," a new brochure from the General Electric Company's Silicone Products Division, Waterford, NY, illustrates the application of **silicone technology** to integrated circuits and power electronics. Featured products include silicone junction coatings, die coatings, and molding compounds for electronic packaging systems; and conformal coatings, solventless coatings, gels, encapsulants, and high-temperature adhesives for macroelectronic protection systems.
Circle Reader Action Number 716.



Optical power meters, attenuators, laser and LED sources, and T1 BER analyzers are featured in Intelco Corporation's 1989 catalog, as well as application articles describing bit error rate analysis, fiber optic attenuation, and optical margin measurement. Moreover, the 66-page handbook contains a glossary of fiber optic testing terminology.
Circle Reader Action Number 704.



A free **glossary of microcomputer data acquisition terms** is offered by the MetraByte Corporation, Taunton, MA. The publication includes nearly 300 definitions — from "absolute accuracy" to "zero power resistance" — encompassing data conversion, signal conditioning, and microcomputer systems and software.
Circle Reader Action Number 712.

The new **Connector Design Guide** from Brush Wellman's Alloy Division, Cleveland, OH, assesses the critical design factors and material properties that dictate contact performance, such as spring force, permanent set resistance, temperature rise, stress relaxation resistance, and fatigue. Design criteria are supported with material properties and performance data for common copper-based alloys. The guide includes sample applications to help the engineer apply material specifications to contact designs.
Circle Reader Action Number 710.

"Technology Management," **a guide to the development, production, and marketing of new technology,** is now available from the Clark Boardman Company, New York City. The 500-page reference book offers pointers on licensing strategies and management; explains antitrust laws and export control regulations; identifies government and university technology sources; and describes how to implement technology transfers. Included are case studies in licensing transactions and examples of licensing forms.
Circle Reader Action Number 720.

To help laboratory personnel choose the right equipment for their water purification needs, Labconco Corp., Kansas City, MO, has published a 12-page **guide that evaluates the effectiveness of various purification methods.** The free booklet also discusses water quality standards and contaminant testing, and includes a glossary and bibliography.
Circle Reader Action Number 714.

More than 150 separate **power supplies, programmable AC power sources, hi-pot testers, and electronic loads** are featured in a full-color brochure from Kikusui International Corp., Torrance, CA. A comparison chart details the operating characteristics of the various supply types, which include bench, dual-tracking, high-current, bi-polar, and burn-in switchers. The free brochure also covers systems applications, programming options, and burn-in testing.
Circle Reader Action Number 718.

A full-color brochure describes the **thermal spray coating services** offered by Sermatech International Inc., Limerick, PA. Sermatech's arsenal of coating technologies includes GATOR-GARD® high-energy plasma spray, conventional plasma spray, and flame-spray coating processes. The free brochure highlights applications to diesel engines, helicopters, missiles, oil field equipment, and computer manufacturing components.
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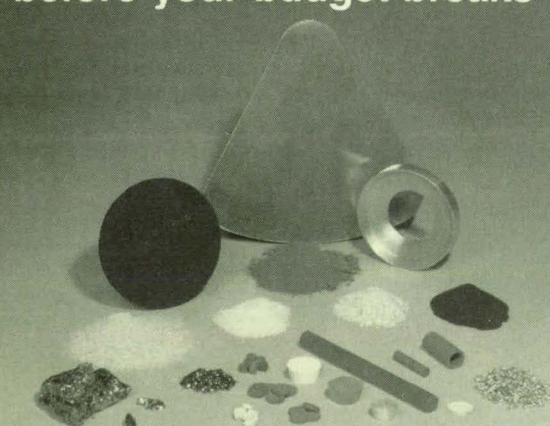

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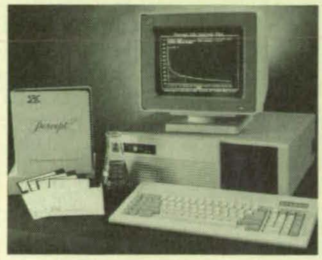
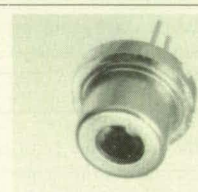


Percept™, a **CAD tool that identifies material incompatibilities** and recommends design solutions, is available from Sendrian Resources, Newbury Park, CA. The software can also estimate polymeric material longevity as a function of service temperature. Program interface is provided by an interpreter "shell" that translates trade names to the nomenclature used by the data libraries — which encompass metals, plastics, elastomers, composites, ceramics, solvents, lubricants, process fluids, and fuels. Percept operates under DESQview presentation manager and runs on IBM PC/XT/AT and compatible computers.

Circle Reader Action Number 774.



Spectra Diode Labs, San Jose, CA, has developed a 100 mW cw, diffraction-limited, single-mode **laser diode** suited for high-speed writing in laser printers or optical data storage systems. The GaAlAs device operates in the 820 to 860 nm range, with a spectral width of less than 10 MHz. Threshold current is 35 mA and operating current for 100 mW output is 170 mA. A modulation bandwidth of more than 2 GHz enables high data rates or multichannel video signal transmission.

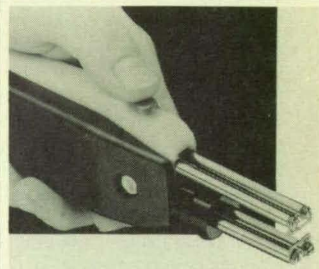
Circle Reader Action Number 776.

Scientific Concepts Inc., Marietta, GA, has created Microplots, a collection of sophisticated **plotting routines** for IBM PCs and compatibles. Starting with up to eight different plot modes, Microplots adds flexible scaling, annotation, color control, and more. The routines can manipulate ASCII data files for two- or three-dimensional displays. This file handling function allows sharing of data between the PC and mainframes, which paves the way for fast, low-cost image networking. Priced at $149, Microplots can be controlled by a menu system, user programs, or batch files.

Circle Reader Action Number 772.

PC MACSYMA™, a **computer-aided mathematics software application package** from Symbolics Inc., Burlington, MA, combines symbolic, numerical, and graphical methods for an automated approach to mathematical modeling. In addition to automating basic operations in algebra and calculus, the PC program performs advanced symbolic computations, such as solving differential and integral equations, computing Laplace and Fourier transforms, automating vector and tensor calculus, and generating finite difference equations. It also features powerful programming tools, including a debugger, compiler, and code generators for C, Fortran, and TeX.

Circle Reader Action Number 768.



The Stripall® **thermal wire stripper** from the HUB Material Company, Canton, MA, applies heat to remove insulation without nicking or deforming the conductor. Designed for electronic assembly to aerospace and Mil-Spec standards, the handheld tool uses no external transformers or power supplies; its solid-state temperature control unit plugs directly into a receptacle. Stripall's alloy blades heat to 927 degrees Celsius in less than four seconds, and also cool instantly, eliminating the need for special racks or holding clips.

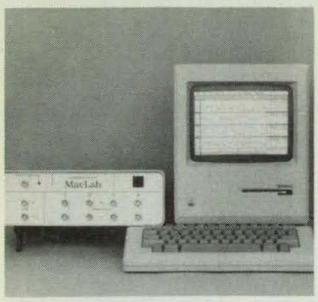
Circle Reader Action Number 770.

A new family of **portable disk drives** called Traveldisks has been introduced by Tradewinds Peripherals Inc., Pacoima, CA. Packaged in self-contained subsystems, the hard disk drives are small and rugged enough to carry in a briefcase. They connect via cable to laptop, Macintosh, and IBM PC/XT/AT computers, and can serve as primary, secondary, or high-speed backup devices. Up to four times faster than traditional backups, Traveldisks are available in capacities from 10 to 200 megabytes.

Circle Reader Action Number 766.

New on the Market

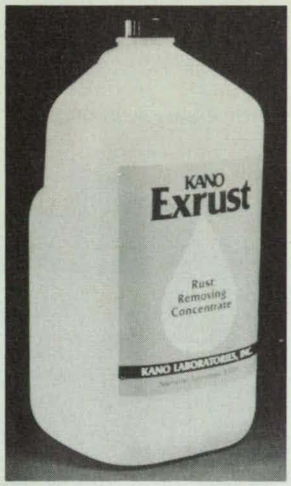
A family of **chip sets** that lowers the cost of fiber optic technology, making it economical for applications such as local area networking, military systems, and corporate data communications, has been introduced by the Signetics Company, Sunnyvale, CA. Priced at approximately 20 dollars per 1000, the HiFI (High-Performance Fiber Interface) chip sets use dense bipolar process techniques to achieve up to 100 megabits per second performance. They support LEDs of any wavelength and multi-mode optical fiber cable of any size. In addition, the receiver components can handle single-mode optical fiber.
Circle Reader Action Number 790.



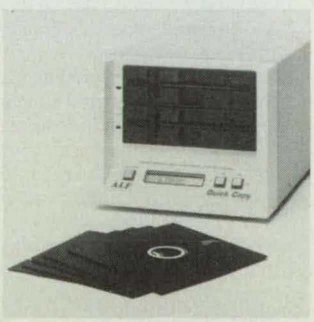
A new **data acquisition system for Macintosh computers** called MacLab™ measures captured data, produces hard copies of oscilloscope tracings, compares waveforms, and stores data for later analysis. Manufactured by World Precision Instruments Inc., New Haven, CT, MacLab includes two applications: "Scope," emulating a single-channel storage oscilloscope, and "Chart," emulating a four-channel pen recorder. Both are compatible with other Macintosh software, allowing data to be transferred via the clipboard to graphics or spreadsheet programs. The hardware unit can be plugged into the modem port of any Macintosh with at least 512K RAM and two disk drives.
Circle Reader Action Number 792.

The MAX-FAX 9624, a **plug-in half card with both fax and modem capabilities,** is now available from Macronix Inc., San Jose, CA. Designed for IBM PC/XT/AT and compatible computers, the half card automatically distinguishes between incoming fax and data calls without interruption, captures text and graphics printer output from an application and sends it as a fax, and converts PC Paintbrush files to a fax-compatible format. MAX-FAX is supported by a menu-driven software package with such options as auto dial and answer, broadcast, message display and printing, and bulletin board capabilities.
Circle Reader Action Number 798.

The RGB/View™ display controller from RGB Technology, Berkeley, CA, allows text, data, and graphics to be integrated with real-time video on any high-resolution workstation display. The video appears as a window on the computer screen, and can be squeezed or expanded from 1/16 to full screen size. Windowing functions are controlled by front panel switches or via an RS-232 port. The controller supports workstations from Sun, Apollo, Silicon Graphics, IBM, DEC, Hewlett-Packard, Tektronix, and others.
Circle Reader Action Number 794.



Exrust, a concentrated chemical **rust remover** from Kano Laboratories Inc., Nashville, TN, quickly dissolves rust by neutralizing ferrous oxide. The product is offered in a variety of sizes, from a pint-size sample selling for $4.50 up to a 55-gallon industrial container.
Circle Reader Action Number 800.



ALF Products Inc., Wheat Ridge, CO, has introduced the Quick Copy family of **portable disk duplicators.** The self-contained units can automatically copy an unlimited number of 5¼" and 3½" disks, and can also be used to format blank disks. Quick Copy models handle IBM PC, Apple II, Macintosh 800K, Commodore, TRS-80, DEC Rainbow/RX-50, Atari, and Amiga disks.
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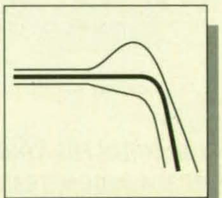

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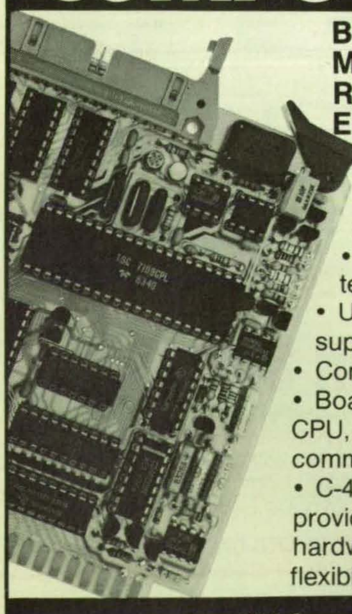

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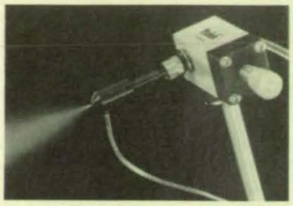
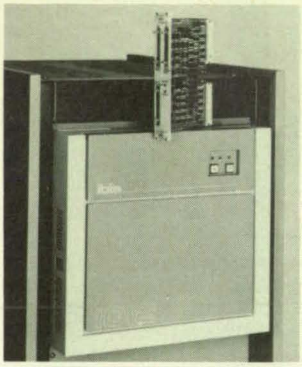


A **precision spray system** from Tridak, Brookfield, CT, handles small-volume jobs — from nanoliters to several milliliters. Fluids ranging in viscosity from solvents to heavy oils and paint are atomized pneumatically and propelled to substrates a maximum of 8 inches from the nozzle. Adaptable to many automatic syringe dispensers, the miniature spray system consists of the nozzle with a regulator and a dispensing unit.

Circle Reader Action Number 780.



IBIS Systems Inc., Westlake Village, CA, has introduced the TRIAD, a parallel-transfer **disk storage subsystem** for VME-based workstations and high-performance computer systems. TRIAD consists of a high-speed, 32-bit VMEbus controller that resides in the host; a 12-megabyte/second, 1-gigabyte capacity disk drive; and a software device driver for UNIX and other VMEbus environments. Applications include data storage for supercomputers and VME-based workstations, high-speed array and real-time image processing, graphics imaging for animation and training simulation, and other specialized industrial and military applications where high-speed I/O capabilities are needed.

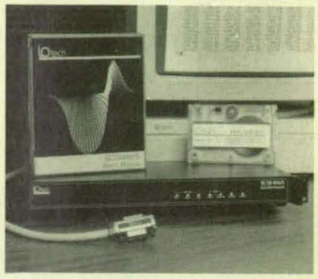
Circle Reader Action Number 788.

DuraTool 250, the first in a family of **prepreg composite tooling materials** for high-temperature applications, is now available from Narmco Materials, a business unit of BASF Structural Materials Inc., Charlotte, NC. An epoxy, "B" staged resin system impregnated into carbon and glass fiber fabrics, DuraTool 250 cures at 93°C in five hours with final postcure at 190°C. Tool service performance is excellent up to 204°C, according to the manufacturer.

Circle Reader Action Number 786.

A free demonstration disk from Applied Computer Solutions Inc., St. Clair Shores, MI, provides an overview of the company's new VSA™ tolerance analysis program. The software tool is applied early in the design process to predict the amount of variation that will occur in an assembly due to fabrication methods and sequence, as well as to nonuniformity of parts. Model creation and analysis can be performed graphically using a mouse and pop-up menus. The demo disk runs on IBM PC-AT, PS/2, and compatible computers.

Circle Reader Action Number 782.



Engineers now can interface thousands of instruments to their Sun desktop workstations with the SCSI488/S, a new **IEEE 488 interface package** from IOtech Inc., Cleveland, OH. The product uses the SCSI port available on all Sun models, even those without slots or disk drives, to link engineers with instruments and laboratory peripherals compatible with the IEEE 488 bus. The SCSI488/S comes with a UNIX device driver that supports true multitasking. Programs can be written in any high-level language (such as C) that controls UNIX system services. IOtech is also offering a companion software package for waveform analysis and graphics on the Sun, DADiSP, that permits users to bring data from IEEE instruments directly into windows for on-screen representation as waveforms.

Circle Reader Action Number 778.

A computer-automated **fax delivery system** that works with the PostScript DTP language has been introduced by Biscom Inc., North Billerica, MA. Designed to operate with a variety of minicomputer systems, the FAXCOM/Publisher generates and stores graphic fax images, acts as a PostScript controller for local printers, and supports multiple printer types and fonts. Interfaced to the host CPU via an RS-232C port, it can transmit PostScript files directly from any terminal to any Group III fax machine worldwide. The usual process of feeding hard copy into a fax machine is eliminated, as is the image degradation caused by the fax machine's optical scanning process.

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Subject Index

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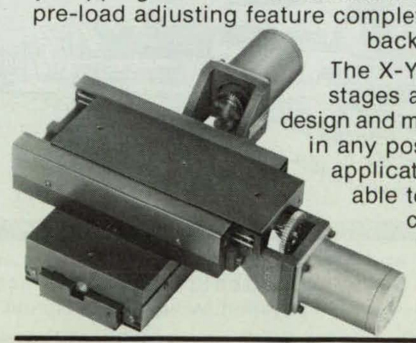

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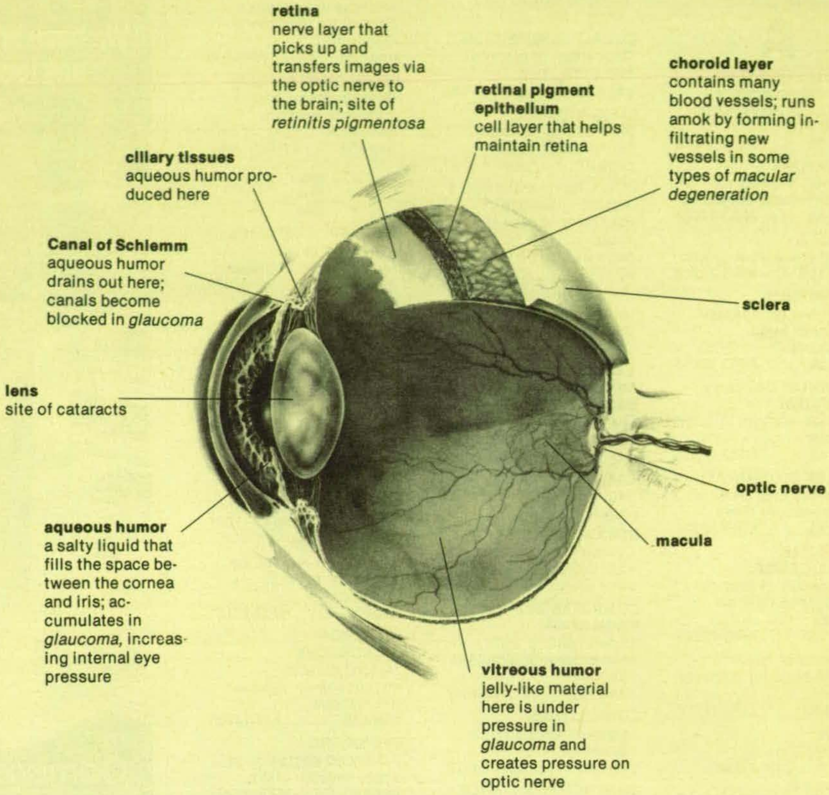
Space-Age Vision Aids

(Continued from page 20)

chine vision systems.

"The technology we're working towards is so radically different than what's out there now," Rickman said, "that it's difficult to perceive what the long-term benefits will be or where the technology will stop. There's been speculation that this device could be an intermediate step towards performing implants in humans to replace damaged retinas, but there's no way to know yet. Right now, the possibilities are endless." □

Where Vision Problems Strike



Approximately 2.5 million Americans, many older than 65, suffer from low vision. Birth defects, injuries, and aging can cause low vision, but most cases are due to eye conditions that affect the retina, including:

Macular Degeneration. Deterioration of the macula, the center of the retina used for sharp focus, causes central vision loss and makes reading difficult. This disability affects 20 percent of those over 75.

Diabetic Retinopathy. Swelling and leakage of fluid in the center of the retina brought on by diabetes can cause scar tissue to form, leading to loss of sight.

Macular Degeneration. Deterioration of the macula, the center of the retina used for sharp focus, causes central vision loss and makes reading difficult. This disability affects 20 percent of those over 75.

Diabetic Retinopathy. Swelling and leakage of fluid in the center of the retina brought on by diabetes can cause scar tissue to form, leading to loss of sight.

Glaucoma. Increased fluid pressure inside the eye damages the optic nerve, resulting in vision loss. Because peripheral or side vision usually is affected first, this disease sometimes is called "tunnel vision."

Retinitis Pigmentosa. In this hereditary condition, the retina progressively deteriorates, causing loss of peripheral vision.

Cataracts (the clouding of the lens), cornea infections, and detachment of the retina also can cause low vision. In addition to loss of central or side vision, low vision patients may lose their color eyesight, have difficulty adapting to bright and dim light, and suffer diminished focusing power.

Source: Johns Hopkins Wilmer Eye Institute

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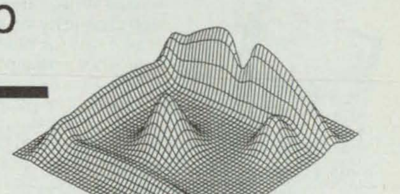

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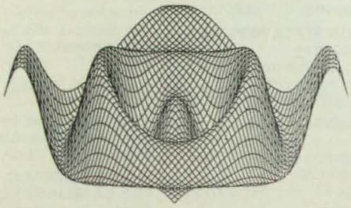

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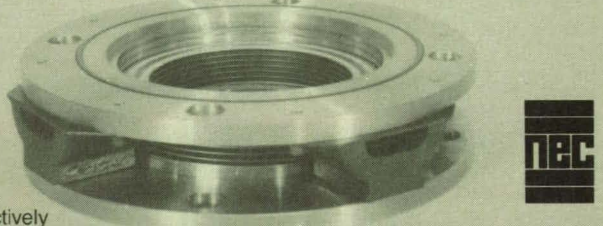

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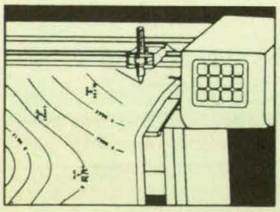

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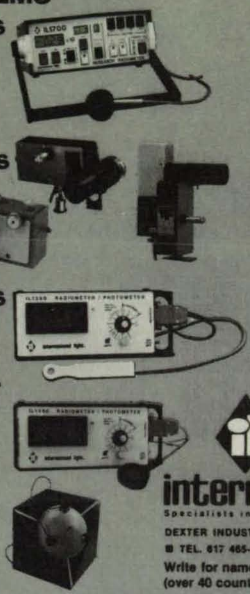

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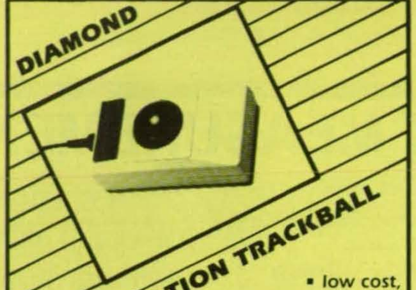

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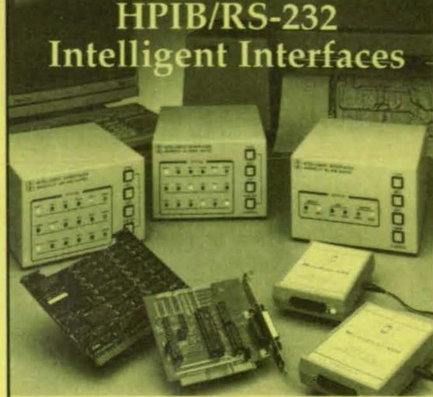

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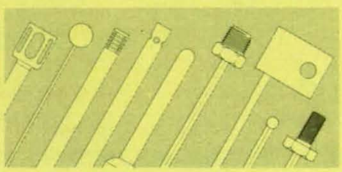

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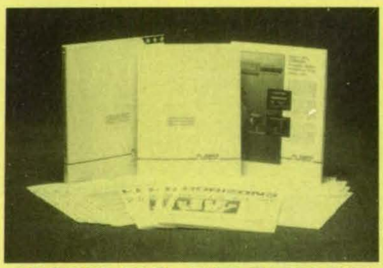

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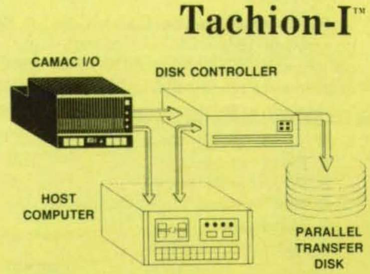

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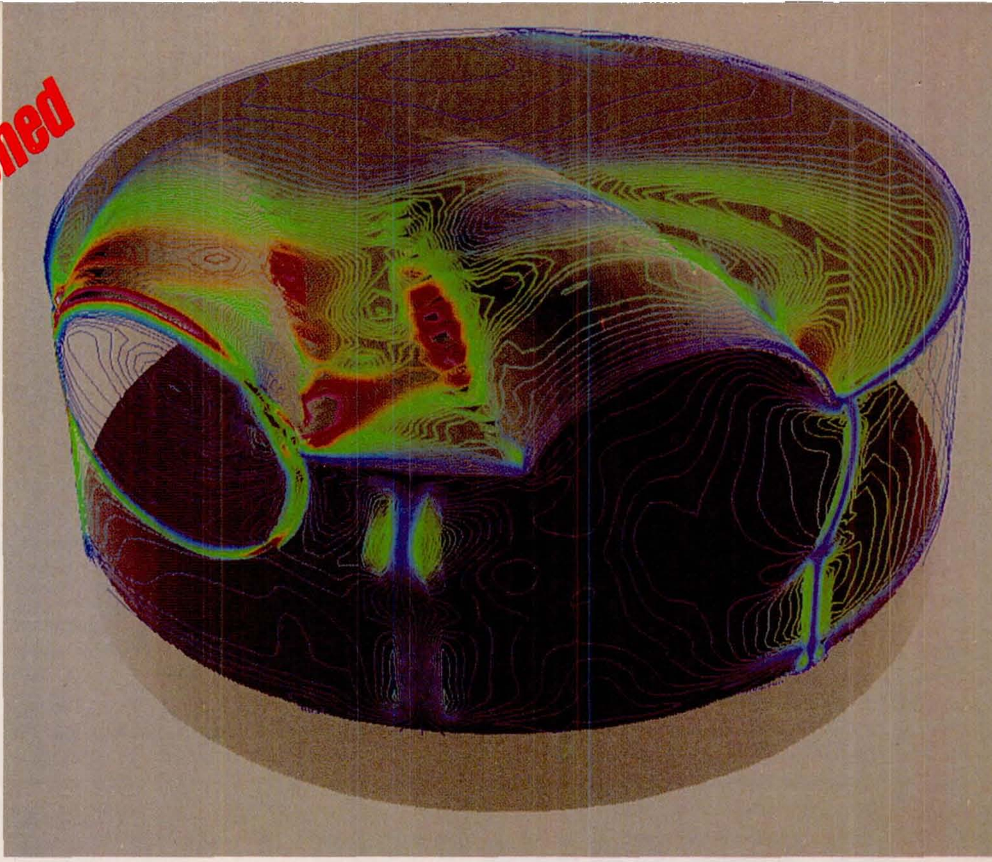


(Photo courtesy NASA)

This simulation shows vorticity magnitude contours on the inside surface of the heart chamber. The fluid, a water-glycerin solution used by experimentors to represent blood, is being pumped out through the open valve by a piston.

Borrowing a design tool from the Space Shuttle program, scientists at NASA's Ames Research Center have created a computer model of the blood flow through an artificial heart. The three-dimensional simulation will help medical researchers to better understand the heart's complex flow field and should lead to improved pump designs.

"Many of the present problems with artificial hearts are directly attributable to the fluid dynamics of the blood flow," said Dr. Stuart Rogers, an Ames research scientist. Embedded regions of turbulent flow can damage the red blood cells, he explained, while flow trapped in corners of the heart can breed clots that cause strokes.

"With increased knowledge of the fluid behavior," said Dr. Paul Kutler, Chief of Ames' Fluid Dynamics Division, "artificial heart manufacturers will be able to suggest configuration changes to improve the flow quality."

The NASA model applies a simulation technique called computational fluid dynamics (CFD). Originally developed to track fluid motion inside components of the Space Shuttle main engine, CFD involves the solution on supercomputers of complicated mathematical equations describing flow behavior. CFD solutions are "information rich," Kutler said, and offer the design engineer a complete picture of the given flow field. Moreover, geometry changes are performed easily in the computer, saving time and money in the design process.

Ames scientists, building on an existing 3D flow code used in aerospace and automotive research, created a time-accurate algorithm to predict the unsteady flow path and constructed geometry definition and grid generation packages that emulate the mechanical heart's pumping motion. Although the simulation of a single heartbeat requires four hours of data processing on a Cray 2 supercomputer, it provides otherwise unobtainable information. Kutler's group is working to speed up the calculations by refining the algorithm.

The CFD tool, now used to recreate the incompressible flow through one chamber of a Pennsylvania State artificial heart, may be applied to several other experimental heart designs. Potentially the biggest benefit is in development of the total artificial heart scheduled for clinical testing in the early 1990's.

Ames researchers next plan to simulate the flow surrounding the valve openings in the Penn State model. "By combining the valve calculations with our present work on the heart chamber," explained Dr. Dochan Kwak, an Ames scientist, "we'll have a complete flow analysis package for artificial heart manufacturers."

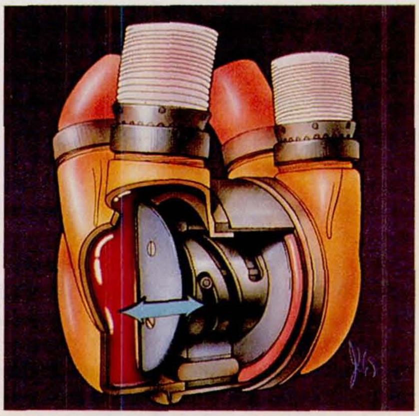
"Spinback" Potential

NASA's loan of space technology to this research project—which involves the Ames Center, Pennsylvania State University, and Stanford University—will be repaid with interest, according to Kutler, who anticipates "spinback" applications of the enhanced code by NASA and the aerospace community. "It's useful anywhere you have unsteady flows with moving boundaries," he said, "such as inside a jet engine."

NASA hopes to use the code to model flow in the shuttle engine's fuel and oxidizer pumps, while the Navy wants to apply it to study the flow field around submarine propellers.

"This code was written for completely generalized coordinates," said Dr. Rogers, "so it can easily be taken from one problem and put onto another."

Developers of the Penn State heart are applying the CFD technology pioneered to date to analyze blood flow behavior and compare it with their experimental observations. The simulation is a first step, Rogers said, towards computer-aided design of mechanical hearts. ☐



(Photo courtesy Pennsylvania State University)

An electromechanical device powered by inductance from an external battery, the Penn State artificial heart features a cylindrical chamber with two openings on the side for valves.

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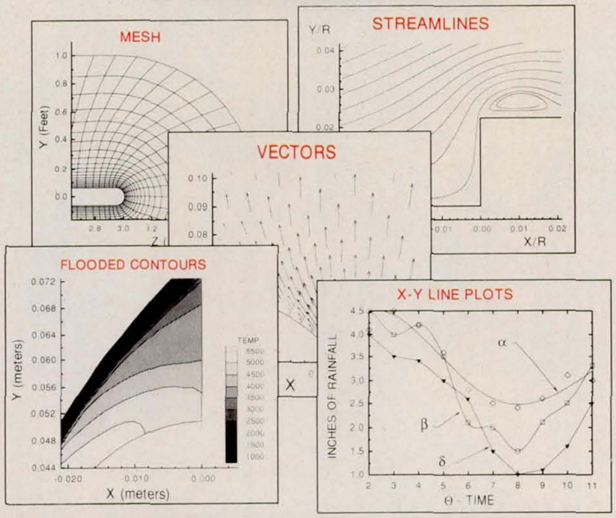

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